

**LIBBY
HEANEY**

EN



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LAS

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INTRODUCTION

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LIBBY

HEANEY IN

CONVERSATION

WITH KAY

WATSON

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ON ENT-

(VIA BOSCH

AND BARAD)

*BY REBECCA
EDWARDS*

Commissioned by LAS (Light Art Space), *Ent-* is a solo exhibition by artist and physicist Libby Heaney. LAS is committed to research and experimentation and the focus on quantum computing responds to our future-centric approach. Heaney's work aligns very well with the overall mission of our foundation: she holds a PhD in Quantum Information Science and an MA in Art and Science and has been experimenting with quantum computing for several years. Only a handful of companies globally are developing quantum computers, and Heaney is one of the first people in the world to use this technology as a functioning artistic medium. No fully fledged quantum computer is yet in existence, but the technology can achieve results and speeds impossible with current computing.

Ent- is a quantum interpretation of the central panel of Hieronymus Bosch's famous triptych *The Garden of Earthly Delights* (c. 1490–1510). By using quantum code, Heaney manipulated her own watercolour paintings of hybrid creatures inspired by Bosch's medieval monsters, landscapes that seem to shift and breathe, and exploding structures that float and re-form. Created using IBM's quantum hardware and Qiskit software, animated with the game engine Unreal Engine and accompanied by a sound composition conceived in collaboration with musician Nabihah, *Ent-* is an immersive installation taking quantum computing as both medium and subject-matter. Designed as a 'black box', the exhibition experience engulfs you in a 360° projection that takes us through the layers of Bosch's painting – sky, buildings and landscapes, and water.

For the artist, Bosch's adjacent depictions of heaven and hell provide an analogue for the double-edged potential of quantum computing. This emerging technology is expected to create a leap in the possibilities of computing power, exponentially accelerating surveillance capitalism and disrupting existing encryption methods for privacy and data protection. Just as Bosch's triptych can be read as

both a celebration of and warning against desire, *Ent-* explores the dangers implicit in our thirst for new technologies.

Heaney also investigates the positive potential of 'thinking quantum'. One of its most important concepts, quantum superposition, allows particles to exist in multiple states or places at once. Quantum entanglement binds particles together in a particular symbiosis unlike anything in the macroscopic world. For Heaney, thinking, experiencing and acting in terms of these new pluralities has the potential to break down binary thinking and political polarisation, engendering community thought that might solve global problems as severe as the climate crisis or allow for new paradigms when considering critical issues such as gender identity.

In an entirely new visual language, Heaney creates plural visual effects only possible using quantum computing; digital images become hybrid and fragmented in a blurred, pixelated aesthetic that attempts to represent the layered reality of the quantum world. However, her work does not require previous knowledge of quantum systems and encourages viewers to make their own perception-based, emotional responses to the disconcerting yet invigorating quantum world.

Ent- is on view at the Schering Stiftung from 10 February to 1 May 2022.

A component part of *Ent-* is currently on view at the ZKM | Center for Art and Media Karlsruhe, as part of *BioMedia: The Age of Media with Life-like Behavior* until 28 August 2022.

Ent- will travel in its entirety to arebyte Gallery, London opening on May 26th, 2022.



**PROBE
THE
FUTURE,
OPTIMISE
NOW**

LIBBY HEANEY IN CONVERSATION WITH KAY WATSON

LONDON,
DECEMBER
2021

KW To begin, I want to talk about quantum computing, which seems almost magical (a phrase you have also used) in terms of our understanding of reality. What possibilities and challenges are we facing here? Where are we in terms of the development of that technology?

LH It is mind blowing. The strangest thing is that not only do we have this weird version of reality, but scientists have learnt how to use it to build computers. You can actually take this complex mess and get something very practical out of it that gives tangible power to those with the resources to apply it.

Quantum computing is fundamental to what comes next and there is a huge amount of investment connected to the hype around Web3¹ – but we will go from Web3 to Web Q (Web Quantum) at some point. The problem is that most of the power and competition is between the big tech companies like Google and IBM. There isn't even a good definition of what a noisy intermediate-scale quantum computer (NISQ)² is because there are different ways of making them: Google and IBM use superconducting quantum bits (qubits); other companies, like Ion Q, use trapped ions; and companies like PSI Quantum use optics, and there are more. I always call the race towards a full scale quantum computer a quantum arms race.

As governments partner with tech firms and universities, geopolitics is involved. The West doesn't want China to have the first full-scale quantum computer and vice versa. This technology has the potential to be weaponised because a full-scale quantum computer in principle has the ability to decrypt all the RSA³ encryption we use. This is massive. For instance, a full-scale quantum computer could destroy the integrity of Web3, which is based on blockchain⁴. And this is not in the public consciousness, in part because quantum computing – and the physics that underpin it – is very difficult to understand for lay people at the moment. The mainstream press barely covers it, and when they do it reads like an advert for IBM or other tech companies. I think it is really important to have these critical conversations outside the quantum world. Otherwise, it's just the scientists and investors having the last word on everything as opposed to the wider public.

At the moment quantum computers are very noisy, meaning that they are prone to error. When I am working with a quantum computer, I'm really working with the quantum assembly code, so still with zeros and ones. Every time you manipulate the zeros and ones, there are errors that affect outcomes. And scientists don't want errors, especially when you're not just making art, but solving problems.

¹ Web3 is an idea for a new iteration of the World Wide Web based on the blockchain, which incorporates concepts including decentralisation and token-based economics.

² The current type of embryonic quantum computer (i.e. one that is not yet fully developed).

³ RSA is a public-key cryptosystem that is widely used for secure data transmission. It is also one of the oldest. The acronym 'RSA' comes from the surnames of Ron Rivest, Adi Shamir and Leonard Adleman, who publicly described the algorithm in 1977.

⁴ A blockchain is a decentralised, distributed and oftentimes public, digital ledger consisting of records called blocks that are used to record transactions.

In terms of actually defining quantum computing and, in particular, a universal quantum computer⁵, there has been a definition of this for more than twenty years. It is theoretical and it gives you a list of things you need in order to solve any problem on a quantum computer: qubits need to be readable and addressable individually, you need to be able to do a universal set of logic gates⁶. Because companies building quantum computers are in a much earlier stage than universal quantum computing, scientists don't have error correction yet, which will be essential. Every computer has some type of error correction in case a bit accidentally flips. With quantum computers this is especially important because quantum systems are really affected by noise. Current quantum computers are what scientists call noisy intermediate-scale. In some sense, Tech companies are only really in the early days. That's why they don't have a good definition of the current hardware they're building. Say you take a quantum computer from Google and then one from Honeywell. Because they're built on different architectures of physical hardware some might have really low noise, but only a few qubits, and some might have loads of qubits, but be quite noisy. Which one is better? They can't agree on a measure. Within IBM, they have their own measure. It's called quantum volume, but then no other companies use that, maybe because they look bad by that measure, and they'll choose a measure that suits their system. So there's no standardisation. They do know what a universal quantum computer is, but it's all in theory. There is no benchmarking across the field right now, so they can't decide on who has the best quantum computer. If you follow these tech companies closely, you can see that they've all got their own strategy for becoming the standard. And you can see how their business models work. Some take a more open approach, others are closed and making partnerships. Others are more collaborative and platform-based, bringing together software and hardware platforms whereas IBM has tried to do a whole stack themselves, and then there are lots of start-ups.

KW Because it is so difficult to understand, public interaction with a quantum computer is always via an interface. You're really not seeing how it works. It is interesting that

⁵ The essence of a universal quantum computer is that it enables the simulation of physics, including and especially quantum mechanics. It is a machine that can run any possible quantum algorithm.

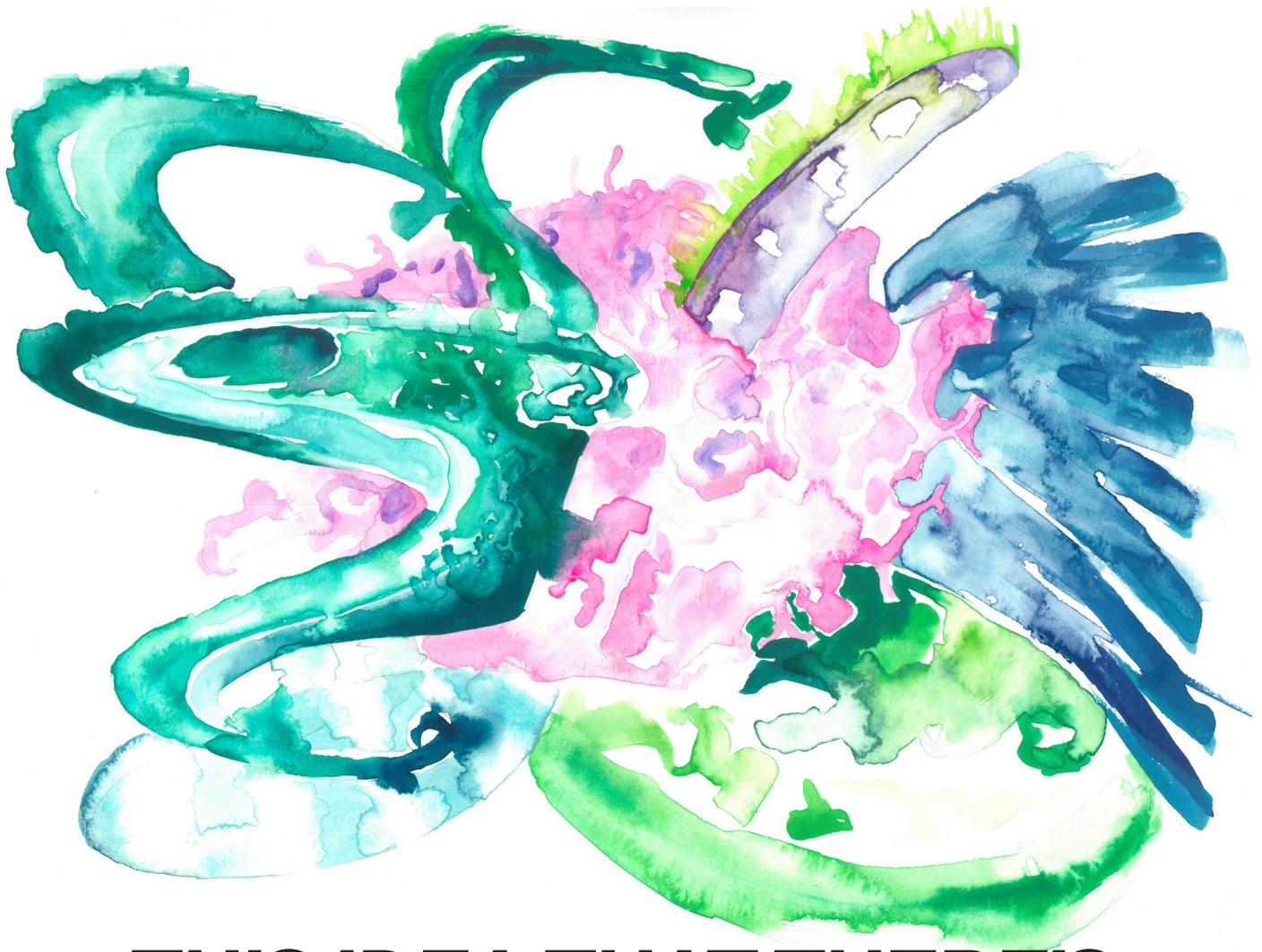
⁶ Logic gates are the basic building blocks of any digital system, performing logical operations on the bits. The relationship between the inputs and the outputs is based on a certain logic. Quantum logic gates are an extension of this for qubits, and always have the same number of inputs as outputs.

scientists are designing the interface at the same time as building the hardware.

LH Scientists have learnt from the development of current digital technology like machine learning what you need for the full stack⁷. Developer's kits, software kits for people who want to use a technology just for applications through to the assembly level and hardware. When the hardware is more sophisticated, you need to have the full package ready.

KW What is your relationship to this as an artist? You have a PhD in Quantum Information and completed three post-doctoral fellowships before training as an artist. Why did you make that shift and how do these two experiences of education, knowledge and formulating an understanding of the world impact your creative practice?

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Libby Heaney, 2021

***THIS IDEA THAT THERE'S
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THAT WE SEE EVERY DAY
REALLY EXCITED ME.***

LH Art was my favourite subject at school. It brought so much joy, escapism and calmness to my life. I would have happily gone to art school but I was also very good at physics and maths. I come from a working-class background and my teachers, friends and family recommended that I not study art because one would never make any money. So I went to university and studied physics, maths and German. I fell in love with quantum because it was really weird. I found it so difficult at first, but the concepts were really magical and strange. This idea that there's a reality beyond the concrete world that we see every day really excited me. I was still making art, but it was always a matter of time and resources. That's why I did my post-doctoral research in Singapore and was able to save up quite a lot of money to pay for myself to go through an arts degree.

I was reading Mark Fisher's book *The Weird and the Eerie* (2016) not long ago. It states that the weird is what does not belong. Quantum is like that in relation to the Newtonian world we experience, but it's part of us as well. It's not like the 'other' is separate from us.

When you practice physics, you have to understand the field and then come up with what you think might be a good idea to research. In order to publish, it needs to be new, which is similar to art because what you think is interesting often comes from your own experience. But when you practice physics and mathematics, you need to follow logical steps in your process. Sometimes the outcome is interesting, sometimes it isn't. And then you have to double check the maths to make sure all the steps are logically correct. This can be quite esoteric.

My area of expertise is in entanglement, in itself a huge field. I know a lot about one aspect of it. Practising physics became frustrating for me because it's so specialised and you can't talk to many people about what you're doing. I had a desire to be able to have broader conversations. When I first encountered quantum, I couldn't believe our microscopic reality was like what was being described. But as I practised the science the magic went away a bit; it became very rigorous and a bit dry. I didn't know how quantum physics connected to art. I just knew I needed to express it from a wider viewpoint and bring in other conversations, to branch out and get that magic back.

KW I've spoken to artists over the years, who have come from research or academia, and then there are lots of scientists who would consider themselves to be artists as well. There is this need to create conversation that involves different voices and that seems more possible in the context of art.

LH It is a matter of hierarchy. Scientists, or at least physicists, believe that scientific modes of knowledge are 'true' knowledge. Knowledge that relates more to our subjective experience or embodied knowledge is less valid to them. I didn't know how to articulate that when I was in science, but I always felt it. I worked in super male-dominated spheres and I was quite shy in my twenties, so sometimes it would be difficult to have my voice heard.

I explore all of these questions in my work now. My practice always has this implicit thread of feminism that comes from my experience and my past frustrations.

KW Could you tell us about your latest work *Ent-* and what the audience will experience?

LH The work is commissioned by LAS in Berlin and will then go to arebyte Gallery in London, and because of that I was thinking about connections between the German and English language. I remembered there was a prefix in German, *ent-*, which means the beginning of an action or a separation. It occurs in words like *entstehen* or *entdecken*, which in German mean to arise or to discover. To me, this relates to where we are with quantum computing and its potential futures. But also in English, words like entanglement, *enter* on the keyboard or to *enter* an immersive space. I liked the idea of not finishing the word and allowing audiences to, of keeping things open, which I think is quite important when working with quantum concepts. That's the title.

KW How does *Ent-* relate to your understanding of 'thinking quantum'?

LH The work is based on two and a half years of research with quantum computing. I've been coding with IBM systems and exploring how I can use data from entanglement within the quantum computers to manipulate digital images, their pixels and 3D structures. The main question was how to generate visual effects that could not be generated using digital technologies. What aesthetics can you make from using the pluralities embodied by quantum mathematics and quantum data? I realised that by revealing interference effects, you could show traces of the wave-like nature of quantum phenomena. I did lots of experiments, made animations, videos and some 3D simulations. All of these have been

⁷ Full stack technology refers to the entire depth of a computer system application, and full stack developers straddle two separate web

development domains: the front end and the back end. The front end includes everything that a client, or site viewer, can see and interact with.

embedded within a wider environment in a 360-degree-projection that audience members will enter and within it experience a transition between what we have now and a quantum world, or my interpretation of one, but with a very critical edge to it, trying not to romanticise quantum.

KW You're using data from entanglement. What is that data?

LH I take a bunch of qubits in a quantum computer. You can apply quantum logic gates to entangle these qubits and create an entangled object inside a quantum computer. There are many different types of entanglement, probably an infinite number. This entangled object is in a high dimensional space and there are different ways in which you can measure it. Imagine if you're in a gallery and you're looking at a sculpture of a human body. Depending on where you stand in relation to this sculpture, you're seeing a different viewpoint. You're seeing different body parts, with different relations to each other. Only once you walk around the whole thing – maybe if you could see it from above – do you get a sense of its entirety. With entanglement, rather than it existing in 3D, it exists in a much higher dimensional space, depending on how many qubits you use.

MY PRACTICE ALWAYS HAS THIS IMPLICIT THREAD OF FEMINISM THAT COMES FROM MY EXPERIENCE AND MY PAST FRUSTRATIONS.

But you can still move around it. We can 'see' the entangled object from different perspectives. What I do is create many identical copies of this entangled state, and each one I measure slightly differently. I start to build a map of what that entanglement was. The data that comes out is just a list of numbers. It might not look particularly interesting. But then my process is to write some

Python code⁸, and to understand how to go through this list of numbers and to use that list to push images, digital data of the pixels around. There are only a few lines of quantum coding; the rest is Python script that enables me to do something visually interesting with the quantum data.⁹

KW When you enter this exhibition space, are you experiencing a narrative of sorts? Is it fixed or shifting in real time?

LH It will be on a loop. The audience encounters an interpretation of the central panel from Hieronymus Bosch's *The Garden of Earthly Delights* on one screen, which then envelops the entire space and you in this game world – a virtual environment built with Unreal Engine. As they move through this space, the forms start to deconstruct and become more quantum: you encounter my quantum animations, everything starts to shape-shift and distort. There are three scenes: the first is a sky scene where the audience fall from a quantum computer into this strange new world. The next is the architectural landscape that is more figurative and directly connects the piece to Bosch; and then an underwater scene. I am using elements in all of the scenes to talk about quantum in different ways. So there's a structure – I don't know if I'd call it a narrative, but you're guided through this series of worlds.

KW At the centre of this work are multiple (quantum) reinterpretations of Bosch's, a monumental triptych depicting Paradise (or heaven) and Hell that was created at a time of enormous shifts in the way we understood our place and role in the universe from Copernicus and so on. Why was it important to focus on this?

LH I like to keep things open rather than fix the meaning. There are multiple layers to why I referenced Bosch, some quite straightforward and some to draw parallels between the painting and quantum computing in detail. On the most basic level, it situated the futures of quantum computing between heaven and hell, thereby posing the question as to which way the development of these technologies will go.

In my work previously, I have referenced pop culture as a starting point to talk about more complex ideas. As quantum computing is complex, a good way to introduce audiences to it is by using something really well known. I see it like a door handle.

⁸ Python is an interpreted high-level general-purpose programming language. Its design philosophy emphasises code readability with its use of significant indentation. Its language constructs as well as its object-oriented approach aim to help programmers write clear, logical code for small and large-scale projects.

⁹ A Python script is a reusable set of code that is essentially a Python programme – a sequence of Python instructions – contained in a file.



Libby Heaney, 2021

***I LIKED THE IDEA OF
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'Oh, there's a door handle, let's go in!' – something to hold onto in the midst of these really new ideas.

In my reading about Bosch's triptych, I found so many parallels between ideas from quantum physics, quantum computing, Bosch and religion in general. It got me thinking about technology as a new religion. It promises us life beyond the body, it's all seeing, it's opaque, it's kind of dogmatic. With current machine-learning systems underpinning a lot of decision-making systems today, people tend to defer to the machine predictions without thinking about what they really believe or if the machine is accurate. One use of quantum computing is quantum machine learning, it is a huge focus among big tech companies. I wanted to position quantum computing and quantum machine learning as an extension of what is already happening and place it in relation to the current discourse shaped by people like author and mathematician Cathy O'Neil and writer Jeanette Winterson, who have both written about technology and religion in terms of machine learning.

Bosch's painting can also be interpreted in dual ways regarding desire: does it depict pure, untrammelled desire as an innocent expression of humanity or is it a condemnation of that desire as well? Depending on who you read on Bosch, you get different opinions. I pose a similar question towards quantum computing and our desires for new technologies, and our desires for immersive experiences – should we condemn it or celebrate it? Is it good that scientists tend to be only celebratory of the new? I'm talking in binaries here, but hopefully the work deconstructs these binaries and uncovers more complex relations.

Maybe we actually need to accept the hybridity of these questions. This is mirrored in the hybrid creatures that populate *Ent-*. In Bosch's time, the understanding was that God had created the world with a specific order, with humans at the top, and monsters were used to depict social ills or something sinful. I created my creatures by using randomness from a quantum computer. When you measure entangled states in a certain way, you get a set of truly random numbers out. There is no way you could predict what will come out. Randomness created by digital systems is always pseudo-random and over a long period of time, some sort of pattern will always emerge. Einstein once said about quantum mechanics that 'God doesn't play dice', rejecting this idea of true randomness in quantum physics. But he was wrong – physics really is random at its most fundamental, atomic level. In that sense, it really is indeterminate. I connect the idea of random-

ness as a fundamental element of the universe and the meaning of randomness in Bosch's time to suggest new forms beyond everyday categories and taxonomies.

KW I'm really interested in the black box as the space within which processes are hidden, to use your quote, a 'system which can be viewed in terms of inputs and outputs, without any knowledge of its internal workings', and that you are asking people to enter that black box to see these quantum internal workings, not in order to be didactic but to show us many possibilities. Could you tell us more about this approach?

LH It works on multiple levels. It's a symbol for quantum computing, and of our minds as well. I ended up working with quantum really intuitively because I have a background in the field. When I was working in science, I was always creating these images in my mind's eye to have an intuition about quantum. The images were super inadequate with weird colours, I don't even know why they looked like they did. On the other hand, I worked very rationally when I was coding for the quantum computer. It's not a medium like clay where you can get hands-on. You just have to write some code. But when we were putting it all together in the game's engine with the developer of my work James B. Stringer and his team, everything was guided by this intuition. The artwork ended up really dreamlike, connected to my conscious and subconscious. Do you know the 1962 minimalist sculpture *Die* by Tony Smith? It's this big metal box about the same height as a human. There is something about this black box that relates to us humans – it's very theatrical. Or Anish Kapoor who uses this deeply black paint, and there is so much going on in there even though it could depict a void. And I haven't even thought about Malevich's *Black Square* (1915).

KW I've heard you talk about the quantum world, as like 'entering a different world' or enabling a new way of seeing/perceiving? Can you explain a little about what that means not just on a technical level but in terms of our systems, bodies, hierarchies and the paradigms through which we experience the (macroscopic) world?

LH What I found fruitful so far is to take quantum concepts like superposition, entanglement and quantum measurement and rework them with other ideas to see how this combination pops out something new. If you read relational aesthetics or think about Bruno Latour's actor-network theory, systems are very relational. Latour's essay in *e-flux journal* ('Some Experiments

in Art and Politics') in which he talks about Tomás Saraceno's work *Galaxies Forming along Filaments, Like Droplets along the Strands of a Spider's Web* (2008) illustrates this. Looking at quantum concepts leads to an even stronger sense of this. I'm a big fan of Karen Barad. Her book *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (2007) is the best reinterpretation of a macroscopic world through quantum that I've read so far: that all matter has agency, the ability to shape-shift and bring into being different forms depending on its relations with other things in the world. Barad writes that relations precede things essentially, and that things come into being through relations.

**THERE IS SOMETHING
ABOUT THIS BLACK
BOX THAT RELATES
TO US HUMANS – IT'S
VERY THEATRICAL.**

One of the things that I find most striking is how quantum is a non-local theory. This means that in Newtonian physics, in the macroscopic world, we usually imagine an object hitting another object and causing a force, so there's a local cause and effect. Even forces like magnetism that act at a distance still propagate locally. And that is very linear. In quantum, objects can be entangled. Entanglement is essentially when two or more objects lose their own individual properties. Imagine you have a physical body here and another physical body over there, but all their properties – mass, position, momentum – are smeared over (across) the two. They become correlated, joined in this non-local way. The idea is to move beyond the individual in such a strong sense that if you try to distinguish an individual in this entangled system, you end up destroying it. There's literally no way of getting an individual out. That moves us beyond most of the Western philosophy, which is quite exciting. Going back to this idea of non-locality and thinking of ourselves as existing in these

entangled systems, as connected to other things, you end up with a non-local responsibility. I don't just mean this materially but how any interaction (e.g. discourse, which is actually material too) within a phenomena can have an effect, even if you're not directly touching it.

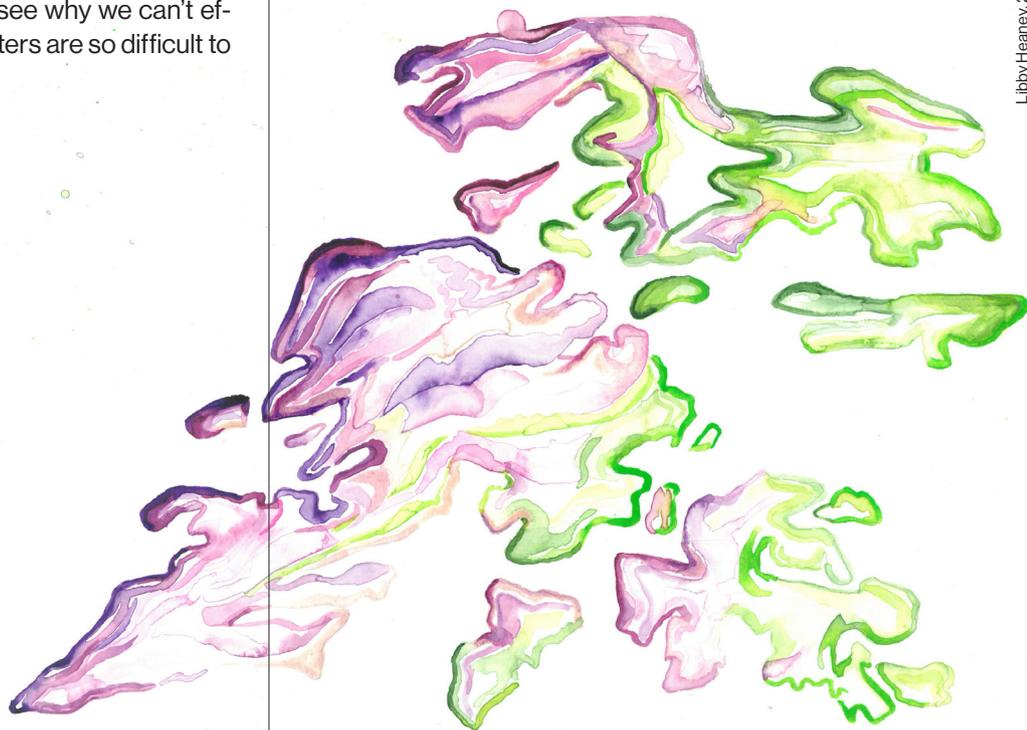
Right now this is just a metaphor to think through new ideas in the macroscopic world through quantum science. While there is a rigorous definition of entanglement in science, no one has yet discovered entanglement between macroscopic bodies like humans.

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KW I think we have a shared belief that art and culture can have a role in the development of advanced technologies. Right now, why is it so important to engage with quantum computing and its infrastructure?

LH The power is quite tightly held by the big tech companies and not many people are talking about quantum computing compared to Web3. If artists and anyone outside the quantum sphere start engaging with it in a sustained way, then we could start to develop more accessible languages. I've spoken a lot about ethics and moral implications of this technology, and having worked in science, and discussing this with lots of scientists, I know there is almost no discussion on this. One thing the critical art world does well, is think through the implications of new technologies as with AI. But with AI I think it was a bit too late to really affect change, because AI systems are really embedded within our lives now. Whereas if anyone who wants to engage with quantum computing shouts loud enough – like what happened with NFTs, where Memo Akten and Joanie Lemercier wrote about CO2 emissions and blockchain and it got picked up by *Wired magazine* and the *New York Times* – then artists can effect change. Artists have always been at the forefront of discussions around new technologies. I don't see why we can't effect change now. Because quantum computers are so difficult to build there is a bit of time.

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Libby Heaney, 2021

**YOU
ARE
THE
BLACK
BOX**

The text "YOU ARE THE BLACK BOX" is rendered in a bold, white, sans-serif font, stacked vertically in four lines. The text is centered against a dark blue background that transitions into a lighter blue and purple gradient at the bottom. The text is overlaid on a complex, abstract graphic consisting of several overlapping, glowing white and light blue lines that form a circular, somewhat chaotic shape. The lines have a soft, ethereal glow and intersect to create a sense of depth and movement. The overall aesthetic is futuristic and high-tech.

ON ENT- (VIA BOSCH AND BARAD)

BY REBECCA
EDWARDS

INHABITING ENT-

The scene opens with a luscious emerald landscape, bursting with life forms and other organic matter thirsty for the sun's rays. Encased within speckled clouds, the baby blue sky is feverish in its anticipation of discovery, and the sun dappling through appears as an orb of pure white light.

**ENT-ER. ENT-ER.
ENT-ER. SHE'S
WHISPERING TO YOU.**

Gliding over a pool of crystal water you accelerate at the approach of the first sculptural monolith. Dazzlingly blue and resembling a sepultura of histories past, it stands tall with ribbon-like appendages topping its bulbous mound. As you come closer, floating, an oculus at its base pulls you in. Time slows down; something in the air changes.

The space around you darkens and thickens and at the centre of the abyss, a creature emerges from the abstracted darkness, glowing now with a lattice of light pathways and rhi-

zomatic, fluorescent pastel tentacles. The creature is fluid, its colour and shape is ever-changing. Transfixing and transformative, it turns into motes of multi-coloured light and whirls into a frenzy, forcing you out of your cocoon.

**ENT-ANGLEMENTS.
ENT-ROPY. ENT-ER.
ENT-WINING.
ENT-HRALLING.
ENT-ICING.**

Now in the water, you watch as more architectural monoliths spin on their axes, glitching in and out of focus. Dynamic, they bounce with animated abandon, vibrating in a state of constant agitation and impulse to move. Shimmering with potential, the landscape opens up to you and becomes a nest of cable-like blue lights, tangled amidst the green and pleasant land of which you were once part. Powder-blue turns cobalt, turns Aegean blue, turns to dusk, fades to black.

BOSCH'S GARDEN

Libby Heaney's *Ent-* is a foray into unknown unknowns, a trip of sorts down a meta-memory lane, carving out a future that might already exist beneath the surface of what is perceptible. Inspired by the central panel of the Hieronymous Bosch triptych *The Garden of Earthly Delights* (c.1490–1510), *Ent-* is a quantum interpretation and exploration of the parallels between Bosch's garden and the potential futures of quantum computing centred around belief, sin, desire and categorisation. In Bosch's work, we see a celebration of human behaviour: bodies pulsate with the possibility of being, winding themselves around the uncanny, untethered and untold.

As a single narrative, Bosch's painting shows a hellish fate for humanity consumed by passion and pleasure. Whereas for *Ent-*, the inevitable end dictates a path of entanglement, of shape-shifting reality, and through queering a sense of stability. With desire at the heart of both works, viewers must tread carefully.

FROM CLASSICS TO QUANTUM

Using quantum theories of entanglement, superposition and interference, the work disbands the structural binaries of classical computing, which uses bits present as zeros or ones. It instead incorporates a quantum understanding, which uses quantum bits present as zeros, ones or a linear combination of both states of being. For example, a classical bit is either on or off, but a quantum bit can be on and off at the same time, a condition known as superposition. If in a superposition, the particles can be in any or both states at once, only when they are observed do they fall into one state or another. Made to solve problems that are unsolvable by traditional methods, the quantum computer calculates in a new way, one that uses a non-binary system as its primary function. This methodology can be applied metaphorically to *Ent-*, which makes visible non-binary reflections on an intrinsically non-binary world. By generously allowing the evolution of forms, matter, pattern, object and materiality, the figures in Bosch's painting are transfigured into what they could have been, stretched, re-interpreted and made anew.

Unlike Bosch's triptych, where 'reading' the work from left to right forms an essential part of the understanding of the work, Libby's world unfolds non-linearly, is generative and randomly collapses. Tentacles of animal and organic matter sway and double-bend, Möbius-like they swell and pull themselves in strange

ways. Everything is weird, but everything feels whole. Throbbing spikes protrude through slimy skin, architecturally built, veins like marble. The city is made drippy where all possibilities exist.

The viewer is led through Bosch's re-made landscape via new combinations of immaterial and material entities, entangled together and ultimately all part of the same state: a state of flux as yet undefined. This interference affords a superposition of looking at the world, to become a powerful tool to reimagine what we might already know. Only by looking do we allow the world to reveal itself to us; until the moment of looking all things are possible and impossible at the same time.

SUPERPOSITION

In quantum computing, with information stored in superpositions, some problems can be solved exponentially faster than in classical computing. In Heaney's work, we see this speed in the shifting and metamorphosis of three main areas: sky, architecture / landscape and water.

The sky pulsates and glitches in and out of focus, harmonising colours sparkling. Made of watercolour swatches and HDRI imagery¹, it breathes and moves in unexpected ways, vectors appearing and disappearing in the distance. The architectural assets in the landscape ebb and spin on their axes, moving simultaneously closer and further away, fever-dreaming in their relentless morphing. They retreat and then expand, exploding out of their shells and then back, as if on repeat. The landscape is a quantum jungle of creatures, zipping in and out of different dimensions and teleporting through layers of (un)reality. All entities are welcome here, a becoming-*with* of connectivity, feedback loops, interdependence and vulnerability. The water is iterative and all-encompassing. Its swirling, oily flow recounts experiences of past, present and future. Rippling under the weight of the changing world, we see our pathways reflected and refracted in it, the rhizomatic feelers reach for something to grasp, like strings of a web blowing in the wind.

The elements created in Heaney's work are ever-evolving in response to all the agents in the environment.

¹High Dynamic Range Image. 'Dynamic range' is the amount of data about the brightness of the

image; such data is the much larger amount of the information than the human eye is able to catch.



Like if time could be sped up and we see our cities changing at a rapid pace too fast to properly decipher. All parts are contingent upon the others.

THROUGH A FEMINIST LENS

Gesturing towards entanglement, hybridity and post-humanity brings with it a feminist perspective on research and outcome. For Karen Barad, the entanglement of matter is inherent to its being. She proposes a theory she calls Agential Realism in which the world is composed of phenomena inseparable from their intra-actions². For her, 'the very nature of materiality is an entanglement. Matter itself is always already open to, or rather 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.³ Here, materiality is constituted as already entangled by its inborn openness to intra-action. This can be explained visually in early watercolour assemblages in Heaney's research. The bleeding together of edges, the ebbing and flowing symbolise quantum reality morphing with different 'objects' bleeding one into another, meshing and blurring boundaries.

**TENTACLES OF ANIMAL
AND ORGANIC MATTER
SWAY AND DOUBLE-BEND,
MÖBIUS-LIKE THEY SWELL
AND PULL THEMSELVES
IN STRANGE WAYS.**

² Intra-action is a Baradian term used to replace "interaction," which necessitates pre-established bodies that then participate in action with each other. Intra-action understands agency as not an inherent property of an individual or human to be exercised, but as

a dynamism of forces (Barad 2007, p.141) in which all designated "things" are constantly exchanging and diffracting, influencing and working inseparably. Intra-action also acknowledges the impossibility of an absolute separation or classically understood objectivity,

**THE SKY PULSATES AND
GLITCHES IN AND OUT OF
FOCUS, HARMONISING
COLOURS SPARKLING.**

THREADS AND ENTANGLEMENTS

To return to the threads of possibilities in Heaney's work, and to align the work with a more research-based exploration between quantum computing and creativity, it's useful to consider Donna J. Haraway's thinking on the game of cat's cradle. This functions both as a way to position the work within a disruptive arena, and also to celebrate the intertwining and endless possibilities afforded when an openness is granted. As a metaphor, the cat's cradle proposes a seriousness in play, and the collaboration required when redefining or making new patterns in the world. This cat's cradle is both local and global, distributed and knotted together⁴, but it is also about movement and the acceptance of knots, tensions and flux within the process of making. The cat's cradle destabilises linear accounts of the research process⁵, becoming increasingly complex and interwoven with successive moves, thus becoming an absorbing means of considering insider and outsider participation from both human and non-human actors. For *Ent-* this takes shape in the quantum remixing of signs and signifiers from the rational world – via Bosch's lucid celebration of the human where bodies throb with frantic

in which an apparatus (a technology or medium used to measure a property) or a person using an apparatus are not considered to be part of the process that allows for specifically located "outcomes" or measurement. W. Stark, intra-action, n.d., newmaterialism.eu.

³ Karen Michelle Barad, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*, Durham, NC: Duke University Press, 2007.

energy, winding themselves around the uncanny, untethered and unknown – into a multifaceted environment full of hybrid creatures in a pulsating, collapsing, rational world, the scattered ruins of which become the (new) plural world.

As a prefix, 'Ent-' is to begin, to enter. As a keystroke on a keyboard, 'Ent' is also to return. But a return to what, to where, or to whom? Does this mixing of human, animal and organic free the human body from its preconceived state into another possible being, or does it canonise the existing hierarchy of the social status by pertaining to dominant and subordinate roles?

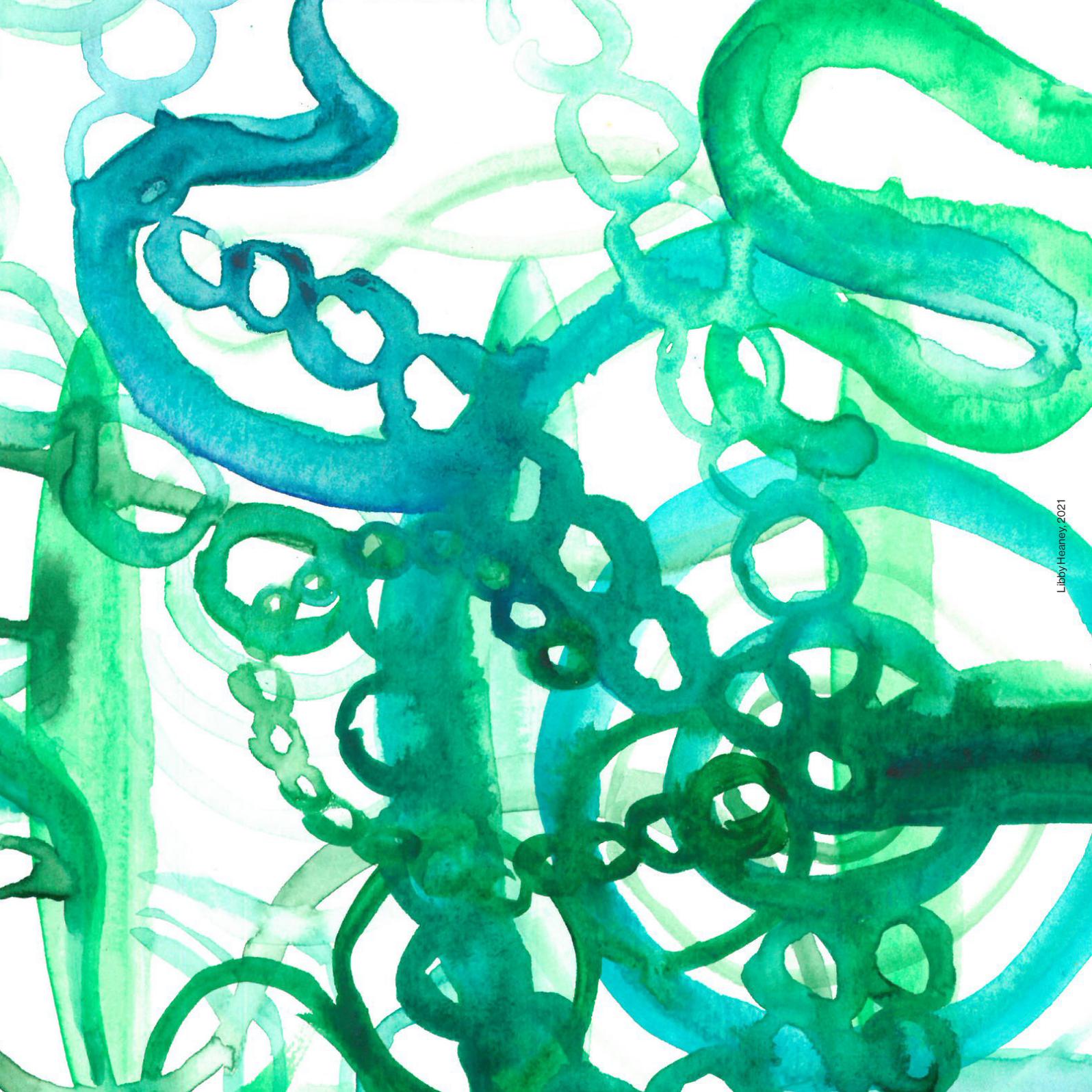
For Heaney, the work places the responsibility of this ordering with the viewer. Since the work has shaken up and re-mixed different categories through quantum processes, how the viewer 'measures' the resulting 'superposition' – i.e. the meanings they may glean from the work – is the collapse of an existing hierarchy or the making of a new hierarchy. Utilising a kind of performativity with the work, the world within *Ent-* isn't merely represented but is iteratively (re)produced, the world 'becomes' through inherently material practices of knowing, thinking, measuring, theorising, observing, of intra-acting within and as part of the world. Following Barad in the way that context is built on 'specific material configurations'⁶, the audience and the work co-constitute the ultimate meaning of it, dynamically reconfiguring the world around them.

**THE WORLD 'BECOMES'
THROUGH INHERENTLY
MATERIAL PRACTICES
OF KNOWING, THINKING,
MEASURING, THEORISING,
OBSERVING, OF INTRA
ACTING WITHIN AND AS
PART OF THE WORLD.**

⁴ See Donna J. Haraway, 'A Game of Cat's Cradle: Science Studies, Feminist Theory, Cultural Studies', *Configurations*, vol.2, no.1, 1994, pp.59–71.

⁵ See Niamh Moore, *A Cat's Cradle of Feminist and Other Critical Approaches to Participatory Research*, Bristol: University Of Bristol, 2018.

⁶ See Barad, *Meeting the Universe Halfway*.



LIBBY HEANEY

Is a British artist and lecturer who holds a PhD in Quantum Information Science from the University of Leeds and an MA in Art and Science from Central Saint Martins – University of the Arts London. She has exhibited widely in galleries and institutions in the UK and internationally, including solo exhibitions at Holden Gallery, Manchester (2021); Emmanuel Church, Loughborough (2021) as part of Radar, Loughborough University's contemporary art programme; Goethe Institut, London (2019) and at Non-Space Gallery, Aarhus (2017) as part of their EU Capital of Culture programming. Group shows include RMIT Gallery, Melbourne (2021); Art-AI Festival, Leicester (2021); MUTEK, Montreal (2021); Etopia Center for Art & Technology, Zaragoza (2021); Science Gallery, Dublin (2021, 2019, 2018, 2017); arebyte Gallery, London (online 2020); LUX with Hervisions (online 2020); Tate Modern, London (2019, 2016); Institute of Contemporary Arts, London (2019); V&A, London (2018); Barbican, London (2019); Somerset House, London (2019); Sheffield DocFest (2018); CogX, London (2018); Sónar+D, Barcelona with the British Council (2017); Ars Electronica, Linz (2017) and Fundación Telefónica, Lima with the British Council (2017).

As well as quantum computing, Heaney's practice incorporates AI and VR technology, using each tool critically to investigate how and who they empower and disempower. Often Heaney's work subverts the usual uses of these technologies, forcing them to work against themselves to expose their drawbacks and dangers. Inspired by Surrealism and Dadaism, Heaney's work incorporates humour and nonsense to investigate subjectivity, truth and perceptions of reality, as well as our seductive relationships with new technologies.

REBBECA EDWARDS

Is a curator at arebyte Gallery, London since 2017 where she curates the on-site exhibition programme and the online programme at aos.arebyte.com. Her interests lie in cultivating new curatorial methods across physical and digital space, interweaving fluid approaches to production, dissemination and representation of voices from artists working at the intersection of technology, online culture and new media. Other than arebyte, she has curated exhibitions at Ars Electronica, Linz; Off Site Project, online; The Royal College of Psychiatrists, London; Zabłudowicz Collection, London and Lewisham Art House, London. She has written texts for +DEDE, Berlin; Space: Women in the Arts; NEON, Athens and all arebyte exhibition booklets.

KAY WATSON

Is a researcher, producer and curator working with art and advanced technologies, photography and video games. She is currently head of arts technologies at the Serpentine in London and a PhD researcher at Birkbeck, University of London.

LAS (LIGHT ART SPACE)

LAS is a Berlin-based art foundation that brings together art, technology and science. Committed to new ways of presenting art, LAS commissions experimental projects, both physical and digital, in unconventional spaces. LAS is dedicated to future thinking and light is the foundation's guiding principle - a symbol of imagination, discovery and innovation.

THE SCHERING STIFTUNG – CONNECTING ART AND SCIENCE

The Schering Stiftung promotes the life sciences, the contemporary arts, as well as scientific and cultural education. A key focus of the Foundation's activities is on projects at the interface of science and art. The Foundation aims to promote the dialogue and exchange between the disciplines. It wants to create a space for new ideas and inject creative ideas into society.

The image features a central graphic of an atom with a glowing nucleus and several elliptical electron orbits in shades of purple and blue. The text "QUANTUM IS COMING" is overlaid in a bold, white, sans-serif font. The background is a dark blue gradient with two bright, four-pointed starburst light effects, one in the upper left and one in the lower right. A thin vertical white line runs through the center of the atom.

**QUANTUM
IS
COMING**

Libby Heaney

Ent- 2022

Immersive 360° installation

Sound composition by Nabihah Iqbal

Commissioned by LAS (Light Art Space)

LAS

Dr Bettina Kames, *Director*

Amira Gad, *Head of Programmes*

Sophie Korschildgen, *Assistant Curator*

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Dr. Katja Naie, *Managing Director*

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Edited by

Amira Gad

Sophie Korschildgen

Nicole Wittmann

Evelyn Nossol

Texts by

Rebecca Edwards

Kay Watson

Translated by

Kobalt Languages

Copy/Line Edited by

Janine Armin

Léon Dische-Becker (Wilk)

Anna Wittmann

Designed by

Studio Yukiko

LAS Team

Jan Fischer, *Founder & Co-Director*
Dr Bettina Kames, *Director*
Kristina Leipold, *Commercial Director*
Amira Gad, *Head of Programmes*
Sophie Korschildgen, *Assistant Curator*
Liz Stumpf, *Assistant Curator*
Nicole Wittmann, *Curatorial Assistant*
Jan Sauerwald, *Head of Production*
Flinder Zuyderhoff-Gray, *Production Manager*
Alexis Convento, *Production Manager*
Harriet Collins, *Exhibition Production and Design Assistant*
Felix Thon, *Head of Marketing and Communications*
Selin Sahin, *Communications Manager*
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The logo for Light Art Space (LAS) consists of the letters 'LAS' in a bold, black, rounded, sans-serif font. The letters are slightly irregular and have a hand-drawn feel.

Light Art Space gGmbH
Almstadtstraße 24
10119 Berlin
visit@lightartspace.org
lightartspace.org

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The logo for Schering Stiftung features the words 'SCHERING' and 'STIFTUNG' stacked vertically. The letters are bold and black, with a white outline. The letters are contained within a circular shape that is partially obscured by the text.

