WHOLLY QUANTUM

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Abstract

Most theories of quantum mechanics do not offer clear yes/no empirical answers to all questions that seem at face value. The Many-Worlds Interpretation (MWI), originated by Hugh Everett in the late 1950s, is unique for its unambiguous envisioning of reality: our universe is one of the numerous parallel universes that frantically branch off from each other nanoseconds by nanoseconds. In many of these worlds, there exist exact replicas of you and me, all evolving independently. My thesis exhibition, entitled *Wholly Quantum*, articulates this controversial theory in a visual way.

My artistic practice, consisting of a hybrid of electronics, lights, and sculptures, recasts reality within an utterly surreal framework based on the Many-Worlds approach of the microscopic world, and investigates the battle between a single reality versus a multitude of realities, what we perceive versus what reality is. This paper, as one of the two components of my thesis, carries out my research on the phenomena of reality and perception, as well as my creative experiments behind my exhibition at the Special Project Gallery at York University.

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Special thanks to my parents for your love and encouragement from thousands of miles away. And the most thanks of all to my partner for your understanding spirit and tolerating me constantly asking for scientific clarification.

Last but not least, it goes without saying that I have learned enormously about the otherworldly realities from extremely intelligent scientists. Many thanks for teaching me to let my imagination fly, never regard any height as inaccessible, and remain resolute to possible truths, no matter the consequences that might follow.

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To Hugh Everett, and all thinkers throughout history
who flew away from haze toward clarity.

Introduction

My artistic approach is based on blending disciplines of art, technology, and engineering, and the incorporation of both social issues, philosophical theories and scientific methodologies that revolve around the notions of perception and reality. I am frequently interested in creating immersive spaces that lead a momentary expansion of consciousness, which allows one to recapture a sense of wonder through adopting temporary freedom from the habitual and biased perceptions. To continually practice and expand my interest in what we commonly translate as *unknown* or *otherworldly*, I have dedicated my thesis project to the MWI, quantum mechanics' version of the *multiverse* or the *parallel universes* theory.

As one of the greatest intellectual achievement of humankind, quantum mechanics is undoubtedly the most comprehensive view of reality we have today. It teaches us that many of our implicit assumptions about ourselves and the workings of the universe (or universes) are not true and might even be mere illusion. This is exactly where my favorite MWI steps forward. My thesis exhibition visualizes this extraordinary dive deep into the nature of reality, where the venerable and satisfying classical laws of physics fail.

This support paper, as the second component of my MFA thesis, parallels *Wholly Quantum*, my solo exhibition at the Special Project Gallery, wherein interactive technology, abstract sculptural objects, and vibrant lights portray that pass into the micro-world of subatomic particles, one's observation causes a quantum system to become entangled with the environment, create decoherence and branch into separate universes. In this paper, I discuss the path I have strolled where various influences and inspirations, such as my own childhood and adolescence experiences, altered states of consciousness, and subjective reality in philosophy and medical sciences, have led to my current methodology in conceptualizing a hidden reality.

Inside the Gallery: Observation and Splitting

Through the large window of the Special Project Gallery, one immediately sees a darkened space, frequently lit by the intense strobing of four coloured lights that surround an abstract sculptural piece. Each light has a distinct colour and flashes at a different speed. Upon entering the gallery, the lighting changes abruptly. Inside, next to the gallery's window, one encounters four LED strobe lights mounted on the three walls around a suspended sculptural object. At this point, only one LED light still functions, while the other three have switched off. The functioning LED light is directed onto the surface of the 37"x28"x11" bubbly sculpture which has a black gloss finish. Three of the LED lights are connected to a PRI motion sensor that switches the lights off as soon as it detects the viewer entering the space. While examining this installation, the viewer can hear vibration sounds and see flickering lights on the other side of the gallery, separated by a black iridescent string curtain.

Walking into the large area of the gallery and passing through the curtain, the viewer is immersed by three distinct installations distributed equally on three walls; each consisting of a sculptural object and a wall-washer light. All three sculptural objects are identical. They are exact replicas of the initial suspended sculptural piece, albeit 1/3 smaller in scale. The interior of these objects is equipped with vibration motors, creating penetrating convulsions and movements. Above and/or below each object is a wall-washer light on flickering mode. Each wall-washer has same colour as each LED light that had been switched off on the first part of the gallery.

This hybrid installation, entitled *Wholly Quantum,* is based on the MWI of quantum mechanics. The exhibition challenges our rich and structured perception of the universe and proposes looking at reality from the counterintuitive, probabilistic, and irrational perspective of the subatomic realm.

Delusions of A Child

"There are experiences that most of us are hesitant to speak about, because they do not conform to everyday reality and defy rational explanation. These are not particular external occurrences, but rather events of our inner lives, which are generally dismissed as figments of the imagination and barred from our memory. Suddenly, the familiar view of our surroundings is transformed in a strange, delightful, or alarming way: it appears to us in a new light, takes on a special meaning".

Albert Hofmann, LSD: My Problem Child

I had one of these profound experiences early in childhood. Contrary to what Hofmann stated, it has remained remarkably vivid in my memory, so much so that it has imprinted itself upon my mind. If I had not had that experience, I might have never developed an obsession with the adventure of moving toward the *unknown*. I had a delusional belief: my parents and brother had deformed faces, which were eternally morphing and melting when I was not looking at them. "They are teasing me", I thought, "my very act of observation would make them appear as how I actually see them". At times, I would randomly and abruptly peek at them in an attempt to catch their non-human beings. This abstract impression provoked a sense of curiosity, which led me to frequently question the notions of what I today know as *reality* and ultimate *truth*. I thought that there should be other aspect(s) to reality, perhaps more vigorous and uplifting. But it was only a philosophy. I did not have a concrete answer as to whether reality I perceived was relational or absolute.

Growing up in Iran, the Islamic educational system taught me to have unconditional faith in accumulated and religious knowledge and to never question the mysteries of the universe. I was told that having any doubt about the existence of Allah and the workings of his Creation would guarantee a seat in Hell! For a few years, believing blindly in God and his prophet was a safe comfort-zone. I supressed my turbulent and boundless imagination as I did not want to be punished. The alternative seemed suitable, albeit lacked inquisitiveness; to entangle with superstitions and prejudices and to fool myself that I had ultimate answers and privileged access

to truth. But intuitively, something was still bothering me.

Figure 1: Barbara Kruger, *Belief+Doubt*, 2012. Courtesy of Hirshhorn Museum and Sculpture Garden, Washington, D.C. Photo: Cathy Carver. https://hirshhorn.si.edu/exhibitions/barbara-kruger-beliefdoubt/ Accessed 30 Nov. 2019

It was bothersome to an extent that I started *doubting* my (imposed) beliefs. In her 2012 site-specific installation at the Smithsonian's Hirshhorn Museum and Sculpture Garden (fig. 1), Barbara Kruger talks about her interest in "introducing doubt at a time when the value of certitude is taken for granted" (Hirshhorn par.2). The title of this immersive installation, *Belief + Doubt*, is taken from a phrase that she had used in an earlier work: *Belief + Doubt= Sanity*. Here, to challenge social relations and networks of power through open ended questions in form of printed- text vinyl, Kruger thinks "with the absence of doubt, each side clings to its values, devaluing the other side's value, making any cooperation an act of betrayal" (Rosenbaum par.38).

Presumably, introducing doubt to belief balances our perspective and eventually presents us with *wisdom* or *clarity*, terms that in Kruger's opinion are possible substitutes for *sanity*. I always enjoy the compatibility of human psychology and science and frequently find patterns where the two disciplines intersect. It is interesting that a radical approach by some mathematicians follows a similar philosophy as Kruger's. They start with a belief and take a formalist approach that is internally coherent. If they find no answer by modifying their approach several times, they tend to think that a new perspective may be needed or generalize their perspective in a way to obtain

more application. Finally, if needed, they revolutionize the initial approach.

Having been overwhelmed with non-realistic religious concepts, I became interested in the *mathematician's approach*. Juggling with ideas that appeared concrete opened my mind to new possibilities of the mechanism of the universe, which were initially triggered by doubt. I was disturbed by certainty, order, and determinacy in nature. Fibonacci numbers, Kepler's laws of planetary motion, or da Vinci's Vitruvian Man suggested that everything in the universe was definitive. Such concepts did not seem to satisfy my desire of exploring things that are outside of our spatiotemporal reasoning. There must had been something in between or beyond the Cartesian worldview, something invisible from the everyday sight that would propose that we are only one component of a far grander reality. Even though the great scientific discoveries of the 20th Century, such as Einstein's general relativity and quantum mechanics, had radically modified our Newtonian image of the world, we were still taught the classical approaches of envisioning the world. It seems even today we have not yet fully adapted to the prolific jewels that the scientists had left for us over a century ago. This tragedy is well explained by Whitehead, "We are told by logicians that a proposition must be either true or false, and that there is no middle term. But in practice, we may know that a proposition expresses an important truth, but that it is subject to limitations and qualifications which at present remain undiscovered" (182).

Later on, I was exposed to vitalism. The first step to answering some of my questions required abandoning traditional scientific materialism. Questions such as "Why does the universe obey a certain set of laws?" or "Why are we so confident that the Earth would never exit its orbit?" seemed to have a rebellious property that objected to our most rooted convictions. I still preferred to learn about the unknown possibilities within a rather scientific framework while also appreciating the idealistic or spiritual approaches to understanding. Having been devastated by religious practices, I valued how honest awareness of our ignorance is the heart of scientific thinking.

Albert Einstein, then 5-years old, was given a magnetic compass by his father. "Something is

deeply hidden", he thought as he was eager to understand how the needle of the compass behaved in such a determined way (Godier 00:13:35). We now know that it is the magnetic field of the Earth that allows the compass to always know the direction of north. I too, like Einstein, assumed that something was invisible underneath layers and layers of dust, something that I was yet to comprehend. I suspected the "actual" could potentially turn out to be illusionary and ephemeral. I was, of course, not yet as gifted and intelligent as Einstein and it took me a decade to realize that examining reality from new perspectives could be pursued in various branches of scientific knowledge. And so, my understanding of reality, perception, and representation radically changed in 2014.

Altered States

The human brain is predisposed to create myths. We are constantly in search of concepts and theories to define and classify our environment. Jerome Bruner, a founder of the cognitive revolution in psychology in the 1950s (On the Move 365) calls this behavior *Narrative Construction of Reality*. In his *Acts of Meaning*, followed by his *Actual Minds, Possible Worlds*, he recognises two modes of thinking that lead us to construct our reality: the paradigmatic and the narrative. "The former is the method of science and is based upon classification and categorization. The alternative narrative approach organizes everyday interpretations of the world in storied form" (Murray 112). It is anticipated that when we lack empirical reasoning, supernatural explanations come to mind. Whereas, "science is made up of experiments, hypotheses, equations, calculations and long discussions" (Rovelli 9). Science has not accumulated its credibility and reliability from providing certain answer. Rather, it is reliable because it is repeatable and consistent, and always evolving, offering us with the best answer we have at the present.

I became interested in studying psychedelics during my final year at OCAD in 2014. The counterculture of psychonauts has always been associated with shamanism and metaphysical thinking, often regarding psychedelic substances as "sacred" with extraordinary power to heal. I tried not to completely ignore this approach. At the same time, it did not interest me much and I thought it would entirely distract me from an objective or epistemological study to conceive the biological and psychological impacts that lead one to a euphoric, transcendental, or even horrific state. I thought that the science of psychedelics was extremely vast, and inherently mystical, that focusing only on supernatural phenomena such as telepathy, out-of-body experience, or miraculous healing was somewhat unavailing. I was rather fascinated by the fragility of human brain, the very organ whose complex mechanism is still not fully understood by the world's most eminent thinkers. How could this complex system of interconnections and synapses between many billions of cells become extensively stimulated and altered by just one-hundred microgram dose of Lysergic Acid Diethylamide (LSD)? How do our limited sensory organs suddenly perceive an expanded version of reality? If we already have in our brain the receptors for

perceiving profound psychic and visionary experiences, then why are they passive in our sober state?

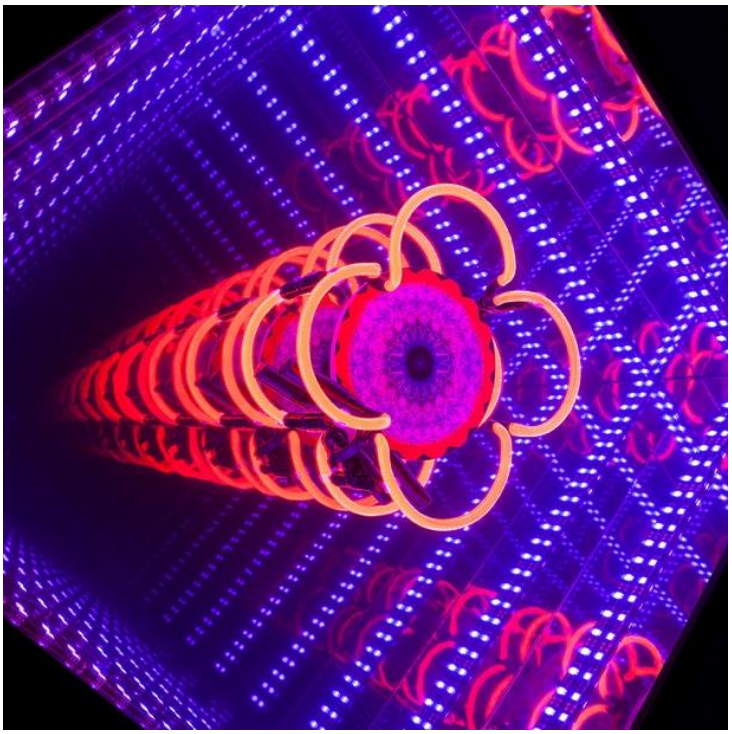

Figure 2: Arma Yari, *A Chemical Love Story*, LED light, neon light, mirror, glass, photographic print, 21x21", 2015. Installation view at Xpace, 2015

I investigated the physiological and psychological effects of LSD through a series of eleven sculptural works, entitled *A Chemical Love Story* (fig. 2). I placed LED strips, geometric patterns made of neon light, MRI scans, and images of neurotransmitters between a regular mirror and a one-way mirror inside square and rectangle shadowboxes. This created a seemingly endless series of reflections of objects that were situated between the mirrors. I literalized this conceptual process by narrating the biological processes during an LSD experience. The series starts with a sculpture that represents the compound being absorbed from the gastrointestinal tract and proceeds to a sequence portraying cerebral stimulation of the sympathetic nervous system, propagation of nerve impulses, and the activation of 5-HT2A receptor, which plays a key role in perception and consciousness (My Problem Child 29). My aim in *A Chemical Love Story* was to visualize the perceptual transformation of an LSD-induced intoxication and to invite people to enter a kaleidoscopic realm of fascination and paradox.

When reading about the entheogens and neuroscience, I found out about other situations where the consciousness and awareness become altered and expanded. I found pleasure in studying the brain abnormalities or dysfunctions, such as temporal lobe epileptic seizures, which according to Oliver Sacks, "arise from a particular area of damage or sensitivity in one part of the brain" and often cause patients to experience olfactory and auditory hallucination (Hallucinations 14). I have never directly created work based on neurologic disorders, but just knowing that these patients experience a very different form of reality, broadened my horizons and taught me to think fluidly.

In works followed after *A Chemical Story*, I did not completely avoid metaphysical thinking. Science (and art) spring from the mysteriousness of the Nature and to invoke anything supernatural is probably not reliable or availing. But, I think, despite scientists' attempt to advocate demystification and clarity, mystery is somewhat inherent in science. Similarly, Hofmann's philosophy suggests that in the process of scientific experimentation "If you don't turn into a mystic, you are not a natural scientist" (Divine Scientist 37). I have always been attracted to this fantastically twisted property of nature. Luckily, there are countless brilliant artists who have tackled such conceptual strategies, and whose works have influenced my practice.

Figure 3: Apichatpong Weerasethakul, *Uncle Boonmee Who Can Recall His Past Lives* (2010), film still. Photo: https://cinema-scope.com/cinema-scope-magazine/apichatpong-weerasethakul/ Accessed 5 Dec. 2019

One of my favorite examples is Weerasethakul's 2010 Palme d'Ore recipient, *Uncle Boonmee*

Who Can Recall His Past Lives. This film, far from the Western notions of reality, possesses Zen-like aura through hypnotic, sensual, and radically nature-based visuals and soundscapes (fig. 3). *Uncle Boonmee* is preoccupied with Heideggerian notions of nature and being, embodying a strange and sublime version of the Nature where the boundaries between the otherworldliness and the everyday as well as the living and the dead dissolve. The duality between humanity and animality, life and parallel universes, rapturous portrayal of Thai countryside and realistic dialogues, offer a rather surreal experience and obliterates the border separating the material world from the spiritual one. This duality became part of my practice from 2016 to 2018.

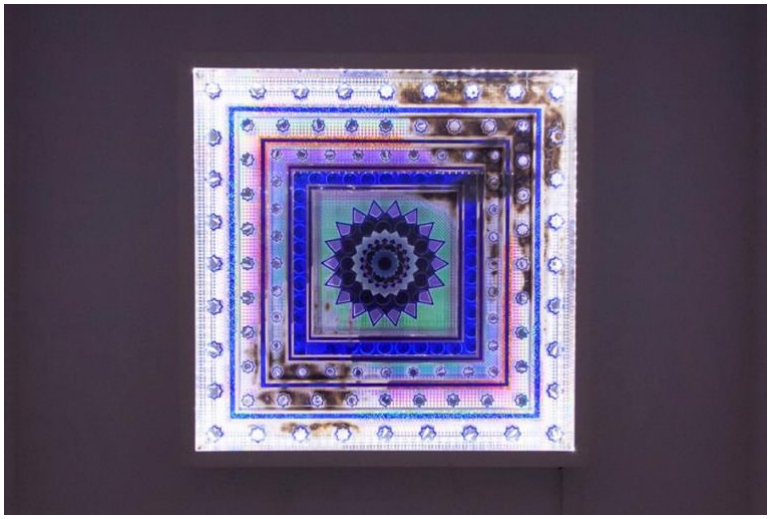

Figure 4: Arma Yari, *Untitled 3 from Can You Pass the Acid Test?*, LED light, vinyl, plastic, photograph, 29x29", 2016. Installation view at Gallery 44, Photo: Jocelyn Reynolds, 2016

Can You Pass the Acid Test? (2016), (fig.4), *3.5-7.5 Hz* (2017) (fig.5), and *ALTER* (2018) (fig.6), were three distinct projects where I straddled the divide between respecting tradition and welcoming innovation, art and science, and the material and the immaterial. I connected to my heritage through the use of Iranian architectural elements, particularly geometric pattern in Iranian mirror-work, that has many symbolic meanings including purity and wisdom, and is commonly found in spaces of great cultural significance, such as places of worship. Geometry in Iranian architecture of post-Islam employs the possibilities of perceiving and understanding realities that are not available to the rational mind. The perfect harmony and proportions engage in the "crystallization and expression of the *mundus imaginalis*, the realm where invisible

realities become visible and corporeal entities are spiritualized" (Nasrollahi 1). The traditional architects are extensively concerned with the relationship between the cosmic imagination and the methods in which the architectural imagination is articulated. This cosmic imagination often entails a sense of immersion, as if the body and the soul float in alternate reality.

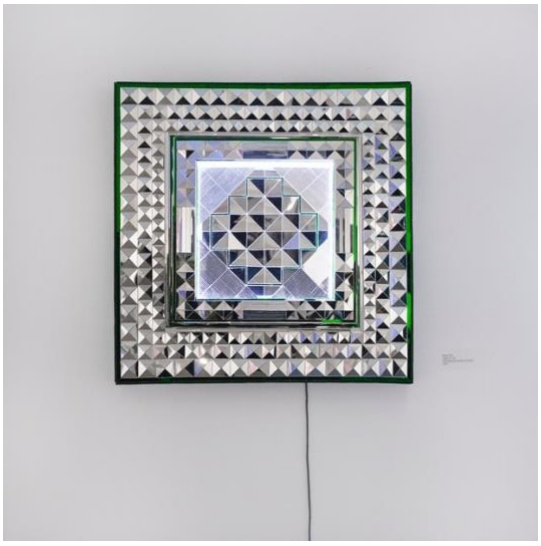

Figure 5: Arma Yari, *3.5-7.5 Hz*, LED light, mirror, 20x20", 2017. Installation view at Narwhal Contemporary, 2017

Figure 6: Arma Yari, *ALTER*, neon light, mirror, glass, 35x35", 2018. Installation view at Arma Yari's studio, 2018

Immersion of the Body and the Soul

In *Wholly Quantum*, I am aiming for a full-body immersion effect. I believe by transforming the character of the room entirely and submerging the viewers into an alternate situation, the habitual perceptions and culturally-biased assumptions will disappear, and ultimately, this can potentially function as "perceptually and invigorating philosophical tool" (Davies 33). Creating immersive spaces has frequently been an important element of my artistic practice. In both *100 µg, Intramuscular* (2018) (fig. 7) and *Sonati, Sanati* (2019) (fig. 8), I created psychedelic temples of sensory overload that pay tribute to the tantalizing human experience through a fusion of texture, linearity, and colour to embrace an ecstasy that is akin to entering a state of *cosmic fantasia*.

Figure 7: Arma Yari, *100 µg, Intramuscular*, 3D modeling, 2018

Figure 8: Arma Yari, *Sonati, Sanati*, LED light, optical fiber, mirror, holographic vinyl, wool, 2019. Installation view at SPG Gallery, York University, 2010 [1]

Basing my project on a subject matter that is entirely quantum mechanical, I think it is crucial to provide a greater degree of autonomy within the space that would allow the viewer to experience the work more directly. The MWI implies that the observer becomes entangled with the environment, meaning that he/she is no longer a mere observer, but a very important part of a quantum system (I will elaborate this further *in Many-Worlds: A Fully Quantum Approach* chapter). In immersive spaces, the boundaries between the self and the artwork, and ultimately the external world, becomes ambiguous. This dissolution of boundaries between inner and outer leads to an "experience of oneness, of the chaos, of the ultimate state of unity to which the mystic seers and philosophers of all ages have referred" (Davies 14). And, in order to illustrate entanglement in the uncanny world of quantum mechanics, the viewer should feel unified with a space that is suggestive of alternative sensibilities.

This type of psychologically absorptive immersion is present in the works of teamLab, a Tokyo-

[1] *Sonati, Sanati* pinpoints a disorientation in the consciousness of time and space caused by the schizophrenia between the past and the present. The installation explores the tensions between tradition and modernity in Iran, while identifying the sociopolitical background and the psychological consequences that have given rise to this issue. The signs are written in Farsi and read sonati (right) and sanati (left), which translates to "traditional" and "industrial". This humorous expression is used to describe someone who is behaving uncontrollably under the influence of a combination of plant-based drugs (such as opium) and synthetic drugs (such as crystal meth).

based interdisciplinary collective whose members are from various fields of practice: artists, architects, programmers, CG animators, mathematicians and web and graphic designers. According to teamLab, "we explore how art is extended through the concept of the digital. What we are interested in is not technology itself but rather how the concept of 'digital' can expand art" (Inoko). Through fabricating virtual and semi-virtual spaces, teamLab explores the existence and behaviour of the human being in a new society. For instance, their *Universe of the Water Particles in the Tank* (fig. 9), the flow of water changes when the viewer stands on or touches the waterfall. This provokes the visitors to kinaesthetically interact with various elements within the space. In *Wholly Quantum*, I similarly use interactive technology to provide the viewers with a very unusual perceptual context. The installation responds to people's behaviour. Their physical presence activates the PRI sensor and disconnects the lights. This process creates a sense of desire as viewers wish they could experience the installation with all lights on. I will explain the reason behind using a motion sensor *in Many-Worlds: A Fully Quantum Approach* chapter.

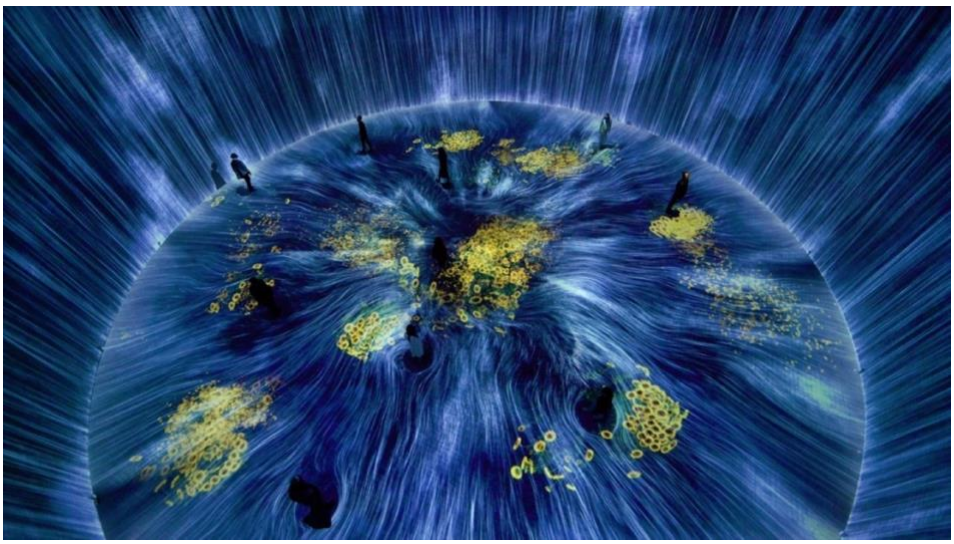

Figure 9: teamLab, *Universe of Water Particles in the Tank, Transcending Boundaries*, interactive digital Installation, 2019, Photo:https://www.teamlab.art/w/universe_of_water_particles_tank/ Accessed 10 Jan. 2020

I am particularly interested in spaces that would both welcome and disturb the immersants. The colours in *Sonati, Sanati* are somewhat mellow, the wool curtain and the rug invite people to physically experience the installation, yet the constant flashing of the LED signs causes discomfort and disembodiment. The same tactic applies *to Wholly Quantum*. This duality creates a sense of confusion, curiosity, and freedom. The viewers can decide whether if they want to

explore the installation further or to leave.

For this approach, I drew inspiration from the cinema of Gaspar Noe. His 2009 feature-length drama, *Enter the Void*, narrates the adventures of Oscar, a young American drug dealer living in Tokyo (fig. 10). Noe follows Oscar's out-of-body experience after he is shot by the police. The film uses psychedelic motifs such as vibrant computer-generated visuals and penetrating sound-effects to establish the story based on *Tibetan Book of The Dead*; a book famous for its psychological insights into the processes of death and dying. Elements such as flickering florescent lights, throbbing ambient soundscape, kaleidoscopic patterns and vibrant fractals to convey a sense of depersonalization and disorientation are among some of the influential characteristics of my thesis exhibition. Whereas Noe's use of disturbance is to represent "the sentimentality of mammals and the shimmering vacuity of the human experience" (Noe 6), I am using interruption in my thesis project because quantum mechanics is characterised by chaos, randomness, and fluctuation.

Throughout my work, I extended my research on the altered mind to a broader study of object-subject relationship discussed in biology and neuroscience in regard to how reality is formed.

Figure 10: Gaspar Noe, *Enter the Void* (2009), film still, courtesy of Fidélité Films, Photo: https://www.imdb.com/title/tt1191111/ Accessed 11 Jan. 2020

The Formation of Reality

The notion of *unity* is frequently bonded with *truth*, which is a fundamental concern in philosophy. *What is truth?* Pontius Pilate once came up with this question. Later in his life, Pilate concluded that there is no truth, everything is relative, and it is all just illusory. Reality is furthermore defined by an experiencing subject, an ego. "It is the product of an interchange between material and energetic signals, which issue from the outer world, and the consciousness-generating center within each individual person" (My Problem Child 169). The *outer world* refers to the entire material and energetic world, to which we belong in our physical embodiment. *Inner world* represents the mental world, the receptive and creative centre of human personality. When we are exposed to information, a *receiver* refers to the functioning of human physiology, and our experience of reality depends on the mechanisms of perception. Throughout this process, in order to make sense of the world around us, our sensory organs are transformed into a meaningful, mentally experienced image of the external world. We define reality through a process that requires constructing a rational description of the relationship between the outer and inner worlds, matter and mind, object and subject.

This is how we define reality. But the world we perceive with our senses is based on the capabilities and limitations of our sensory organs. For example, in order to make the world visible, "our eyes and inner psychic screens register a very small slice of the broad spectrum of electromagnetic waves" (My Problem Child 169). Our visual apparatus responds only to a very limited range, from 0.4 to 0.7 thousandths of millimetre, that is perceivable by us as light. The human eye cannot register the remaining radiation from the domain of electromagnetic waves. Other creatures, having different register impulses from distinct bands of wavelengths, experience a completely different outer world. The number of visual elements varies in the eyes of different animals, and thus, their environments differ correspondingly. German biologist, Jakob von Uexküll, describes the unique sensory and muscular mechanism of various creatures. To support this argument, he coined the terms *Umwelt* and *Merkwelt* which are translated to "environment" and "note world", respectively. The two expressions refer to species-specific and spatiotemporal subjective perception of viewing the world.

As discussed above and in the previous chapters, reality and perception are the notions that have been historically touched by biologists, neuroscientists, psychologists, and artists. In my thesis, I am concentrating on how quantum physicists approach and reflect on the mechanism of reality and perception. It interests me because quantum mechanics completely upends the fantastically successful Laplacian perspective, namely predicting the entire future history of the world from its present state, and instead draws an apparent distinction between what we see and what reality is. In the following short chapter, I will explain why I am using art to express this idea.

Art and Science

So, why visual art? Foremost, I think quantum mechanics is important and beautiful: there has not been a single verifiable experiment whose result conflicts with its predictions. Except art, I know no other language that could bring the importance and beauty of reality at nature's fundamental level to life so tangibly. Secondly, this project incorporates sociopolitical implications, albeit not as solidly and openly.

In chapter 4, I explained the importance of immersion to embody a space of unusual perception, a space of delirium. Despite my childhood imagination, which I started this paper with, part of my interest in quantum physics (and science in general) originates from the fragmented identity I have experienced in Iran. I grew up in a country where the government regards religious values to triumph over the great power of economic imperialism. Out of the Islamists' rejection of modernity and its fruits, a whole underground life has emerged where literally everything that the Islamic Revolution militates against is practiced by the youth under clouds of horror and anxiety. I clearly remember the immense lack of predictability within my crisis-driven society that offered no place for criticism, alternative, or solution. We had to learn to live with it. The result was an escalated sense of confusion between the younger generation. To me, everything seemed to be floating. My "underground" life was not simply a confident reality that was only hidden; it was rather a resentfully bizarre state where I had no clue how much of what I knew and experienced was real, and how much of it was illusion. Experiencing political unrest was perhaps one reason I became interested in science at first place. Because, on the surface, science appears to be absolute; it promised certainty to a confused young girl who was hopelessly seeking for solid answers.

Hence, perhaps, *Wholly Quantum* contains sociopolitical associations, even though the installation does not point at it. On the other hand, this project is not entirely scientific. Illustrating a scientific model or representing the formalism of quantum mechanics is not the prime concern of my thesis. I am rather responding intuitively to the provocative, yet simple MWI while also taking into account the mechanism of the *observer* effect, *superposition*,

entanglement, and *splitting*. Throughout my thesis, I intentionally aimed for a project whose art side overpowers the science side, at least aesthetically. At the same time, in order to make sense of the installation, I inevitably need to explain the associated and related features of quantum mechanics and the evolution of the MWI in the following chapter.

Quantum Mechanics

The 20th Century radically modified Newtonian principles. The deepening understanding of our world is based on two theories: general relativity and quantum mechanics. While Einstein's general relativity is studied within a rather classical framework, quantum mechanics immensely troubled Newtonian physics in the first quarter of the 1900s. Being immune to the laws of classical physics, it has strived to study the mechanism of matter at the scale of photons, electrons, atoms, molecules, and even macromolecules over the past century. The question as to whether quantum laws are applicable to systems larger than macromolecules has not yet been fully addressed. In fact, reconciling relativity and quantum mechanics continues to be an enigma, whose discovery would lead to *theory of everything,* and a world-shattering Nobel Prize to the scientist who formulates it. But, let me focus on the latter theory as my thesis borrows from its configurations.

The behavior of the world at the deepest level is weird, ambiguous, and counterintuitive, but it is not as baffling and impossible to understand as we know it to be. Richard Feynman, who more than anyone has known how to juggle with quantum theory, has written, "I think I can state that nobody really understands quantum mechanics" (Rovelli 140). More than a century after its birth, quantum mechanics remains shrouded in obscurity and incomprehensibility. The textbooks of quantum mechanics advocate the famous "Shut up and calculate" position. Nonetheless, the goal of some quantum scientists is to make the micro-realm maximally understandable. Despite the fact that the probabilistic nature of a quantum system creates substantial enigma, it is not intrinsically unintelligible, and the aim is to learn to live with it while trying to honor clarity over vague mysticism. I studied the works of several theoretical physicists who passionately practice the ontological pursuits (the "why") alongside the epistemic ones (the "how"). Carlo Rovelli, Brian Greene, and Sean Carroll are some of the most notable theoretical physicists whose books helped me to attain a better understanding of quantum physics. In the quantum mechanics community, these scientists are sadly in the minority for their attention to the associated ontological issues. Similar to these geniuses, my aim in *Wholly Quantum* is to touch the ontological concepts by creating a highly sensual and experiential space while making quantum

mechanics' MWI as straightforward as possible. I have tried my best to distort the *shut-up and calculate* mentality and delineate the ethereal and sublime qualities of the MWI.

Before getting into other properties of quantum mechanics that are important part of my work, I would like to start with *vacuum state fluctuation* and how it inspired the aesthetics of the sculptures in my thesis project. Vacuum state fluctuation refers to the temporary fluctuation in the amount of energy in a field, and because fields are governed by the laws of the atomic world, it falls within the realm of quantum mechanics. David Tong and his collaborators used computer stimulation to visualize *pure vacuum* (fig. 11), which according to Tong, explains "…even if the particles are not there, fields are constantly bubbling and fluctuating" (00:22:00). This representation of *absolutely nothing*, inspired me to create the bubbly sculptural objects that symbolize quantum fields and nothingness. The larger sculpture in the first part of the gallery is made of foam core, coated with plaster and finished with a mix of epoxy-resin and black ink (fig. 12.a and 12.b). As for the smaller sculptures, because I sought the exact copies of the larger object, the larger object was scanned, modeled in Rhinoceros, and then 3D-printed (fig.13). They are also coated with a mix of resin, black ink, and iridescent paint.

Now, let's review the other features of quantum mechanics that influenced my project.

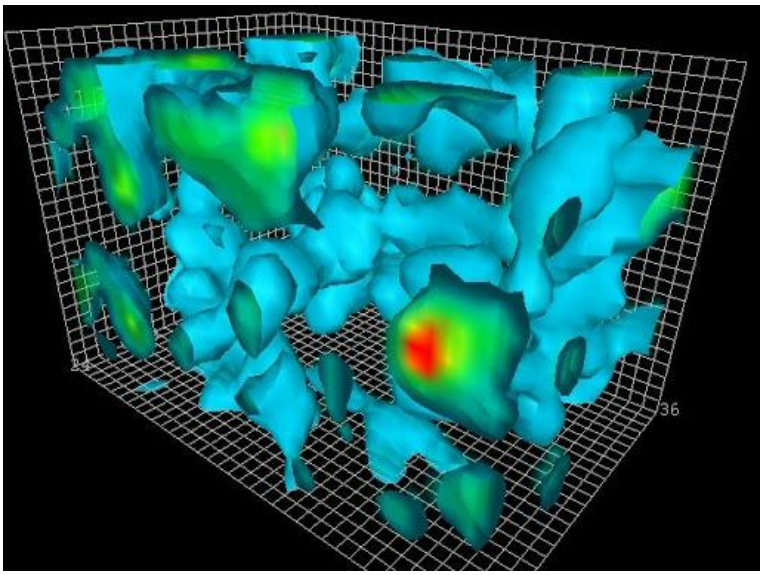

Figure 11: Vacuum state fluctuation, courtesy of Adelaide University, 2003, 2004. Photo: http://www.physics.adelaide.edu.au/theory/staff/leinweber/VisualQCD/Nobel/index.html
Accessed 15 Feb. 2020

Figure 12.a: Early stages of fabricating the sculpture, 2019

Figure 12.b: Applying pigmented resin to the sculpture, 2020

Figure 13: 3D-printed models, 2020

At minute scale, space and time change their nature. Instead of the deterministic, clockwork behavior of electrons orbiting the nucleus of an atom, the electrons are not in an actual and unvarnished state in a quantum phase. The location and momentum of particles fluctuate widely and dissolve into a cloud of possibility (fig. 14). Rovelli argues that indeterminacy, as one of the three features of quantum mechanics, explains that chance operates at the atomic level. This means that, “while Newton’s physics allows for the prediction of the future with exactitude, if we have sufficient information about the initial data and if we can make the calculations, quantum mechanics allows us to calculate only the probability of an event” (95).

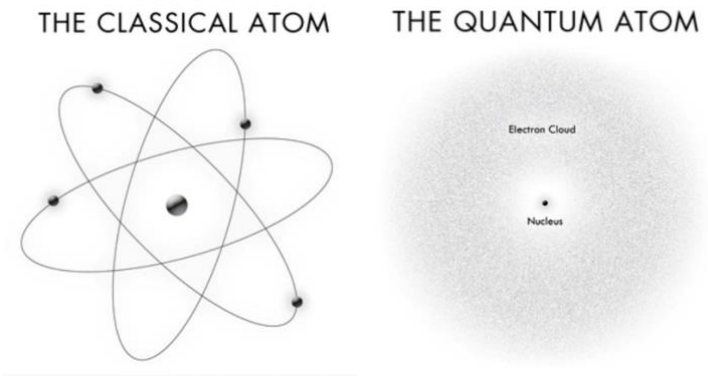

Figure 14: Classical vs. quantum atom, courtesy of Recreating Shambala. Photo: https://www.recreating-shambala.org/the-quantum-you/ Accessed 20 Feb. 2020

The range of possible states in quantum mechanics is known as *superposition*. Before human's interference for measurement or observation purposes, the various *superposed* states interact with one another in a wavelike manner: the particles can be in two locations at the same time. They can also vanish and reappear abruptly. This radically changes once we make a measurement or an observation: the superposition of the particles will be replaced with only **one** outcome. Correspondingly, this process inspired my choice of materials, namely LED lights and vibration motors, whose random and furious strobing and convulsions represent the fluctuant behaviour of the particles.

The universe is inherently quantum mechanical and probabilistic. We and everything around us are made of atomic particles. So, if an electron can be in a superposition (which is the case), can we be in a superposition of being in different locations too? Can we be at two or more different places at the same? Is this a clue to something profound regarding the structure of the world, which we have yet to fully decipher? Whether or not thinking about unperceivable reality causes us existential anxiety, we should acknowledge the fact that the fundamental nature of reality at the deepest level is determined by probability, chance, and randomness. In quantum world, Heisenberg's uncertainty principle[2] plays a fundamental role. Einstein was skeptical of the anti-realist nature of the micro-realm. In his well-known 1920s and 1930s debates with Niels Bohr, he famously said, "God does not throw dice" (Corn and Rosen 00:22:45). Contrary to the

[2] Uncertainty principle claims that there are no states for which both position and momentum are simultaneously definite.

popular belief, Einstein was not a conservative Oldman who disapproved the uncertainty principle. He was not terrified of the randomness. He rather insisted that the theories of quantum mechanics were incomplete, and a lot more had to be done. Today, we have well-defined theoretical physics frameworks that address such concerns. The problem is we have more than one. In the next chapter, I will examine my favorite theory, which is the focus of my thesis work.

Many-Worlds: A Fully Quantum Approach

In standard quantum mechanics, a quantum system such as a subatomic particle is represented by a mathematical abstraction called the *wave function.* Erwin Schrödinger invented an equation in 1926 to allow physicists to calculate how a particle evolves with time and to define all possible observable states of a quantum system, such as the various possible locations of a particle. When applying the Schrödinger's equation to a quantum system, the equation must evolve and operate from start to finish.

The *Copenhagen Interpretation* is one of the earliest theories that attempted to justify probability process of the wave function, that is what the probability of various possible measurement outcomes will be should you choose to observe it. Named after Danish scientists, Niels Bohr and his colleagues, the Copenhagen Interpretation is a valiant effort, but fails to fully address the evolution of the Schrödinger's equation. According to this theory, reality is created upon observation. Known as the *observer effect*, this means that before the presence of an observer, the particles are spread out everywhere, constituting all and every possible position. Once we come to the scene, all possibilities, except one, *collapse* and reality is reduced to one particle that assumes a definite location. Correspondingly, the probability wave surges to one-hundred percent at that spot, while collapsing to zero-percent everywhere else. The fundamental problem of the Copenhagen approach is that the Schrödinger's equation is set aside at the moment of observation. This violates the law of wave function, that is, the equation should continue to apply during a measurement. In addition, the theory fails to explain how mathematical formalism can explain reality. It is aligned with *shut up and calculate* motto as it only encourages observation and probability and does not consider the possible hidden variables. Einstein was right to call the Copenhagen Interpretation a "philosophical monstrosity" (Godier 00:35:00) and to criticize the incomprehensiveness of quantum mechanical theories.

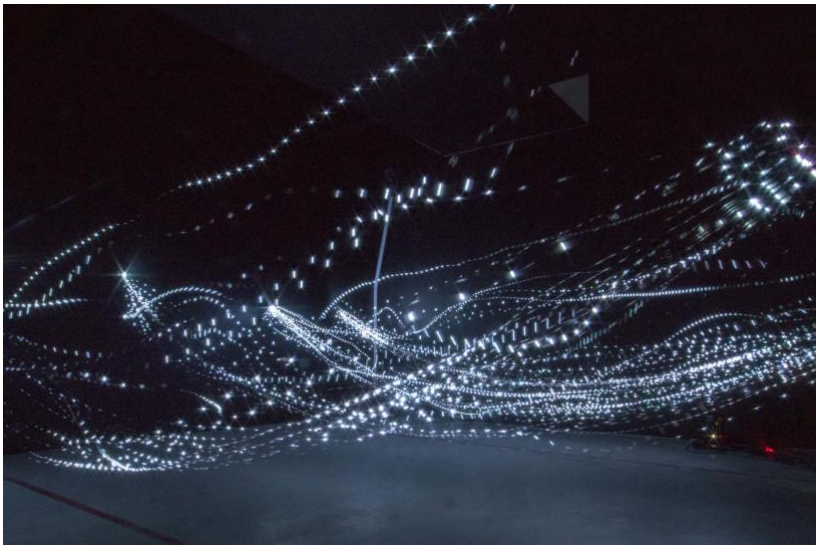

Figure 15: ::vtol::, *Wave Is My Nature*, interactive kinetic audiovisual installation, 2015. Installation at ArtScience Museum, Singapore, 2018. Photo: https://vtol.cc/wave-is-my-nature Accessed 10 Dec. 2019

A series of famous experiments, known as *double-slit experiment*, was performed in the 1970s, long after it was proposed (Carroll 75). The idea was to better understand the mechanism of the quantum system. Shockingly, scientists found that when an observer is looking at the scene, electrons behave like particles, while behaving wave-like in the absence of an observer. Dimitry Morozov, a.k.a ::vtol::, depicted this wave-particle duality in his *Wave Is My Nature*, which was exhibited at ArtScience Museum in Singapore in 2018(fig.15). This project is an interactive kinetic audiovisual installation which reacts to the presence of the audience and creates an autonomous sound and light composition.

Alternative theories principally try to either advance a realist approach- that quantum systems have inherent properties independent of observer and measurement- or avoid a measurement-induced collapse, or both (Ananthaswamy par. 26). In my opinion, the most beautiful alternative to the Copenhagen Interpretation is the MWI, quantum mechanics' version of the *parallel universes* which has unsurprisingly captured the most imagination in the popular culture. The MWI was invented by a PHD candidate from Princeton University named Hugh Everett III. In 1954, Everett risked his education by proposing a startling and controversial view: the existence of many invisible universes. He was aware of the incompleteness of Bohr's team's theory and claimed that in order to obey the Schrödinger's equation, the observer and the quanta particles

combine during a measurement. Physicists call this state *entanglement*. Everett furthermore argued that there is no mysterious and abrupt collapse of the wave function, and it only appears to us that the other probabilities vanish upon measurement. This process is known as *decoherence.*

What makes the MWI unique is that unlike other theories, it "required no changes or additions to the standard mathematical representation of quantum mechanics" (Ball par.22), and above all, it bears no dependence on classical physics. The title of my exhibition comes from this fact that the MWI is entirely quantum mechanical. The Copenhagen approach and the MWI seem to agree on the first half of the scenario. Particles are everywhere before observation. After measurement, the observer meets only one of the many outcomes. The first part of my exhibition illustrates the observer effect, as the presence of the viewer activates the PRI sensor to turn three out of four lights off. The Copenhagen Interpretation stops here, stating that the other possibilities suddenly vanish, and do not ask where and why they have disappeared. The MWI, however, goes further to solve the measurement problem, and so does my installation.

Imagine throwing a dice. The chance of having a "four", for instance, is one in six. In this case, the Copenhagen Interpretation tells that all of the other five probabilities-- one, two, three, five, and six—have collapsed, and you are confronted with only one of the six outcomes. The MWI, on the other hand, describes that all outcomes happen. The reality *splits*, or *branches off,* into separate worlds as each result entangles with the observer (the observer+ "one", the observer+ "two", and so on). Based on this revolutionary logic, whenever we make a decision that leads to more than one outcome, every outcome and a version of us entangle and inhibit its own distinct universe. This means that the world is constantly splitting. There are "many copies of what we think of as the *universe*, each slightly different, but each truly real in some sense" (Carroll 39).

The second half of my thesis exhibition depicts the above scenario. The viewer can now see the lights that had been switched off inhabiting their own independent universe. Each universe has a separate physical existence, represented by a vibrating sculptural object and a flickering wall-washer light. The vibration implies that in the world of quantum mechanics "…everything

vibrates; nothing stays still. The impossibility of anything being entirely and continuously still in a place is at the heart of quantum mechanics" (Rovelli 226), where matter is removed, and vibrations are studies (Whitehead 36). Furthermore, by standing close to each universe (installation), the viewer becomes symbolically entangled with that one universe without being able to intersect or communicate with other universes simultaneously.

Everett's mathematically- motivated insight that we are part of a multiverse is refuted by many physicists. To them, this theory violates the spirit of science that the predictions should be testable. They claim that the theory replaces verified facts with "an experience of pseudo-facts" (Ball par. 38). If we are not able to test the other universes, how can we confidently say that they actually exist? On the other hand, the proponents of the MWI argue that Everett's theory is above all extraordinarily simple and straightforward. It evolves with Schrödinger's equation and fits the data perfectly. The price we pay is that these many worlds are not observable, at least not for now.

Final Remarks

Being in heart and soul of modern physics, quantum mechanics promoted our 19th century steam engines and telegram signals to the age of electronics and transistors. It is plausible that among all theories of quantum mechanics, the MWI wins all the publicity. Sadly, outside of its glamorous depiction in the popular culture, the quest to understand it is not a high-status specialty in contemporary physics. Many physicists prefer to stay in comfort-zone of writing down equations in silence and value tangible results rather than considering what Einstein felt was crucial: to approach the foundations of quantum mechanics ontologically (instead of reducing it to epistemological knowledge) and to always ask what is happening behind the scene.

Unfortunately, the works of scientists who agree with Einstein are frequently left unappreciated and undervalued. Everett was no exception. His invention was a direct assault on Bohr's picture and was not considered "legitimate" or "serious" by his contemporaries. He gave up the academic fight with Bohr and his colleagues and quit physics all together. He then picked up a heavy drinking and smoking habit and died at the age of 51 (Carroll 127).

Reading about Everett's tragic career and life left me in awe. I immediately knew that such boundless imagination deserves an artistic demonstration. In my thesis exhibition, I try to remain faithful to the Everettian view while aiming to make sense of the MWI, because this stubbornly minimal theory advocates bold clarity. Furthermore, in this support paper, I mapped out my life experience and my creative experiments that fed my quest for comprehending what seemed to be baffling and inscrutable.

Wholly Quantum, while challenging our very sense of self, suggests that the MWI is the purest way of making sense of quantum physics. Accordingly, perhaps we should not be challenged much, we should not be afraid of being situated in a space that is not immediate and predictive, because after all, the Nature at its deepest level is quantum mechanical. We live with it. We are part of it.

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Appendix A: Thesis Exhibition Documentation

Video documentation: https://youtu.be/i1TtE9dV1sw

Figure 16: Arma Yari, *Wholly Quantum*, Installation view, 2020

Figure 17: Arma Yari, *Wholly Quantum*, Installation view, 2020

Figure 18: Arma Yari, *Wholly Quantum*, Installation view, 2020

Figure 19: Arma Yari, *Wholly Quantum*, Installation view (detail), 2020

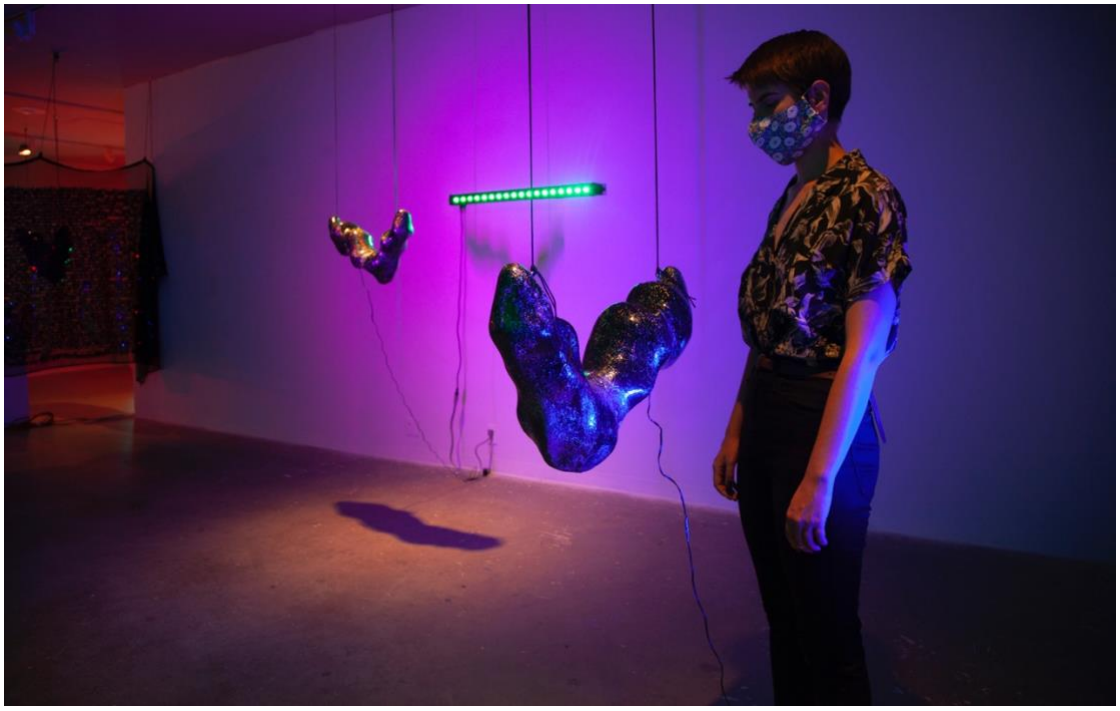

Figure 20: Arma Yari, *Wholly Quantum*, Installation view, 2020

Figure 21: Arma Yari, *Wholly Quantum*, Installation view, 2020