

**CHARLES UNIVERSITY IN PRAGUE**

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**Towards A Quantum Poetic Method: Quantum  
Computing and the Limits of Language**

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## **DECLARATION**

I hereby declare that this thesis document is the product of my independent work. It is authored by using the literature and resources which are duly and carefully cited. I also declare that this bachelor thesis is not intended to be used in order to receive any other diploma from any other institution established in the Czech Republic or abroad.

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# ABSTRACT

Scientists writing about quantum systems have encountered profound problems with language, problems entailed by the difficulty of accurately describing their theoretical constructions and experimental observations – both of which are highly counterintuitive. This thesis explores the history of quantum poetics, a field focused on the ways in which poetic language may provide tools to describe a counterintuitive reality and aiming to show, for example how quantum physics and poetry could intertwine to provide a better understanding of quantum computing. The goal of this thesis is to examine how poetic language may describe experience in ways similar to quantum phenomena, thereby attaining what scientific language cannot attain on its own. Additionally, the thesis argues for a distinction between two tendencies of viewing quantum poetry – as writing about quantum ideas or writing within quantum ideas. In order to achieve its purpose, the thesis undertakes a formal analysis of selected modernist poems by W.B. Yeats, Ezra Pound, and T.S. Eliot, and reviews how they incorporated the quantum discoveries of their times into their poetry and thought. The work concludes with an analysis of Amy Catanzano’s “World Lines: A Quantum Supercomputer Poem”, a poem which explores some concepts of quantum computing theory in a literary and visual way, inspired by a topological quantum computer.

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# INTRODUCTION

From its beginning, the quantum scientific inquiry challenged classical physics with values of quantization, the wave-particle duality of objects, the limited precision of quantity measurement, and many other “unusual” traits. Physicists used mathematical language to explain quantum dynamics, therefore this language is not easily understood by a readership without a specific scientific literacy. A distinctive characteristic of the quantum revolution was that, the “classical” laws of nature formulated in “classical” math did not match with the experiments and findings of quantum mechanics, which were highly counterintuitive; Heisenberg, Planck, Bohr, Einstein and other physicists wrote about the quantum world in an understandable language, yet to really grasp the concepts they were describing was challenging: Dirac addressed how quantum ideas need to depart from classical methods to describe the structures that challenges classical physics itself<sup>1</sup>, and Bohr described how physicists were faced with the need for a radical revision of the bases for description of physical phenomena.<sup>2</sup> We can see how physicists already noticed that ordinary language does not seem suitable to explain reality at the quantum level; for example, we might “understand” what a particle is or what a wave is, without really “comprehending” complementarity – we can only “imagine” it from our classical view. Nowadays, quantum phenomena and discoveries continue to amaze us; these ideas, no matter how complex, are not exclusive to scientists, as non-specialist audiences also demonstrated interest in the quantum world.

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<sup>1</sup> Dirac, P.A.M. *The Principles of Quantum Mechanics*, Oxford University Press, 1958. p. 12.

<sup>2</sup> Bohr, N. *Quantum Theory and Measurement*, Wheeler, J.A. and Zurek, W.H. (eds.), Princeton University Press, 1983. p. 9-49.

The present work examines the poem “World Lines: A Quantum Supercomputer Poem”, whose author Amy Catanzano explores some concepts of Quantum Computing theory, in a literary and visual way, providing tools for thinking about a system that is otherwise quite difficult to comprehend. Grasping ideas such as entanglement or superposition might be challenging to some, but it seems easier to follow the lines of Catanzano’s poem and decide on your own what happens when you encounter a word that exists in two sentences at once. This poem, inspired by a topological quantum computer, was written during a residency at the Simons Center for Geometry and Physics at Stony Brook University, New York, and attracted the attention of Katherine Wright, a senior editor of American Physical Society’s online magazine *Physics*. Wright explains how some aspects of quantum computing were incorporated into the structure of the poem, and in this article, Catanzano expressed her motivation to do this, which was to propose a solution, or at least begin the search towards a new language that could describe more precisely the apparently indescribable quantum world. Catanzano says that the qualities of poetry are suited for quantum physics, since “[p]oetic language is a hyperbolic language that can inspire fresh ways of seeing and being. It can deconstruct and challenge our assumptions.” She argues that poetic language is compatible with quantum dynamics, and she thinks that the general public could avoid confusions if poetry were more assimilated into our everyday lives.<sup>3</sup> The question is, even if we accept that poetic language can provide the tools to describe a counterintuitive reality, and that there might be a wide range of poetic literary devices with which to explore invisible worlds, play with the flow of time, and discover otherwise unthinkable things, can poetry really keep up with contemporary physics?

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<sup>3</sup> Wright, Katherine. “Arts & Culture: Poetry Takes on Quantum Physics”. *Physical Review Journals*, Published by the American Physical Society, 2018. Web. Accessed 9 April 2019, [www.physics.aps.org/articles/v11/103](http://www.physics.aps.org/articles/v11/103)



This is by far not the first time that artists have approached physics through art. Often, poets have tried to incorporate the science and new technology vital to the world “outside” in their texts. This required the development of new poetics that could draw upon theoretical physics, so the idea of using literary devices to explain science is not new. In 1995, Patricia Monaghan introduced the term “quantum poetics” in her dissertation of the same name, analyzing how some American writers included ideas of physics into their poetry, and in 1997 Daniel Albright examined the works of W.B. Yeats, Ezra Pound, and T.S. Eliot in consideration of their studies of physics.

It is important to note that the historical and social contexts have changed since the advent of quantum inquiry. To illustrate how it is worth discussing C.P. Snow’s famous lecture “The Two Cultures”, in which he talks about the social division and underestimation between the sciences and humanities in the intellectual environment in Cambridge University during the 50’s. Snow defends his proposition of the two cultures by identifying a set of attitudes, standards, approaches and assumptions that seep deep into mental patterns, affecting their work and emotional life, giving an “unscientific” flavor to *traditional* culture, increased by the emergence of scientific thought in the Western society. In Snow’s view, there was no apparent meeting point for these two cultures—i.e. humanities and science—for they are regarded as two different subjects, two disciplines, two worlds that once bridged, could bring creative opportunities; he claims:

It is bizarre how very little of twentieth-century science has been assimilated into twentieth-century art. Now and then one used to find poets conscientiously using scientific expressions, and getting them wrong—there was a time when 'refraction' kept cropping up in verse in a mystifying fashion, and when 'polarised light' was used as though writers were under the illusion that it was a specially admirable kind of light. Of course, that isn't the way that science could be any good to art. It has got to be assimilated along with<sup>4</sup> and as part and parcel of the whole of our mental experience, and used as naturally as the rest.

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<sup>4</sup>Snow, C.P. “The Two Cultures.” *The Rede Lecture*, Cambridge University Press, 1959. p. 9.

Technology, for instance, is a part of human experience that can be learned about in a systematic way, yet we have made ourselves believe that we are constantly being swept along the stream of unpredictable technology incompatible with art. As this gap between the “two cultures” grows wider, it seems impossible for society to think with wisdom.<sup>5</sup> The main critique of Snow’s propositions is their obsolescence: he gave this lecture in the 1950’s, and some of his ideas might not apply to the present time – for example, the kinds of social divisions he describes appear to have softened. However, the problem of translating possibilities between poetry and physics still persists. Physicists now seem to talk to artists, similarly, artists are fascinated by physics, but can poetry truly speak the same language as physics?

The social situation might have changed, yet Snow’s problem still permeates academic thought, so in beginning this thesis on Quantum Poetics, this idea must be addressed. Despite the improvement of the social situation, divisions among and within languages persist. An example of this can be seen in the Sokal Hoax, an article written by physicist Alan Sokal called “Transgressing the Boundaries: Towards a Transformative Hermeneutics of Quantum Gravity” which was highly celebrated until he revealed that it was a satire on “philosophers” fantasizing in fancy words about things they cannot understand. In another article called “A Physicist Experiments With Cultural Studies”, he exposed his motivations and concerns about the proliferation of a postmodern academic “sloppy thinking” denying objective realities, taking experimental physics as a hostage in what he describes in terms of intellectual political campaign.<sup>6</sup>

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<sup>5</sup> Snow, C.P. *op.cit.* pp. 23-26.

<sup>6</sup> Sokal, Alan. “A Physicist Experiments With Cultural Studies” *Department of Physics*, New York University, 1996. Web. Accessed 9 April 2019, [https://physics.nyu.edu/faculty/sokal/lingua\\_franca\\_v4/lingua\\_franca\\_v4.html](https://physics.nyu.edu/faculty/sokal/lingua_franca_v4/lingua_franca_v4.html)

Nevertheless, technology and science, as all other human activities, are part of a network of relations, and as such should be studied in connection with economic, political, cultural, and philosophical discourses, keeping in mind that these discourses are social to a degree. Word itself is already technological; once we grasp this, we understand that the human cannot represent itself without the use of technology, in this case writing, and the existence of culture itself relies on technologies of inscription and representation.<sup>7</sup> When we speak of literacy—reading and writing—we are assuming repetitive relations amongst text, image, and sign operations, including binary functions. Literacy, then, is a matter of apprehension which presupposes re-cognition, and to the modern human, immediate perception and abstract thought appear as organized realms of signs. So *literacy* may be taken to refer to “operating with visible signs”, a navigation of signifying or interpreted environments.<sup>8</sup> Still, word as technology has been used not only for the preservation of knowledge, but also to describe and structure abstract and ephemeral human experiences in the form of a wide range of genres from epic to poetry. In the preface of his book *The Principles of Quantum Mechanics*, Paul Dirac addresses how quantum ideas need to depart from classical methods to describe the structures of a dynamic system that challenges classical physics itself; newer concepts in physics can only be mastered with long-term familiarity with their properties and uses, and that’s why his book is concerned more with the mathematical language of quantum mechanics, in order to avoid confusion with the interpretations and assumptions attached to any word.<sup>9</sup>

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<sup>7</sup> Louis Armand writes that the word never existed in a purely pre-technological way, since word itself is *technological*. In Armand, Louis. *Literate Technologies*. Litteraria Pragensia, 2006. p. 5-10. See also: Greaney, Michael. “Suspended Animation: Futures of Technophobia”, In Bradley A. and Armand, L. (eds.) *Technicity*. Litteraria Pragensia, 2006. p. 347.

<sup>8</sup> Armand, Louis. *Literate Technologies*. Litteraria Pragensia, 2006, pp. 101

<sup>9</sup> Dirac, P.A.M. *op. cit.* 1958. p. 12.

The present thesis tries to examine how language, in this case poetry, *may* describe experience in ways similar to quantum physics. However, we must ask: Is Quantum Poetry writing about quantum ideas, or within quantum ideas? The working hypothesis was formulated as follows: since language is a tool with which we comprehend our reality, quantum poetics incorporates quantum dynamics into its literary devices, making the quantum ideas more accessible for readers without the specific scientific literacy, and perhaps poetics can attain something that even the scientific language and knowledge cannot attain on its own. In order to confirm or disconfirm this hypothesis, the thesis will undertake a formal analysis of a selection of modernist poems, in order to review how they have incorporated the quantum discoveries of their times, concluding with an analysis of Amy Catanzano's "World Lines: A Quantum Supercomputer Poem". The argument of this thesis will be structured as follows:

Chapter 1 provides an introductory historical background of the problems associated with quantum language, followed by an analysis of excerpts from the selected poems by W.B. Yeats, T.S. Eliot, and Ezra Pound, for these three are considered to be part of the genre of "quantum poetry" by Monaghan and Albright. This chapter will discuss how these modernist poets attempted something like "the quantization of poetry", putting emphasis on their methods and metaphors. In conclusion, this chapter will offer a very brief outline of the path that brought poetry into the realm of electronic textuality, and the advent of quantum computing.

Chapter 2 covers critical and theoretical sources relevant for the subject matter of this study, and reviews the basic principles of entanglement and superposition in quantum computing using the Bloch sphere, which provides visualization of a single qubit, useful for

testing ideas in quantum computation. All this with the view towards building a theoretical background needed for the analysis of Amy Catanzano's "World Lines: A Quantum Supercomputer Poem". As further tools for analysis, I will be employing the Constellation effect, Multiverse and Mapping, in the hope of providing a better understanding of Catanzano's poem.

Chapter 3 will outline Catanzano's development of her Quantum Poetry, and will finally undertake a detailed analysis of her "World Lines: A Quantum Supercomputer Poem. The Conclusion will attempt a synthesis of the partial observations of individual chapters, and will bring the argument to a close.

As with any other research work, an important note must be made regarding its limitations. This is a highly experimental study: on the level of the framework, due to its academic level, this thesis had to put certain topics aside. The work is written from the point of view of someone without the specific scientific literacy of quantum computing, and the analysis of "quantum poets" is mostly concerned with metaphors, so in order to assess the success or failure of poets in incorporating quantum into either metaphors and structures, serious scientific verification would be needed from technologies as of yet nonexistent. Regarding the content, much more research would be needed in order to do justice to the complexity of the works of Yeats, Eliot and Pound and the same could be said about the mathematical principles incorporated in the theoretical background, since this work could not go into the more technical aspects of quantum computing. This work is offered as an experimental study in the field of humanities.

Still, my personal motivations for writing this thesis were stimulated by reading Catanzano's poem. At present I am inclined more toward the view that quantum poetry has

been written *about* quantum, and not *within* quantum. That is to say, writing in ordinary terms and linguistic structures about the quantum versus using language that is meaningful and structured in ways similar to the nature of quantum reality itself – for example, entangling the meanings of terms or superimposing multiple grammatical structures on a single sequence of words. But the very process of questioning everything just for the sake of knowledge, of challenging the knots of our perception, its representations, and accepting the quantum implications of uncertainty in the scientific method means amplifying our thought. The idea that consciousness is endowed with a self-initiating nature and inductive generation may contribute to a general healing and improving of the consciousness field of humanity, when individual and collective methods entangle for experimentation. But so far, this experimentation is not very well received by the institutionalized “approved” science, lacks serious funding for research, or falls into the realm of the “pseudo-sciences”. In the past we have seen the work of individuals who have approached a problem from either side, art or science, shunned to the margins of reputability by unclear counterarguments. One example would be the cases of the Fundamental Fysiks Group, formed by several graduate students from the University of California, Berkeley, group which held informal discussions open to anyone interested, to explore the philosophical implications of quantum theory. Some of the members wrote several works about quantum mechanics in relation to questions of consciousness, and as a consequence seriously damaged their credibility as scientists.<sup>10</sup>

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<sup>10</sup> Woit, P. “Fun with Fysiks”, *American Scientist*, Vol. 9, No. 4, July-August, 2011. p. 332. Web. Accessed 05 May 2020. Retrieved from [www.americanscientist.org/article/fun-with-fysiks](http://www.americanscientist.org/article/fun-with-fysiks)

Strategies and approaches in poetry will be briefly mentioned in this dissertation, but I believe the field of humanities has not taken full account of the implications that could aim towards a full redefinition of their anthropological practices and considerations.

# HISTORICAL BACKGROUND

In 1900, Max Planck's paper postulated the elementary quantum of action, a discrete unit of energy, and this marked the beginning of Quantum Physical Theory. He discovered that to explain the heat-radiation from a body as the vibration of atoms, energy was exchanged in tiny parts instead of a continuous gradation. Planck discovered that light seemed to move in wave formation, but also packs of individual energy, which was termed "wave-particle duality", and the breakthrough of the discovery was that quanta behave both as particles and waves, a phenomenon known as "complementarity". He also observed that a particle of light (photon) depends on its frequency, and this proportionality is what we know as Planck's constant; it was Heisenberg who first noticed that the new laws of quantum mechanics have fundamental limitation to the accuracy of experimental measurement, deriving from Planck's equation the Uncertainty Principle where: (Uncertainty in position) times (Uncertainty in momentum -velocity-) is approximately equal to (Planck's Constant).<sup>11</sup> During the 20th century, quantum theory extended, but paradoxically, the more information physicists acquired about quantum mechanics, the more elusive it became; the motion of quanta cannot be visualised or determined as in Newtonian physics, making matter at this core level, unpredictable and unobservable.

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<sup>11</sup> Hey, T. and Walters P., *The New Quantum Universe*, Cambridge University Press, 2003. p.21-23.



## 1.1 A Language problematic.

The observations of quantization of energy inspired some artists, who aimed towards a new method in their own fields. In the past, rhetoricians tried to name different speech-acts, including poetic units, but it was not until the twentieth-century when certain poets, inspired by the scientific method, added specific terminology to their techniques, just as Ezra Pound with the ideogrammic method,<sup>12</sup> or T.S. Eliot's objective correlative.<sup>13</sup> Eliot also tried to integrate the scientific idea of the minimum unit of atom/quantum, in what Albright describes as "molecules of handiness,"<sup>14</sup> departing from the idea that man is a large jellyfish surrounded by the reality it investigates, philosophy stated in Eliot's PhD dissertation *Experience and the Objects of Knowledge in the Philosophy of F.H. Bradley (1913-16)*.<sup>15</sup>

Some academics, such as Sokal or Snow, may seem embarrassed by poets attempting to integrate science that they may not fully comprehend by using metaphors, but despite that metaphors cannot be easily accountable for physical phenomena, some scientists hoped to explain their discoveries not only with mathematical language, but also by metaphoric means. Isaac Newton, for instance, seemed to be aware (or at least intuit) that certain aspects of the behavior of light belonged to the waves, yet it's somewhat revealing that he wrote about these ideas in his diary:

Then I began to suspect whether the rays, after their trajection through the prism, did not move in curved lines, and according to their more or less curvity tend to divers parts of the wall. And it increased my suspicion, when I remembered that I had often seen a tennis ball struck with an oblique racket describe such a curved line. For, a circular as well as a progressive motion being communicated to it by that stroke, its parts on that side where the motions conspire, must press and beat the contiguous Air more violently than on the other, and there excite a reluctancy and refraction of the Air proportionably greater. For the same reason, if the

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<sup>12</sup> Pound, Ezra. *The ABC of Reading*, London: Faber and Faber, 1991. p. 18-27.

<sup>13</sup> Eliot, T.S. "Hamlet and His Problems", *The sacred wood; essays on poetry and criticism*, New York: Alfred A. Knopf, 1921. Retrieved from *The Poetry Foundation*. Web. Accessed 04 Nov. 2019, [www.poetryfoundation.org/articles/69399/hamlet](http://www.poetryfoundation.org/articles/69399/hamlet)

<sup>14</sup> Albright, Daniel. *Quantum Poetics: Yeats, Pound, Eliot, and the Science of Modernism*. Cambridge University Press, 1997. p. 223.

<sup>15</sup> The next subchapter will go deeper in this analysis.

rays of light should possibly be globular bodies, and by their oblique passage out of one medium into another, acquire a circulating motion, they ought to feel the greater resistance from the ambient Aether on that side where the motions conspire, and thence be continually bowed to the other.<sup>16</sup>

A couple of years later, he wrote in *Opticks*: “Are not the Rays of Light very small bodies emitted from shining Substances? For such Bodies will pass through uniform Mediums in right Lines without bending into the Shadow, which is the Nature of the Rays of Light.”<sup>17</sup>

Newton did not seem to avoid using metaphors to explain science; the Queries included in *Opticks* (Book 3 Part I) were written in the period where scientific publications were “talkative”, and has more definitions and axioms than mathematical formulas, heavily relying on metaphorical language to describe the nature of light. Even two centuries after Newton, mediating two contrasting ideas proved to be tricky; in the Particle Model, a cluster of bits is more relevant than the interactions among them, whereas the Wave Model promotes the idea of the universe as a sophisticated web, elastic, able to modify itself as a whole by vibration, and even the scientists couldn’t avoid sound poetical when they tried to explain it.

Newton opted for light as particle, but Bohr’s complementarity principle states mutual exclusiveness and joint completeness of the two descriptions of the quantum systems; it is hard to design an experiment in which both particle and wave aspects could be observed at the same time, and they would correspond to the observation of an interference pattern, where the measurement event would be unmistakably linked to the disturbance.<sup>18</sup> In Bohr’s opinion, this indeterminism was a consequence of the wave-particle dualism (complementarity), and

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<sup>16</sup> Newton, I. A Letter of Mr. Isaac Newton, Professor of the Mathematicks in the University of Cambridge; Containing His New Theory about Light and Colors: Sent by the Author to the Publisher from Cambridge, Feb. 6. 1671/72; In Order to be Communicated to the R. Society. *Phil. Trans.* 6, 3075–3087. Retrieved from The Royal Society Publishing. Web. Accessed 04 Nov. 2019, [www.royalsocietypublishing.org/doi/pdf/10.1098/rstl.1671.0072](http://www.royalsocietypublishing.org/doi/pdf/10.1098/rstl.1671.0072)

<sup>17</sup> Newton, I. *Opticks or A treatise of the Reflections, Refractions, Inflections & Colours of Light*. New York: Dover Publications, 1952. pp. 370

<sup>18</sup> Bohr, N. *Quantum Theory and Measurement*, Wheeler and W.H. Zurek (eds.), Princeton University Press, 1983. p. 9-49.

later wrote that we are faced with the need of a radical revision of the bases for description of physical phenomena, and stated “Here, it must above all be recognized that, however far quantum effects transcend the scope of classical physical analysis, the account of the experimental arrangement and the record of the observations must always be expressed in common language supplemented with the terminology of classical physics.”<sup>19</sup> Him and Dirac were not the only ones to stress the lack of appropriate language for quantum, but to figure out a route towards this development is still not very clear. Werner Heisenberg wrote in *Physics and Philosophy* that art is an idealization different from reality, but idealization is needed for understanding, and explains the comparison of the concepts of science and art, where art it’s an arbitrary product of the mind, and science represent an non-arbitrary objective reality taught to us by nature, but here Heisenberg questions if art is really an arbitrary product. He points out that style in art arises from the interplay between the world and ourselves, with the spirit of the time (*Zeitgeist*) and the artist, where the spirit of the time might be a fact just as objective as the natural science. This spirit brings out aspects of the world that are even-dependent of time, and the artist tries to make these aspects understandable. That’s why Heisenberg claims that these two processes, of science and art, are not different, both form the course of human language that allows us to speak about remote parts of reality: “Therefore, the two processes, that of science and that of art, are not very different. Both science and art form in the course of the centuries a human language by which we can speak about the more remote parts of reality, and the coherent sets of concepts as well as the different styles of art are different words or groups of words in this language.”<sup>20</sup>

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<sup>19</sup> Bohr, N. “On the Notions of Causality and Complementarity”, *Science New Series*, Vol. 111, No. 2873, Jan. 1950, pp. 52. Web. Accessed 04 Nov 2019,

[www.informationphilosopher.com/solutions/scientists/bohr/Notions\\_of\\_Causality\\_and\\_Complementarity.pdf](http://www.informationphilosopher.com/solutions/scientists/bohr/Notions_of_Causality_and_Complementarity.pdf)

<sup>20</sup> Heisenberg, W. *Physics and Philosophy*, London: Penguin Books Ltd., 1990. p. 66-67.

## 1.2 Modernist Poetics

The nomenclature of Modernist poetics -symbol, image, absolute rhythm, metaphor, vortex, objective correlative- suggests that as well as in physics, a poem is divisible into quantities, referrers to identifiable states/entities (things, emotions), and presents something similar to a formula, but we cannot assume a poetic expression as a valid equation of absolute values, since poetry is still a product of the language, for instance, a scientific formula refers to a experimentally stable observation of reality, an experiment that can be repeated with the same results, but a poem about certain emotion is being simultaneously invented in a language, i.e. Physics may describe a sunrise in terms of wavelength or atmospheric optics, which will be there regardless if such description is made or not, but it is *beautiful* insofar as it is being poeticised. Nonetheless, what was central to quantum theory was also somehow relevant to Modernist poetry. In the book *Quantum Poetics*, Albright saw some methodic parallels between Pound, Yeats and Eliot, and what was going on in quantum physics. The following sections will summarize how some of the methods of these poets, seen from a distance, seem to have followed, at least rhetorically, the “quantum” vocabulary and grammar. Nonetheless, this thesis does not try to assume there is a connection between the “poetic formulae” of these Modernist poets, and the scientific observations of particles and waves, since there is not enough evidence to prove its correspondence; we must be aware of the limits of these systems of metaphors to explain “quantum” phenomena. Still this subchapter attempts to show that somehow, the scientific discoveries of their time were in the minds of these poets.

### 1.2.1 Ezra Pound (30 October 1885 – 1 November 1972)

Ezra Pound, U.S. born poet and critic, was a major figure of the early modernist movement. In the 1930s Pound was already thinking about new methods that would reflect the reality that he was living in, and by doing this, he was incorporating science into his poetic studies. In the first chapter of his book of *The ABC of Reading* (1934), he stressed that we live in the age of science, and realized that the method that suited him the best to develop his poetics were those of the contemporary biologists, that is: a first hand examination, and then the continuous comparison between specimens,<sup>21</sup> yet he explains that this method of modern science is not just inventing numbers of abstract entities corresponding to the thing one wishes to find out. Pound writes that in the middle ages, when there was not a “material” science, learning consisted in splitting up terminology, giving a lot of attention to the general exactitude in the use of abstract terms.<sup>22</sup> In his opinion, the first assertion of the scientific method for literary criticism is found in Ernest Fenollosa’s “Essay on the Chinese Character”, yet Fenollosa never claimed to use this method; he was trying to explain the Chinese ideograph as means of transmission and registration of thought.<sup>23</sup> Instead of this method of abstraction, concerned with defining things in more general terms, the “scientific method” of Fenollosa includes the philosophic discussion about how Chinese deal with this abbreviated picture writing. As Armand explains in *Literate Technologies*, Pound seemed to understand the relevance of finding new methods to digest the technologisation of literacy, and by looking into the infrastructures of technology itself, we can recognize the implications of technology in the way we perceive cognition, literacy, and language.<sup>24</sup> Focusing on the

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<sup>21</sup> Pound, Ezra. *The ABC of Reading*, London: Faber and Faber, 1991. p. 17.

<sup>22</sup> Ibid. p. 19.

<sup>23</sup> Ibid. p. 20.

<sup>24</sup> Armand, Louis. *Literate Technologies*. Litteraria Pragensia 2006. p. 90.

method of superposition or “assemblage” of graphic characters that together build a signifying whole, Pound sought to grasp the thought away from the material to the abstract, locating the poetic economy of hieroglyphic assemblage, as the way Chinese use ideographic picture writing. He offers the example of “sun”, “tree” and “sunrise”, where the juxtaposition of the symbol “tree” and “sun” gives an image of *the sun tangled in the in the tree’s branches, as at sunrise*, demonstrating how metaphoric superposition can provide an association between this abbreviation, and in this example, the concept of directionality:

木 tree  
日 sun  
東 sun tangled in the tree’s branches, as at sunrise, meaning now the East.<sup>25</sup>

Fenollosa was telling how and why a language written in this way simply had to stay poetic. So in the search for a more accurate method, Pound found that the “thought particle” or monad didn’t rely solely upon metaphors, standard patterns or diction, but somewhere else. He noted that “The Egyptians finally used abbreviated pictures to represent sounds, but the Chinese still use abbreviated pictures AS pictures, that is to say, Chinese ideogram does not try to be the picture of a sound, or to be a written sign recalling a sound, but it is still the picture of a thing; of a thing in a given position or relation, or of a combination of things. It means the thing or the action or situation, or quality germane to the several things that it pictures.”<sup>26</sup> Later, he wrote in *Guide to Kulchur (1938)* “Leibniz was the last philosopher who ‘got hold of something’, his unsquashable monad may by now have been pulverized into sub-electrons, it may have been magnified in the microscope’s eye to the elaborate structure of a solar system, but it holds as a concept. If you let go of it, you are wafted out among mere nomenclatures.”<sup>27</sup> We can see how the idea of the monad had some influence in his work,

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<sup>25</sup>Pound, Ezra. *The ABC of Reading*, London: Faber and Faber, 1991. p. 21.

<sup>26</sup> Ibid. p. 21.

<sup>27</sup> Pound, Ezra. *The Guide to Kulchur*, New York: A New Directions, 1970. p. 74

since Leibniz offered something useful for the development of Pound's method: the elementary particle -monad- that was subjective and objective, the minimum unit of thought and perception together with the minimum unit of matter;<sup>28</sup> or in the case of his studies, a minimum unit of writing, perhaps in the form of an elementary assemblage, just like the "East" sign. For example, we can read in the Canto 49 Pound's influence of Chinese poetry, which he might have caught while translating *Cathay*,<sup>29</sup> visible in the idea-superposition of the Chinese character, and in the structure peculiarities, where *sun* and *dig* are paired with other particles:

Sun up, work  
sundown, to rest  
dig well and drink of the water  
dig field, eat of the grain  
Imperial power is? and to us what is it?<sup>30</sup>

But by the use of these particles, he didn't aim to make the poem shorter, or simpler. In the essay "*A Few Don'ts*", Pound suggests how to keep the poem from over-simplification, to avoid the accusations that a poem communicates something in a hazy and dark manner, when it could have been stated clearly.<sup>31</sup> According to Encyclopedia Britannica, *vers libre* (free verse) "is a 19th century poetic innovation that liberated French poetry from its traditional prosodic rules. In *vers libre*, the basic metrical unit is the phrase rather than a line of a fixed number of syllables, as was traditional in French versification since the Middle Ages. In *vers libre*, the lengths of lines may vary according to the sense of the poem, the complete sentence

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<sup>28</sup> Back in Pound's day, the concept of quark was not yet introduced, which are even smaller constituents within a proton. Gell-Mann and Zweig introduced the quark model in 1964, naming it after a word in James Joyce's novel, *Finnegan's Wake*. Since in the quark theory of matter, the proton is made up of three quarks, the quotation from Joyce, 'Three quarks for Muster Mark!' seemed appropriate to name it. . In Hey, T. and Walters P., *The New Quantum Universe*, Cambridge University Press, 2003. p. 162-163.

<sup>29</sup> *Cathay* is a collection of classical Chinese poetry translated into English by Ezra Pound in 1915, using the notes of Ernest Fenollosa, despite a complete lack of knowledge of the Chinese language. In Alexander, Michael. *The Poetic Achievement of Ezra Pound*. Berkeley: University of California Press, 1981. p. 99-105.

<sup>30</sup> Pound, Ezra. *The Cantos*, London: Faber and Faber, 1975. p. 245.

<sup>31</sup> Pound, Ezra. "'A Retrospect' and 'A Few Don'ts'", *The Poetry Foundation*, Originally published in *Poetry Review*, 1913. Web. Accessed 05 Nov. 2019, [www.poetryfoundation.org/articles/69409/a-retrospect-and-a-few-donts](http://www.poetryfoundation.org/articles/69409/a-retrospect-and-a-few-donts)

replaces the stanza as a unit of meaning, and rhyme is optional.”<sup>32</sup> At the time he wrote “A Few Don'ts”, this poetic form was still popular among some poetic circles, but he considered that *vers libre* could easily become tediously lengthy, with “bad” phrasing not even excused by filling a metric pattern.<sup>33</sup> Instead he considered three propositions: demanding direct treatment, economy of words, and the sequence of the musical phrase. Apparently, Pound provided little reference, trying to save the poem from a direct correspondence symbol-reference, and in “*Vorticism*” he stated that *imagism* is not to be confused with *symbolism*, since “the symbolists dealt in ‘association,’ that is, in a sort of allusion, almost of allegory. They degraded the symbol to the status of a word. They made it a form of metonymy. One can be grossly ‘symbolic,’ for example, by using the term ‘cross’ to mean ‘trial.’ The symbolist’s *symbols* have a fixed value, like numbers in arithmetic, like 1, 2, and 7. The imagiste’s images have a variable significance, like the signs *a*, *b*, and *x* in algebra.”<sup>34</sup>

In the search for the elementary particle -as an elementary image that could be loaded with specific symbolic value-, he interacted with poets with different methods and observed their work. It is well known that Pound spend time with Yeats during the winters of 1913-1916, but it’s still unclear the influence they had on each other; Ezra Pound identified Yeats in his essay *The Later Yeats* as a symbolist, not imagiste, but Yeats’ progress will be reviewed in the next section of this work.

Despite Ezra Pound having never expressed literal interest in quantum theory, he addressed indirectly the language problematic that Heisenberg and Dirac realized while writing about quantum theory, in which we lack a proper form of language to keep up with

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<sup>32</sup> “Vers Libre”, *Encyclopædia Britannica*. July 20, 1998. Web access 03 Jan 2020  
[www.britannica.com/art/vers-libre](http://www.britannica.com/art/vers-libre)

<sup>33</sup> Pound, Ezra. *op.cit.* 1913.

<sup>34</sup> Pound, Ezra. “Vorticism”, *The Fortnightly Review*, No. 96, p. 461–471, London, September 1914. Retrieved from The Fortnightly Review. Web. Accessed 05 Nov. 2019, [www.fortnightlyreview.co.uk/vorticism/](http://www.fortnightlyreview.co.uk/vorticism/)



scientific experimentation. Pound's studies on the Chinese Character have been criticized for being biased in his consideration of "otherness", raising concerns about his perception of difference while doing rigorous linguistic and etymological research,<sup>35</sup> yet in his attempt to integrate the scientific method in the study of poetry, Pound began a road of experimentation that inspired, and was inspired by other writers, challenging classical modes of poetics, and challenging the ideological division observed by Snow, in which science had nothing to do with art.

### 1.2.2 William Butler Yeats (13 June 1865 – 28 January 1939)

W.B. Yeats was an Irish born poet, considered an important figure of the 20th century literature. When Max Planck and other scientists came around with his theories, he was already a published author. For the purpose of this work, this section will review Yeats in the sense of his transition from classical assumptions into more experimental thinking. In 1936, he compiled different poets in *The Oxford Book of Modern Verse 1892-1935*, and in the Introduction, Yeats describes the evolution of Victorian literature as a shift from mirror, where the artist is an idle recorder of phenomena, to Modern poetry, which he perceived as a flux. He wrote "When my generation denounced scientific humanitarian pre-occupation, psychological curiosity, rhetoric, we had not found what ailed Victorian literature. The Elizabethans had all these things, especially rhetoric... The mischief began at the end of the seventeenth century when man became passive before a mechanized nature... Change has come suddenly, the despair of my friends in the nineties part of its preparation. Nature, steel-bound or stone-build in the nineteenth century, became a flux where man drowned or

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<sup>35</sup> Hugh Kenner presents an argument using the word *fang* as an example: *fang* (方 = square) is a syllable with many different significances: "square," "district," "spin," "room." When *fang* is joint with the "earth" pictogram we get "district"; if we join the "silk" pictogram we get "spin"; if the "door" pictogram, "room." The *fang* radical by itself means "square." But Kenner argues that the square is not relevant, only the sound. In Kenner, Hugh. *The Pound Era*, London: Faber and Faber, 1972. p. 228.

swam; the moment had come for some poet to cry ‘the flux is in my own mind’<sup>36</sup>. It seemed that – unlike Pound – Yeats found in the free form of *vers libre* a kind of revolution, a way of poetry that would allow him to innovate, while departing from classical modes of poetics into other possibilities, where the phrase replaced fixed numbers of syllables, and the complete sentence replaces the stanza as unit of meaning; with this, there are some parallels with the physics discoveries of the time, where fixed values were being replaced by uncertainty, even without Yeats literally expressing this influence. Even so he recognized that despite how innovative *vers libre* could be, it would not be enough to allow the poem to arise out its own rhythms as Yeats contends, Pound did.<sup>37</sup> Yeats saw that the revolt against Victorianism meant to the young poets a rebellion against irrelevant descriptions of nature, scientific and moral discursiveness. He argued that some poets told one another “we must purify poetry of all that is not poetry”, and they meant poetry as it had been written by Catullus, or Baudelaire, great names in their times. “Poetry was a tradition like religion and liable to corruption, and it seemed that they could best restore it by writing lyrics technically perfect, their emotion pitched high, and as Pater offered instead of moral earnestness life lived as ‘a pure gem-like flame’ all accepted him for master.”<sup>38</sup> What Pater offered was a critical method outlined in the Preface to *The Renaissance* (1873) where he argued initially for a subjective, relativist response to music, poetry, artistic and accomplished forms of human life, as opposed to the drier, more objective, somewhat moralistic criticism.<sup>39</sup> Yet for Yeats, it seemed that this “pure gem-like flame” was still insufficient motive. We can see how the fluidity between

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<sup>36</sup> Yeats, W. B., editor. *The Oxford book of modern verse, 1892-1935*. New York: Oxford university press, 1936. p. XXVIII

<sup>37</sup> Ibid. p. VIII

<sup>38</sup> Ibid. p. IX

<sup>39</sup> Pater, Walter. *The Renaissance, Studies in art and poetry*. London: Macmillan, and Co, 1910. Web. Accessed 24 Dec 2019, [www.gutenberg.org/files/2398/2398-h/2398-h.htm](http://www.gutenberg.org/files/2398/2398-h/2398-h.htm)

subject-object appealed to Yeats in the 1938's poem "A Drunken Man's Praise of Sobriety", where sobriety is best praised by a drunken man:

A DRUNKEN MAN'S PRAISE OF SOBRIETY (1938)  
*Come swish around, my pretty punk,  
And keep me dancing still  
That I may stay a sober man  
Although I drink my fill.  
Sobriety is a jewel  
That I do much adore;  
And therefore keep me dancing  
Though drunkards lie and snore.  
O mind your feet, O mind your feet,  
Keep dancing like a wave,  
And under every dancer  
A dead man in his grave.  
No ups and downs, my pretty,  
A mermaid, not a punk;  
A drunkard is a dead man,  
And all dead men are drunk.*<sup>40</sup>

Yeats was trying to transcend the rigid limits, grammar and topics of Victorian poetry, and indirectly, he did find the inspiration in modern physics seen as a flux, but at the same time, he resisted the full takeover of the avantgarde poetics. There is no way to prove if Yeats studied the quantum theory that was developing in his time, but he did spend a while thinking about fluidity, waves, and bilocation. This brings forth what Heisenberg noted about the spirit of time (Zeitgeist) and the artist, where the interplay between the aspects of the world that are even-dependent of time and the person, influences their style in art, while trying to make these aspects understandable. In the letters Yeats exchanged with Sturge Moore, he attempted to recognize the boundary between the real and the unreal, objecting the diffuse model of reality he found in modern science. "Here is another problem... 'Bilocation.' I have several times come upon such cases. My wife has seen me sitting in my study working when I was in reality -so far as I knew - walking in the street a mile off... If you say the fact that we think of

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<sup>40</sup> Yeats, W.B. *The Collected Poems 1889-1939*. Open Source Collection. p. 327. Web. Accessed 24 Dec 2019. [www.archive.org/details/WBYeats-CollectedPoems1889-1939](http://www.archive.org/details/WBYeats-CollectedPoems1889-1939)

one image as “phantasmal” decides the matter, we are in great perplexity to decide what we mean by “phantasmal”. Certainly the “phantasmal” image is the more isolated, just as “Ruskin’s cat” is isolated - it does not seem to have kittens - but is one bead by itself less real than a bead upon a string?”<sup>41</sup> (1926).

From his earlier work, such as “The Meditation of the Old Fisherman” (1889), Yeats seemed comfortable with his usage of symbols, and one could say that the images were reliable and the poem was structured, but the ideas he shared with Moore in their correspondence, came to be reflected in his work almost ten years later, in poems such as “A Drunken Man’s Praise Of Sobriety” (1938) or “Byzantium” (1933), where he seemed to move towards a more fluid form of poetics, assembling symbols harder to embody:

THE MEDITATION OF THE OLD FISHERMAN (1889)

You waves, though you dance by my feet like children at play,  
Though you glow and you glance, though you purr and you dart;  
In the Junes that were warmer than these are, the waves were more  
    gay,  
When I was a boy with never a crack in my heart.

The herring are not in the tides as they were of old;  
My sorrow! for many a creak gave the creel in the-cart  
That carried the take to Sligo town to be sold,  
When I was a boy with never a crack in my heart.

And ah, you proud maiden, you are not so fair when his oar  
Is heard on the water, as they were, the proud and apart,  
Who paced in the eve by the nets on the pebbly shore,  
When I was a boy with never a crack in my heart.<sup>42</sup>

BYZANTIUM (1933)

The unpurged images of day recede;  
The Emperor’s drunken soldiery are abed;  
Night resonance recedes, night walkers’ song  
After great cathedral gong;  
A starlit or a moonlit dome disdains  
All that man is,  
All mere complexities,  
The fury and the mire of human veins.

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<sup>41</sup> Yeats W.B. and Sturge Moore T., *Their correspondence, 1901-1937*. New York: Oxford University Press, 1953. p. 72-73.

<sup>42</sup> Yeats, W.B. *The Collected Works of W. B. Yeats*, Vol. II. New York: Scribner, 2001. p. 18

Before me floats an image, man or shade,  
Shade more than man, more image than a shade;  
For Hades' bobbin bound in mummy-cloth  
May unwind the winding path;  
A mouth that has no moisture and no breath  
Breathless mouths may summon;  
I hail the superhuman;  
I call it death-in-life and life-in-death.

Miracle, bird or golden handiwork,  
More miracle than bird or handiwork,  
Planted on the star-lit golden bough,  
Can like the cocks of Hades crow,  
Or, by the moon embittered, scorn aloud  
In glory of changeless metal  
Common bird or petal  
And all complexities of mire or blood.

At midnight on the Emperor's pavement flit  
Flames that no faggot feeds, nor steel has lit,  
Nor storm disturbs, flames begotten of flame,  
Where blood-begotten spirits come  
And all complexities of fury leave,  
Dying into a dance,  
An agony of trance,  
An agony of flame that cannot singe a sleeve.

Astraddle on the dolphin's mire and blood,  
Spirit after Spirit! The smithies break the flood.  
The golden smithies of the Emperor!  
Marbles of the dancing floor  
Break bitter furies of complexity,  
Those images that yet  
Fresh images beget,  
That dolphin-torn, that gong-tormented sea.<sup>43</sup>

In "The Meditation of the Old Fisherman", Yeats seemed to be portraying an ideal man personified in the symbol of the Fisherman, who fits perfectly in the landscape. The narrative of Byzantium, on the other hand, is both personal, and impersonal. The narration first locates us in the distance, and soon it becomes a first person description. Byzantium symbolizes artistic magnificence and permanence, and works along other symbols that evoke indefinable

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<sup>43</sup> Ibid. p. 251

but precise emotions, such as those evoked by a bird of gold, which is a precious metal that never rusts, or the presence of the moon, a symbol the of cycle of time or the different phases in life. Albright observed formlessness, empty backgrounds, dispersed textures in Yeats' work, and these "proto-poetic" materials are pertinent to what he called "Aesthetics of the wave."<sup>44</sup>

Yeats was a symbolist who was not resistant to experimentation, and *A Vision* (1925), which began as an *automatic writing* experiment he was doing with his wife, seems to put him between the attraction and repulsion towards the avantgarde. *A Vision* comprises philosophical, historical, occult and poetic concerns, and seems to be modeled in reaction against the systematic destruction of the classic structures of discourse perpetuated by the younger authors that he knew. In the 1937 edition of *A Vision*, Yeats starts with *A Packet for Ezra Pound*, which is relevant because there really is no proof of the influence Pound and Yeats had on each other during the time they spent together in the winters between 1913-1916, and their interaction has long been the cause of critical dispute,<sup>45</sup> but the fact that he was addressing him, meant that, at least, he was listening to Pound's ideas, those of a scientific method, and perhaps, also about monads. Yeats stressed their opposing characters, "a man with whom I should quarrel more than with anyone else if we were not united by affection"<sup>46</sup> and discusses Pound's 27 Cantos published so far,<sup>47</sup> wondering about the order of the images Pound was offering, but later Pound explained to him that when the Hundredth Canto was finished, it would resemble the structure of a Bach's Fugue, where there won't be a plot, a chronicle of events, or logic of discourse, but two themes: The Descend to Hades

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<sup>44</sup> Albright, Daniel. op. cit. 1997. p. 29.

<sup>45</sup> Parkinson, T. "Yeats and Pound: The Illusion of Influence". *Comparative Literature*, 6 (3): 256–264. 1953. p. 256. See also: Walker, T. "Our More Profound Pre-Raphaelitism: W.B. Yeats, Aestheticism, and BLAST" Coleman, Philip, Kathryn Milligan, and Nathan O'Donnell (eds.) *Blast at 100: A Modernist Magazine Reconsidered*, Brill, 2017. p. 79-92.

<sup>46</sup> Yeats, W.B. *A Vision*. London: Palgrave Macmillan, 1962. p. 3

<sup>47</sup> In the edition of 1937 edition of *A Vision*, Yeats notes that there were already 49 Cantos published.

from Homer, and the Metamorphosis from Ovid, and mixed with these, medieval or modern historical characters, in his attempt to create a poem in which nothing can be taken out or reasoned over, for its dream association of words and images.<sup>48</sup> Yeats continued explaining in *A Vision*, that Pound scribbled letters on the back of an envelope with sets of letters representing emotions or archetypal events “A B C D and then J K L M, and then each set of letters repeated, and then A B C D inverted and this repeated, and then a new element X Y Z, then certain letters that never recur, and then all sorts of combinations of X Y Z and J K L M and A B C D and D C B A, and all set whirling together... The Descent and the Metamorphosis -A B C D and J K L M- his fixed elements, took the place of the Zodiac, the archetypal persons -X Y Z- that of the Triumphs, and certain modern events -his letters that do not recur- that of those events in Cosimo Tura's day.”<sup>49</sup> This reminds us of Pound's example in *Vorticism* to recognize imagists from symbolists, and Pound's envelope made Yeats go deeper into the imagist images, enriching his perception of mathematical structure, which when taken up to the imagination, is more than just mathematical and apparently irrelevant details fit together into one theme, allowing a discovery of beautiful detail.<sup>50</sup> We might also question the influence of Pound's ideas of the Leibniz monad, for throughout *A Vision*, we can see Yeats' *daimon*, a concept difficult to grasp. It can be explained as soul's immortality, but it is not a mere spirit, which Yeats describe as “objective”, but reality itself is found in the *Daimon* in commemoration of the “Ghostly Self.”<sup>51</sup> This *daimon* is a timeless entity that goes through reincarnations in a neutral way and keeps memories of its past lives.<sup>52</sup> If we assume that the schema of *A Vision* is that of reflection and balance, in this form of

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<sup>48</sup> Yeats, W.B. *A Vision*. London: Palgrave Macmillan, 1962. p. 4.

<sup>49</sup> Pound showed Yeats a paint of Cosimo Tura, which was divided in 3 parts, the Triumph of Love, the Triumph of Chastity, in the middle Zodiac signs, and in the lower part, Contemporary events of Tura's times (c. 1430 – 1495).

<sup>50</sup> Yeats, W.B. *op.cit.* 1962. p. 5.

<sup>51</sup> *Ibid.* p. 209.

<sup>52</sup> *Ibid.* p. 83.

duality (human-*daimon*), the *Daimon* is their active controller, resembles the human, and enforces awareness of this opposition.<sup>53</sup> The relation with the *daimon* is unpredictable, it evades, shifts and is interconnected with other *daimons* of its network. Yeats wrote “Nations, cultures, schools of thought may have their *Daimons*. These Daimon may move through the Great Year like individual men and women and are said to use men and women as their bodies, to gather and disperse those bodies at will. Leibniz, whose logical monads resemble somewhat my perceptive *Daimons*, thought there must be many monads much greater than those of individual men and women,”<sup>54</sup> showing that Yeats was aware that his *daimon* shared some traits with the monad. The *daimon* was important for Yeats’ metaphysics, and the idea of an elusive, unpredictable reality was part of the quantum observations of his time.

And just as bilocation and monads, multiplicity threatened his work, as a maze of unintelligible images in which the over creative poet might get lost, so Yeats seemed to look for a principle to limit indiscriminate reality, or it would become shapeless. Reality to him then, consisted in a “phantasmal darkness”. In the introduction to *Fighting the Waves*, Yeats wrote that Woolf’s *The Waves*, and Pound’s *Draft of XXX Cantos*, suggested that both mental and physical objects are material, similar to the Ancient Indian school of Samkara, “a deluge of experience breaking over us and within us, melting limits whether of line or tint; man no hard bright mirror dawdling by the dry sticks of a hedge, but a swimmer, or rather the waves themselves,”<sup>55</sup> and this duality, swimmer/waves, vaguely corresponds to the particle/wave theory.

Many aspects of contemporary poetry cannot be easily traced to their sources, and it is possible that Yeats wished to discover if he could adapt the modern developments in poetics

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<sup>53</sup> Ibid. p. 131.

<sup>54</sup> Ibid. p. 209.

<sup>55</sup> Yeats, W.B. *The Collected Works of W. B. Yeats*, Vol. II. New York: Scribner, 2001. p. 703.



to his own needs. We have little proof of Yeats knowledge of the quantum theory of his time, but while thinking about waves, monads and bilocation, he was able to incorporate this concerns to his work, and the relationships he developed with other modernist poets, may have helped him to continue to develop a technique that suited him the most in order to make sense of his reality, despite not embracing the avantgarde completely. He recognized this *wave-like* nature in his own work, when he wrote in the Introduction of his Modern Verse compilation “A musician, he imagines Heaven as a musical composition, a mathematician, as a relation of curves, a poet, as a dark, inhuman sea.”<sup>56</sup>

### 1.2.3 Thomas Stearns Eliot (26 September 1888 - 4 January 1965)

T.S. Eliot was an American born poet who subsequently became a British subject. He is also considered an important poet from the 20th century, and his work “The Love Song of J. Alfred Prufrock” is a landmark of the modernist movement. In the Introduction of *The Oxford book of Modern Verse*, Yeats wrote how Eliot had a big effect on his generation because he renounced to rhythms and metaphors popular amongst the Romantics, as he described how humans got out of bed for mere habit, and by describing this life, Eliot’s art became gray, cold and dry.<sup>57</sup> But Eliot may have opted for different approaches to write poetry, especially noticeable in the poem “The Death of Narcissus”, which stands out thematically and stylistically from “The Love Song of J. Alfred Prufrock”:

#### THE LOVE SONG OF J. ALFRED PRUFROCK (Excerpt. 1915)

And indeed there will be time  
To wonder, “Do I dare?” and, “Do I dare?”  
Time to turn back and descend the stair,  
With a bald spot in the middle of my hair —  
(They will say: “How his hair is growing thin!”)

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<sup>56</sup> Yeats, W. B., editor. *The Oxford book of modern verse, 1892-1935*. New York: Oxford university press, 1936. p. XXX.

<sup>57</sup> *Ibid.* p. XXII.

My morning coat, my collar mounting firmly to the chin,  
My necktie rich and modest, but asserted by a simple pin —  
(They will say: “But how his arms and legs are thin!”)  
Do I dare  
Disturb the universe?  
In a minute there is time  
For decisions and revisions which a minute will reverse.

For I have known them all already, known them all:  
Have known the evenings, mornings, afternoons,  
I have measured out my life with coffee spoons;  
I know the voices dying with a dying fall  
Beneath the music from a farther room.  
So how should I presume?

And I have known the eyes already, known them all—  
The eyes that fix you in a formulated phrase,  
And when I am formulated, sprawling on a pin,  
When I am pinned and wriggling on the wall,  
Then how should I begin  
To spit out all the butt-ends of my days and ways?  
And how should I presume?<sup>58</sup>

THE DEATH OF NARCISSUS (Excerpt. 1915)  
Struck down by such knowledge  
He could not live men’s ways, but became a dancer before God.  
If he walked in city streets  
He seemed to tread on faces, convulsive thighs and knees.  
So he came out under the rock.

First he was sure that he had been a tree,  
Twisting its branches among each other  
And tangling its roots among each other.

Then he knew that he had been a fish  
With slippery white belly held tight in his own fingers,  
Writhing in his own clutch, his ancient beauty  
Caught fast in the pink tips of his new beauty.

Then he had been a young girl  
Caught in the woods by a drunken old man  
Knowing at the end the taste of his own whiteness,  
The horror of his own smoothness,  
And he felt drunken and old.

So he became a dancer to God,  
Because his flesh was in love with the burning arrows  
He danced on the hot sand

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<sup>58</sup> Eliot, T.S. “The Love Song of J. Alfred Prufrock”. *The Poetry Foundation*. Originally published in *Poetry A Magazine of Verse*, June 1915. Web. Accessed 16 Dic. 2019.  
[www.poetryfoundation.org/poetrymagazine/poems/44212/the-love-song-of-j-alfred-prufrock](http://www.poetryfoundation.org/poetrymagazine/poems/44212/the-love-song-of-j-alfred-prufrock)

Until the arrows came.

As he embraced them his white skin surrendered itself to the redness of blood, and satisfied him.

Now he is green, dry and stained<sup>59</sup>  
With the shadow in his mouth.

In “The Death of Narcissus”, Eliot juxtaposes two archetypes, in one hand we have the patriarch of Jerusalem St. Narcissus, who is accused of a crime, exiled and who finally returns after the revindication of his innocence, to die of old age, and on the other hand, the boy Narcissus who falls in love with himself, a story traceable to Ovid’s *Metamorphosis*, which is a theme that Yeats also observed in Pound’s work. Both these images of Catholic theology and Greek mythology are not presented as opposites, but as a correlative, a type of wandering abstemious going in through a series of metamorphosis, where he is the fish, and also the hand which holds the fish, the two as one. This treatment of the “self” and the monad, was explained by Eliot in his is PhD dissertation *Experience and the Objects of Knowledge in the Philosophy of F.H. Bradley* (1913-16):

The self, we find, seems to depend upon a world which in turn depends upon it; and nowhere, I repeat, can we find anything original or ultimate. And the self depends as well upon other selves; it is not given as a direct experience but is an interpretation of experience by interaction with other selves... When an event occurs within my world it occurs to me, but I would not be I apart from the event; it is from the beginning coloured by my personality, as my personality is coloured by it. A theory of internal relations is thus implicit; and perhaps a recognition of the continuity of terms and relations contributed to the doctrine of monads... And the pre-established harmony is unnecessary if we recognize that the monads are not wholly distinct, and that the subjective self is continuous with the self as object. A monad was for Leibniz, I believe, something real in the way in which a physical organism is real: he imagined the monads, that is, on this analogy, and identified the monad with the phenomenal soul.<sup>60</sup>

These ideas about the monad and what it represents, is a motif present not only in Eliot’s work, but also in Yeats’ *Daimon*. Albright noticed that Eliot used undersea creatures perhaps because the sea represented a palpable matrix where all aspects are unitary systems,<sup>61</sup> where “It is not true that language is simply a development of our ideas; it is a development of

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<sup>59</sup> Eliot, T.S. “The Death of Saint Narcissus” *T.S. Eliot: The Complete Poems and Plays*. London: Faber and Faber, 1969. Retrieved from Illinois University Repository. Web. Accessed 16 Dic. 2019, <http://faculty.wiu.edu/M-Cole/TheDeathofSaintNarcissus.pdf>

<sup>60</sup> Eliot, T.S. *Knowledge and Experience in the philosophy of F. H. Bradley (1913-16)*. London: Faber and Faber, 1964. p. 146-147.

<sup>61</sup> In this submarine world, to touch is to eat, and Eliot uses this jellyfish as it ingests a sea slug and has interactions apprehensive to the human eyes, providing an image for St. Narcissus’ auto-cannibalism of touch. In Albright, Daniel. *Quantum Poetics: Yeats, Pound, Eliot, and the Science of Modernism*. Cambridge University Press, 1997. p. 224.

reality as well... Wherever there is an appreciation of a presentation and a relating of it to the subject's world there is an idea and a judgement: and this is practically universal. The sea-anemone which accepts or rejects a proffered morsel is thereby relating an idea to the sea-anemone's world."<sup>62</sup> Eliot explains that we are able to see a growth in the clearness of the objects in higher forms of life, because they seem to have a greater degree of detachment and independence, and "that subject and object emerge from a state of feeling."<sup>63</sup> The reality then, becomes more palpable for a person, in the form of a jellyfish, included in the poem "Suite Clownesque" (1910):

Here's the comedian again  
 With broad dogmatic vest, and nose  
 Nose that interrogates the stars,  
 Impressive, sceptic, scarlet nose;  
 The most expressive, real of men,  
 A jellyfish impertinent,  
 A jellyfish without repose.<sup>64</sup>

What is remarkable of Eliot for this topic, is that, unlike Pound and Yeats, he did study physics, and he did explicitly write poetry about quantum. In 1988, the discovery of Eliot's manuscripts suggests that he had knowledge of physics, and these poems seem strongly influenced by the quantum theory that was being developed during his youth, as the measurement problem,<sup>65</sup> the *Decoherence* approach, and the thought-experiment of Schrödinger's Cat.<sup>66</sup> The titles of the poems discovered in this manuscript are a reminiscence

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<sup>62</sup> Eliot. T.S. *Knowledge and Experience in the philosophy of F. H. Bradley (1913-16)*. London: Faber and Faber, 1964. p. 44.

<sup>63</sup> Ibid. p. 165.

<sup>64</sup> Eliot. T.S. *The Poems of T.S. Eliot Volume I: Collected and Uncollected Poems*. London: Faber and Faber, 2015. p. 249.

<sup>65</sup> The equation to illustrate the the essence of the quantum measurement problem is:

$$\psi = \cos \theta V + \sin \theta H$$

When the photon reaches, i.e. a vertical polaroid, we cannot predict with certainty whether or not it will pass through. All quantum mechanics can say is that the photon has a probability  $(\cos\theta)^2$  to pass and a probability  $(\sin\theta)^2$  not to pass. In other words, the photon must be regarded as being in both the V and H states at the same time. In Hey, T. and Walters P., *The New Quantum Universe*, Cambridge University Press, 2003. p.162-163.

<sup>66</sup> Decoherence is an approach that argues that quantum systems can never be totally isolated from the environment, and that Schrödinger's equation (a linear partial differential equation that describes the wave function or state function of a quantum-mechanical system) must be applied not only to the quantum system but also to the coupled quantum environment. Schrödinger's thought experiment highlights the peculiarity of a situation supported by the experiment of Serge Haroche and Jean-Michel Raimond. There are three different parts to an experiment that can all interact, the quantum system, the 'classical' measurement apparatus and the environment. In this experiment, the quantum system consists of an atom that can be prepared in one of two states, then they measure the quantum state of this atom by injecting it into a cavity, using the electromagnetic

of “The Waste Land” (The Waste Lecture), and “Old Possum’s Book of Practical Cats”  
(From Old Possum’s Book Of Quantum Vivisection).

#### THE WASTE LECTURE

Momentum is not well defined, being  
Canonical to place, failing  
To commute exactly, leaving  
Necessary doubt.  
Newton spoke firmly, writing  
Definitive equations, moving  
His particles on clean trajectories.

And when we were pupils, studying the rudiments,  
How confident we were, precisely calculating  
x and p (not one but both!) with such abandon.  
But at the university our teachers—  
Murmuring of commutation—frown, and flunk us.  
We read, much of the night, but are none the wiser.  
(Rayleigh, Jeans  
Had not the means,  
Einstein didn't want 'em;  
It took Niels Bohr  
And several more  
To figure out the quantum.)

Ultraviolet catastrophe  
Came on us unaware;  
Came up the Strand  
To Carlton Terrace, down the stair  
At Piccadilly Underground, where I, Max Planck,  
Am wont to play an anharmonic air

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field of the ‘cavity’ as a classical ‘pointer’. If the cavity is treated as a second quantum system in its own right, the classical pointer is now predicted to be in a ‘Schrödinger cat’ state - a quantum superposition of two classical states of the ‘pointer’. In Hey, T. and Walters P., *The New Quantum Universe*, Cambridge University Press, 2003. p. 177.

Upon my violin, so marvellously tuned  
To modes of hydrogenic unison.

But where are the short-wave rays that fail to light  
The incandescent blackness? I have found  
Degrees of freedom powerlessly bound  
In chains of integer constraint,  
And atoms, governed by the selfsame laws  
Quiescent, in a cold ground state.

And when the spectrum slides  
Beyond the violet end,  
Touched by the last dim rays  
The silver surface spits electrons and displays  
The undivided energy of light!  
(O James Clerk Maxwell I can sometimes see  
A wave, like you, sometimes a particle like me—  
Can both of us be right?)

And I Max Planck,  
Old man of schizophrenic views,  
Have brought you more  
And even stranger news,  
A prettier pebble:

P. Dirac, the well-known theorist  
Renormalises constants and is known to be  
A dab hand when it comes to conjugating charge,  
Reversing time or violating parity.  
This sea, he said, is full of latent holes,  
And each a replica  
(Apart from certain signs)  
Of that which empties it.

But on the other hand it's

Quark, quark, I'm in the dark

I think I'll never see

Why some have two with coloured glue

And baryons have three.

FROM OLD POSSUM'S BOOK OF QUANTUM VIVISECTION

Schrodinger's cat's a mystery cat, he illustrates the laws;

The complicated things he does have no apparent cause;

He baffles the determinist, and drives him to despair

For when they try to pin him down—the quantum cat's not there!

Schrodinger's cat's a mystery cat, he's given to random decisions;

His mass is slightly altered by a cloud of virtual kittens;

The vacuum fluctuations print his traces in the air

But if you try to find him, the quantum cat's not there!

Schrodinger's cat's a mystery cat, he's very small and light,

And if you try to pen him in, he tunnels out of sight;

So when the cruel scientist confined him in a box

With poison-capsules, triggered by bizarre atomic clocks,

He wasn't alive, he wasn't dead, or half of each: I swear

That when they fixed his eigenstate—he simply wasn't there!<sup>67</sup>

This is an interesting development for Eliot, still he seems to be working with the quantum terminology as to how it's popularly regarded. In the case of these last poems, they are not incorporating the science of his times in the poem, as part and parcel of the whole of our mental experience, to be used as naturally as the rest, but rather writing *about* quantum. This takes us back to the question: is quantum poetry writing *about* quantum, or writing *within* quantum propositions? Nonetheless, the examples provided of Eliot's work show an active thinking which reflected the *Zeitgeist*, for instance: juxtaposing archetypes unlikely to be

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<sup>67</sup> Lowell, John. "Mr. Eliot's Guide to Quantum Theory" *Physics Today* Vol. 42, Issue 4, p. 46. Published by the American Institute of Physics, 1989. Web. Accessed 16 Dec 2019. [www.doi.org/10.1063/1.881166](http://www.doi.org/10.1063/1.881166)

juxtaposed, the Decoherence of his jellyfishes in the ocean, and the self as an independent monad inherently affected by its relation with other monads in its network, as a unitary system.

#### 1.2.4 Modernist Poetry – Conclusion

As already noted above, Patricia Monaghan coined the term Quantum Poetics in her dissertation about the Science and Spirit of the 20th century, and in his book *Quantum Poetics* Albright studied Yeats, Pound and Eliot for their knowledge of physics. Despite there is no source admitting that Pound and Yeats were deliberately working with quantum theory, this doesn't take away the value of their studies and considerations, being an argument for Heisenberg's claim that art, despite being regarded as "subjective", is affected by the events and the spirit of time, that can be "objective". Monadic models, intuitions of superposition (Juxtaposition of images, symbols, or archetypes; bilocation), and waves are present in their work and letters, as none of these authors were oblivious of the developments of 20th century science. Eliot, unlike Pound and Yeats, did work directly with quantum theory, but besides the poems published posthumously, all we really have is interpretations of his quantum ideas in examples such as the jellyfishes, or in Yeats' case, *Daimons*. These poets' search to integrate science into the everyday life, doing what they did best, was elusive, full of contradictions, and just as the physicist Dirac or Heisenberg, they realized that language - as a tool to explain our world - was unsuited to describe reality, and they tried to cope, developing their methods along with the happenings of their century.



### 1.3. Towards a Quantum Poetic Method

These iconic modernist poets were not the only ones experimenting and developing literary modes and methods, and other people from different fields have attempted to redefine modernist legacy. The progress of technology, new scientific discoveries, shifts in society, and all the characteristics of a given epoch, evolved into complex currents of poetic and intellectual interests. In order to analyze Amy Catanzano's *Post-Digital Poem*, I would like to briefly outline the path that poetry took towards electronic literature, before we can talk about "World Lines: A Quantum Supercomputer poem."

In his 1962 book *The Gutenberg Galaxy: The Making of Typographic Man*, philosopher Marshall McLuhan analyzed the effects of the printing media on western society and human consciousness, but as Louis Armand notes in *Literate Technologies*, the awareness of the consequences of these effects has not always evolved contemporaneously with the effects themselves.<sup>68</sup> Just as the invention of the press in the 15th century had its effects in the world and how we perceive it, newer technologies have done the same. People in different fields continued the road of language experimentation, using precisely these emergent technologies, unaware of the effects of these experiments. Just a year after the publication of McLuhan's analysis, Theodore Nelson, an Information Technology pioneer, philosopher and sociologist, coined the term hypertext to describe a non-sequential form of writing displayed digitally, interlinked units of text with references (or hyperlinks) to other text that the reader can immediately access.<sup>69</sup> The early applications of hypertext include projects such as ENQUIRE, a software project written in 1980 by Tim Berners-Lee at CERN, which is a

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<sup>68</sup> Armand, Louis. *Literate Technologies*. Litteraria Pragensia, 2006. p.88.

<sup>69</sup> Nelson, T.H. "Complex information processing: a file structure for the complex, the changing and the indeterminate." *Proceedings of the 1965 20th national conference*. New York: Association for Computing Machinery, 1965. p. 94.

hypertext database system on which users collaboratively modify and structure content, and it's regarded as predecessor of the World Wide Web.<sup>70</sup> With the development of computer science —eventually also of quantum computing—, and in the process of assimilation of these technologies into their everyday lives, artists didn't miss the change to interiorize new forms of language and representation, such as programming language or digital platforms.

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<sup>70</sup> Berners-Lee, Tim. "A Brief History of the Web". *World Wide Web Consortium*, 1993. Web. Accessed 30 Dec 2019 [www.w3.org/DesignIssues/TimBook-old/History.html](http://www.w3.org/DesignIssues/TimBook-old/History.html)

## TOOLS FOR ANALYSIS

Nowadays, quantum physics continues to amaze us. In her work “World Lines: A Quantum Supercomputer Poem”, Amy Catanzano explores some concepts of quantum theory, in a literary and visual way, providing tools for thinking about quantum computing, a system that is otherwise quite difficult to comprehend. Grasping ideas such as entanglement or superposition might be tricky to some, but it seems easier to follow the lines of Catanzano’s poem and decide on your own what happens when you encounter a word that exists in two sentences at once, getting us closer to an understanding of what quantum computers do.

Due to the academic level of this essay, it is impossible to give a thorough look into the principles of Entanglement and Superposition in quantum computing, constellation effect, or transversality, but to better understand Catanzano’s poem, we must at least review these concepts. The principles included in this chapter have been consulted and reviewed by actual physicists, who aided greatly in clarifying and correcting the science behind this work.

We should make clear that “World Lines: A Quantum Supercomputer Poem” refers to a topological quantum computer, which uses a different mathematical model than the traditional quantum computer. In this chapter, we will use the mathematical concepts of a traditional quantum computer to understand how qubits are implemented, and we will get to concepts included in the poem, such as *world lines* and *anyons*. At the end of this chapter, we will talk about methods of reading.

## 2.1 A Brief Overview of the Principles of Entanglement and Superposition in Traditional Quantum Computing.

Quantum computing is a form of computation that uses quantum-phenomena, for instance entanglement and superposition, for its processes. Conventional computing uses particular cases of programming paradigms, i.e. constraint programming—a case of declarative programming—uses a form of constraints to determine the relations between variables, or imperative programming —“First do this and next do that”—, which does not specify the path the sequence, but delimitates the characteristics of the expected solution.<sup>71</sup> Programming languages such as C, C++, Java, Python and C# are typically used for imperative programming, and there is a language called Q# in which you can develop and simulate your quantum algorithms on any computer, announced in 2017.<sup>72</sup>

The limits of quantum mechanics in computers became ‘respectable’ in the academic field after Richard Phillips Feynman, American theoretical physicist, attended a conference on ‘The physics of computation’ at MIT in 1981, by the Computer Scientist and Digital Physics pioneer Edward Fredkin, who wanted to devise a *reversible* computer. Turing machines, which are a hypothetical computing device that could recognize undecidable propositions without failure,<sup>73</sup> are used by computer scientists to encapsulate the principles of

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<sup>71</sup> Normark, Kurt. “Overview of the four main programming paradigms”. *Department of Computer Science*, Denmark: Aalborg University, 2011. Web. Accessed 05 Jan 2020.

[www.people.cs.aau.dk/~normark/prog3-03/html/notes/paradigms\\_themes-paradigm-overview-section.html](http://www.people.cs.aau.dk/~normark/prog3-03/html/notes/paradigms_themes-paradigm-overview-section.html)

<sup>72</sup> “Announcing the Microsoft Quantum Development Kit”, *Microsoft Quantum Cloudblogs*, Microsoft Quantum Team, December 11, 2017. Web. Accessed, 11 April 2020.

[www.cloudblogs.microsoft.com/quantum/2017/12/11/announcing-microsoft-quantum-development-kit/](http://www.cloudblogs.microsoft.com/quantum/2017/12/11/announcing-microsoft-quantum-development-kit/)

<sup>73</sup> These “undecidable propositions” are, for example, “those mathematical statements that, within a given formal axiom system, cannot be shown to be either true or false. (The mathematician Kurt Gödel had demonstrated that such undecidable propositions exist in any system powerful enough to contain arithmetic.) Turing instead proved that there can never exist any universal algorithmic method for determining whether a proposition is undecidable”. In “Turing machine”, *Encyclopædia Britannica*. June 14, 2019. Web. Accessed 05.01.2020 [www.britannica.com/technology/Turing-machine](http://www.britannica.com/technology/Turing-machine)

conventional computers, but as Feynman appreciated, a computer operation according to quantum mechanics laws would be of a different type, which might be able to do calculations that the conventional computers cannot perform.<sup>74</sup> Conventional computers are built up from elementary “logic gates” implemented in silicon chips. Fredkin came up with a set of logic gates that are reversible, and he also showed that it was possible to duplicate everything that conventional logic gates can do using reversible gates; these reversible gates are relevant for quantum computing, since the laws of quantum mechanics are reversible in time.

The binary bit (bit) is an important basic unit of information in classical computation, and quantum computation uses the analogous concept of the quantum bit (qubit); in a physical system where information can be stored as qubits on individual quantum systems, the information can not only be 1s or 0s but also quantum superpositions of ‘1’ and ‘0’.<sup>75</sup> To explain this more clearly, qubits are described as mathematical objects, and qubits, just as the bits, are actual physical systems. Nielsen and Chuang write in *Quantum Computation and Quantum Information* that “The beauty of treating qubits as abstract entities is that it gives us the freedom to construct a general theory of quantum computation and quantum information which does not depend upon a specific system for its realization.”<sup>76</sup> The two main ways of implementing a quantum computing nowadays, are analog and digital, and both approaches use qubits, so as a classical bit that has two possible states (0 or 1), a qubit has a state of either  $|0\rangle$  or  $|1\rangle$ .<sup>77</sup> The difference between bits and qubits is that a qubit can be in *other* state than  $|0\rangle$  or  $|1\rangle$ , and it’s also possible to form linear combinations of states, called *superpositions*.<sup>78</sup> This “uncertainty” is not sheer ignorance, but part of the superposition principle where a system,

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<sup>74</sup> Hey, T. and Walters P., *The New Quantum Universe*, Cambridge University Press, 2003. p. 199.

<sup>75</sup> Ibid. p.200.

<sup>76</sup> Nielsen, M.A. and Chuang, I.L. *Quantum Computation and Quantum Information*. Cambridge University Press, 2010. p. 13.

<sup>77</sup> Notation such as “ $| \rangle$ ” is called *Dirac Notation*, it’s the standard notation for states in quantum mechanics.

<sup>78</sup> Nielsen, M.A. and Chuang, I.L. *op.cit.* 2010. p. 13

for instance, a particle, is in all possible states at the same time, until it is measured, then it falls into one of the basic states forming the superposition, destroying the original configuration. This was explained by Schrödinger with a cat, and has been observed in the “double-slit” experiment, resulting in an interference pattern that doesn’t fit in classical mechanics. Paul Dirac explained that “The word 'state' may be used to mean either the state at one particular time (after the preparation), or the state throughout the whole of time after the preparation... The original state must be regarded as the result of a kind of superposition of the two or more new states, in a way that cannot be conceived in classical ideas. Any state may be considered as the result of a superposition of two or more other states, and indeed in an infinite number of ways.”<sup>79</sup> So when a quantum object arrives at a forking path, it doesn’t choose between left or right, but travels both paths simultaneously.

Other quantum computing principles relevant for the study of this essay is *entanglement*. Quantum entanglement is a phenomenon where, roughly speaking, multiple particles are connected somehow, and the measurement of one particle’s state determines the possible state of the other particles, regardless of their position in space. Entanglement is one of the central principles in quantum physics, where this violation of “physical reality” doesn’t violate classical speed of light, since nothing is being carried through space. This phenomena was the subject of the article by Albert Einstein, Boris Podolsky, and Nathan Rose “Can Quantum-Mechanical Description of Physical Reality be Considered complete?” (1935), discussed and described by Bohr,<sup>80</sup> and Schrödinger in the same year,<sup>81</sup> giving the classic example of quantum entanglement called the EPR paradox. Andrew Zimmerman Jones

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<sup>79</sup> Dirac, P.A.M. *The Principles of Quantum Mechanics*, Oxford University Press, 1958. p. 12.

<sup>80</sup> Bohr, N. "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?". *Physical review*, Institute of Theoretical Physics, University Copenhagen. July 13, 1935. Web. Accessed 04 Feb 2020 [www.cds.cern.ch/record/1060284/files/PhysRev.48.696.pdf](http://www.cds.cern.ch/record/1060284/files/PhysRev.48.696.pdf)

<sup>81</sup> Schrödinger, E. “Discussion of Probability Relations between Separated Systems.” *Mathematical Proceedings of the Cambridge Philosophical Society*, Vol. 31, No. 04, October 1935, p. 555-563. Web. Accessed 04 Feb 2020 [www.informationphilosopher.com/solutions/scientists/schrodinger/Schrodinger-1935.pdf](http://www.informationphilosopher.com/solutions/scientists/schrodinger/Schrodinger-1935.pdf)

simplifies it as the following: “Consider a particle with quantum spin 0 that decays into two new particles, Particle A and Particle B. Particle A and Particle B head off in opposite directions. However, the original particle had a quantum spin of 0. Each of the new particles has a quantum spin of 1/2, but because they have to add up to 0, one is +1/2 and one is -1/2. This relationship means that the two particles are entangled.”<sup>82</sup> So whatever observation made in one particle, has an impact in the spin of the other particle, and this was confirmed in experiments using Bell’s Theorem, published in John Bell’s 1964 paper “On the Einstein Podolsky Rosen Paradox.”

### 2.1.1 The Bloch Sphere

To read Catanzano’s poem, we have given attention to the meaning and interpretation of superposition states, and of the latent probabilistic nature of observation on quantum systems. But if we recur to the mathematical and conceptual pictures, we might understand more the possible relations. The Bloch sphere provides visualization of a single qubit, useful for testing ideas in traditional quantum computation, but although this is a great tool to describe many operations, there is not a generalization of the Bloch sphere for multiple qubits. Just for the sake of example, a qubit might be in in the state of

$$\frac{1}{\sqrt{2}} |0\rangle + \frac{1}{\sqrt{2}} |1\rangle,$$

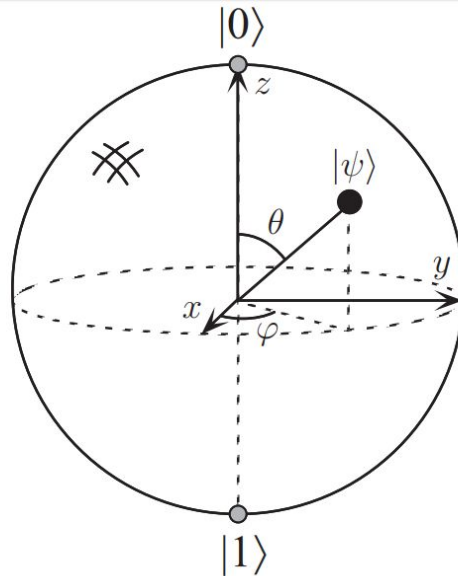
which when observed, 50% of the time results in 0, and 50% of the time 1, this state is denoted as  $|+\rangle$ . For a three-dimensional purpose and focusing on observable effects, Nielsen and Chuang write the formula as following:

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<sup>82</sup> Zimmerman Jones, Andrew. “Quantum Entanglement in Physics” *ThoughtCo*, June 22, 2018. Web. Accessed 05 Jan 2020. [www.thoughtco.com/what-is-quantum-entanglement-2699355](http://www.thoughtco.com/what-is-quantum-entanglement-2699355)

$$|\psi\rangle = \cos \frac{\theta}{2} |0\rangle + e^{i\varphi} \sin \frac{\theta}{2} |1\rangle.$$

where numbers  $\theta$  and  $\varphi$  define a “point” in the sphere:



Bloch sphere representation of a qubit (From Nielsen and Chuang)

We can say that there is an infinite number of “points” on the unit sphere, so we could store an infinite binary expansion of  $\theta$ , but this can be misleading if we forget that the measurement of a qubit is either 0 or 1, and measurement *collapses* the state of the qubit from its superposition -the continuum state of  $|0\rangle$  and  $|1\rangle$ - to the specific state of the measurement result. If the measurement of  $|+\rangle$  is  $|0\rangle$ , the post-measurement state of the qubit will be 0, and although nobody really knows why this type of collapse happens, it’s still a fundamental postulate of quantum mechanics.<sup>83</sup>

<sup>83</sup> Nielsen, M.A. and Chuang, I.L. *Quantum Computation and Quantum Information*. Cambridge University Press, 2010. p. 14-15.



## 2.2 A Brief Overview of the Concepts of World Lines and Anyons in Topological Quantum Computing

A topological quantum computer is a theoretical computer that employs *anyons*, which are two-dimensional quasiparticles whose *world lines* create braids in a three-dimensional spacetime (One time dimension plus two space dimension). Such braids constituted the logic gates of a topological computer, and they pose an advantage over using restrained quantum particles, since they seem more stable. Different cumulative perturbations may cause errors in the computation, but these small perturbations don't change the topological properties of the braid.<sup>84</sup> These elements of a topological quantum computer are purely mathematical, but experiments indicate that these elements may be created in the “real world”. Traditional quantum computers are limited by a number of qubits they can work, that prevents taking speed advantage over the traditional computers, but certain algorithms were first developed in the topological model and later converted and extended in the traditional quantum circuit model.<sup>85</sup>

A topological quantum computer must provide computation properties that a traditional quantum computer can do, and in principle, it was proved by Michael H. Freedman, Alexei Kitaev, Michael J. Larsen, and Zhenghan Wang in 2002.<sup>86</sup> They found that in a traditional quantum computer, given an error-free operation of its logic circuits, will give a solution with absolute accuracy, whereas in a topological quantum computer with flawless operation, will provide a solution with a finite level of accuracy, nonetheless, any level of

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<sup>84</sup> Freedman, M., Larsen, M., and Wang, Z. "A Modular Functor Which is Universal for Quantum Computation". *Communications in Mathematical Physics*. 227 (3): 605–622. February 2002. Web. Accessed 11 April 2020. [www.microsoft.com/en-us/research/wp-content/uploads/2017/09/universality-02.pdf](http://www.microsoft.com/en-us/research/wp-content/uploads/2017/09/universality-02.pdf)

<sup>85</sup> “Scalable Quantum Systems”. *Quantum Computing at IBM*. Web. Accessed 11 April 2020. [www.ibm.com/quantum-computing/learn/what-is-ibm-q/](http://www.ibm.com/quantum-computing/learn/what-is-ibm-q/)

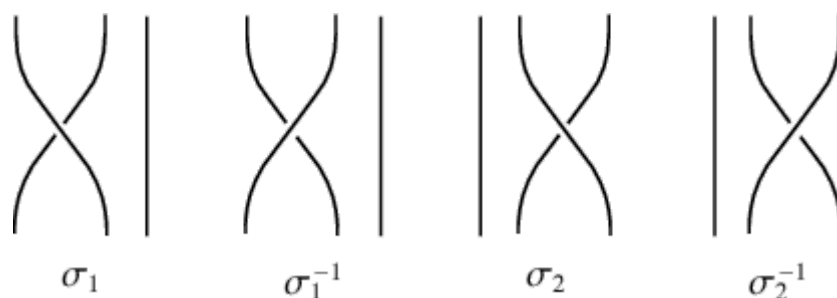
<sup>86</sup> Freedman, M., Kitaev, A., and Wang, Z. "Simulation of Topological Field Theories by Quantum Computers". *Communications in Mathematical Physics*. 227 (3): 587–603. January 2002. Web. Accessed 11 April 2020. [www.arxiv.org/pdf/quant-ph/0001071.pdf](http://www.arxiv.org/pdf/quant-ph/0001071.pdf)

precision for the solution can be obtained by adding more braids (logic circuits) in a simple linear relationship, that is, the more the braid twists, the higher the degree of accuracy.<sup>87</sup>

### 2.2.1. World lines, Braids, and Anyons.

The world line of an object is the path that it traces in 4-dimensional spacetime. Spacetime is mathematical model which uses the three dimensions of space and the one dimension of time into one four dimensional manifold,<sup>88</sup> and spacetime diagrams help visualize relativistic effects, like why different observers perceive the location and the time when events happen in a different way.<sup>89</sup> A *world-line* then, traced the path of a single point in space time, and a *world-sheet* is the analogous two-dimensional surface traced by a one-dimensional string travelling through spacetime.

Ph.D. Eric Weisstein explains it as follows: A braid is the intertwining of a certain number of strings, attached at the top and bottom by “bars”, so a braid doesn’t come “back up”, we could imagine it as a falling object that traces a path acting by gravity. For the purpose of this study, we will introduce braids and their possible variations with illustrations and generalized values.

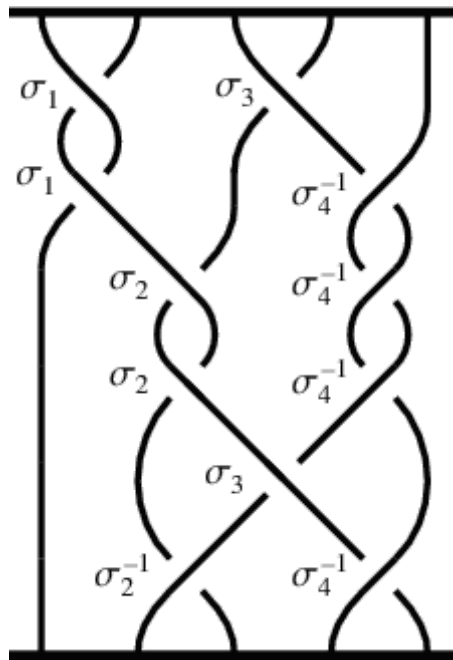


<sup>87</sup> Freedman, M., Kitaev, A., and Wang, Z. "Simulation of Topological Field Theories by Quantum Computers". *Communications in Mathematical Physics*. 227 (3): 587–603. January 2002. Web. Accessed 11 April 2020. [www.arxiv.org/pdf/quant-ph/0001071.pdf](http://www.arxiv.org/pdf/quant-ph/0001071.pdf)

<sup>88</sup> Rowland, Todd. "Manifold." *MathWorld, A Wolfram Web Resource*, created by Eric W. Weisstein. [www.mathworld.wolfram.com/Manifold.html](http://www.mathworld.wolfram.com/Manifold.html)

<sup>89</sup> Minkowski, Hermann. *Space and Time: Minkowski's papers on relativity*. Translated by Fritz Lewertoff and Vesselin Petkov. Montreal: Minkowski Institute Press, 2012. p. 7.

“A given braid may be assigned a symbol known as a braid word that uniquely identifies it (although equivalent braids may have more than one possible representation). In particular, an n-braid can be constructed by iteratively applying the  $\sigma_i$  ( $i=1,\dots,n-1$ ) operator, which switches the lower endpoints of the  $i$ th and  $(i+1)$ th strings --keeping the upper endpoints fixed-- with the  $i$ th string brought above the  $(i+1)$ th string. If the  $i$ th string passes below the  $(i+1)$ th string, it is denoted  $\sigma_i^{-1}$ .

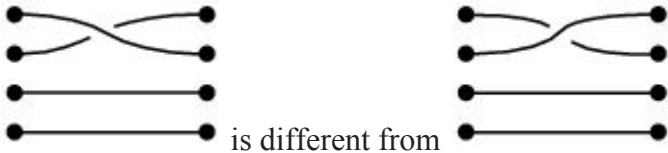


An ordered combination of the  $\sigma_i$  and  $\sigma_i^{-1}$  symbols constitutes a braid word. For example,  $\sigma_1 \sigma_3 \sigma_1 \sigma_4^{-1} \sigma_2 \sigma_4^{-1} \sigma_2 \sigma_4^{-1} \sigma_3 \sigma_2^{-1} \sigma_4^{-1}$  is a braid word for the braid illustrated above, where the symbols can be read off the diagram left to right and then top to bottom.”<sup>90</sup>

So for this study, let’s imagine two sets of four items, which are arranged in a vertical line, and they sit next to each other (the black dots). Using four strands (the line), each item of the first set will be connected with the items on the second set, so there is a one-to-one

<sup>90</sup> Weisstein, E.W. "Braid Word." *MathWorld, A Wolfram Web Resource*, Web. Accessed 08 Feb 2020 [www.mathworld.wolfram.com/BraidWord.html](http://www.mathworld.wolfram.com/BraidWord.html)

correspondence in the results of the arrangement. Sometimes the strands will have to pass over or under others, and these two connections are different braids.



and this, for instance, is not a braid:



A permutation, is also called an “arrangement number” or “order”, which is the rearrangement of the elements of an ordered list, into a one-to-one correspondence; a permutation group is a finite group, whose elements are permutations of a given set.<sup>92</sup> For us to understand visually what a permutation group is, in this image we see 24 elements of a group of 4 elements as braids. Here all crossings are left-over-right type, but further choices are possible, where the changing of the order of operations may change the result.

<sup>91</sup> Illustrations by Axel Boldt. Released into the public domain through English Wikipedia. Retrieved from [www.commonswiki.org/wiki/File:Braid\\_nobraid.png](http://www.commonswiki.org/wiki/File:Braid_nobraid.png)

<sup>92</sup> Weisstein, E.W. "Permutation Group." *MathWorld, A Wolfram Web Resource*, Web. Accessed 08 Feb 2020 <https://mathworld.wolfram.com/PermutationGroup.html>

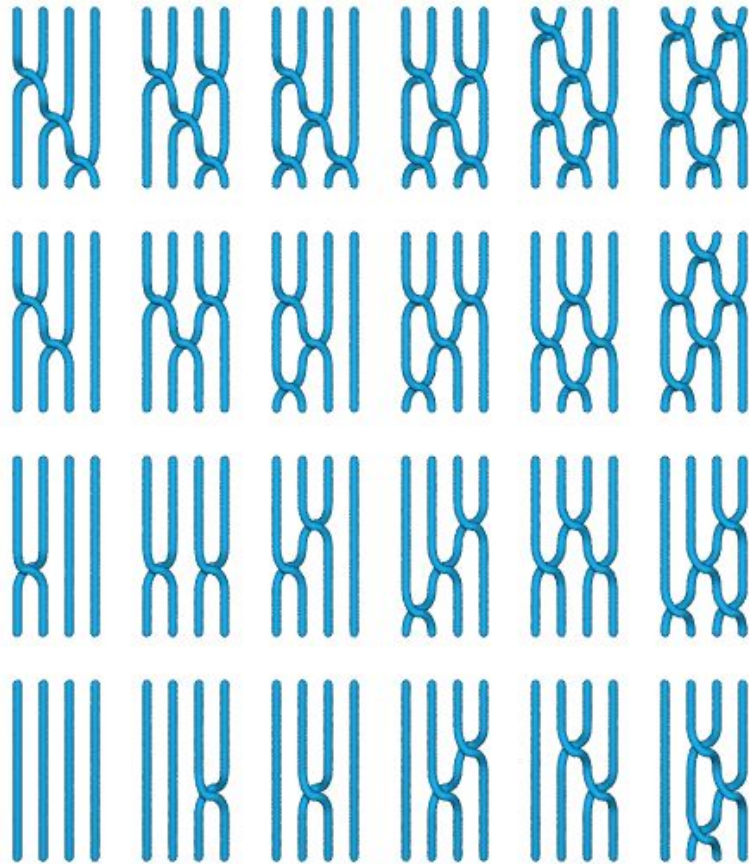


Image by Claudio Rocchini

One of the fields of intense investigation involving braids and other topological concepts in the context of quantum physics, is in the theory and experimental implementation of *anyons*. An *anyon* is a type of quasiparticle that occurs only in two-dimensional systems, and its physical properties depend on the knots that their world lines have formed. Depending on the knot that has been formed, these quasiparticles may or may not be able to annihilate another particle at the end of the knot. This came as a surprise to scientists, since one rarely thinks that a property of a particle would depend on its history. In his article “Knots, world-lines, and quantum computation”, Steve Simon explains that these effects are very nonlocal in both space and time, for instance, two particles that wrap around each other may never have even been close to each other in space, but if one world-line wraps around the others, it becomes physically altered, so its antiparticle can’t annihilate it anymore. Since this space-time knots

that form by the world-lines affect the properties of this particle, it became important to distinguish different knots from each other.<sup>93</sup> “We generally need to know if the two knots can be deformed into each other without cutting any of the strands. If two knots can be deformed into each other, then we say they are equivalent knots – otherwise we say they are inequivalent (two equivalent space-time knots will produce equivalent particle properties at the ends of the knots). While it might sound simple to determine whether two knots are equivalent, it can be quite hard if the knots are complicated. In fact, determining the equivalence or non-equivalence of knots remains a modern topic of mathematical research.”<sup>94</sup>

The physics of anyons remains to be explored in experiments, but measuring whether the anyons annihilate at the end of the knot, repeating this experiment several times to determine the probability of annihilation is something that still, in 2015, the world’s largest computer was not be able to do. Anyons have calculational ability that modern computers do not have, so the idea of building a quantum computer using anyons is the approach known as topological quantum computation. We should not forget that although this field is young and experimental, yet according to Simon, it is still considered one of the most promising approaches towards building a quantum computer.<sup>95</sup>

### 2.3 Constellation Effect, Multiversality, Mapping.

Quantum theory seems “outworldly”, and despite how intriguing quantum poetics may seem, it is hard to collate actual experiments with a poetic method, that’s why this section will introduce some concepts that might aid understanding the shift to “World Lines: A Quantum Supercomputer Poem”.

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<sup>93</sup> Simon, Steve. “Knots, world-lines, and quantum computation” *Department of Physics Newsletter*, No. 6. University of Oxford, 2015. p. 6

<sup>94</sup> Ibid. p. 7

<sup>95</sup> Ibid. p. 8

At first glance, the poem might remind us of hypertext poetry, but just as Catanzano has attempted to develop a method of quantum writing, we must also consider a quantum method of reading. As stated in Chapter 1, Ezra Pound gave the example of the Chinese character as a superposition of several meanings that once together, create a signifying whole; with these, Pound was giving a thought of alternative ways of perceiving language, literacy and cognition, or a different method of reading. Catanzano, for instance, has challenged readers in the past with poems such as “The Imaginary Present”:

THE IMAGINARY PRESENT (Excerpt. 2009)

~~contemporary poetry~~  
~~insert: poem here~~  
~~insert: essay here call it:~~  
~~essay-poem insert:~~  
~~appropriated text~~  
~~call it: poetry insert:~~  
~~sound poem call it:~~  
~~wave score insert:~~  
~~visual poem call it:~~  
~~if sound could see~~  
~~claim: the text is dead~~  
~~just schrödinger: the text!~~  
~~insert: tired formatting~~  
~~like strikethrough~~  
~~fade: your erasures~~  
~~use: basic font variations~~  
~~insert: another footnote~~  
~~please instead please~~  
~~insert: some nu-sonnets~~  
~~inject: the bacterium!~~  
~~insert: interactive~~  
~~irony call it: data~~<sup>96</sup>

About this format, she wrote “By writing this poem in strikethrough I am trying to challenge both prescriptive reading tendencies and what I see as an unimaginative formal device. To read a strikethrough one must get beyond a physical limitation with the line being partially occluded... The reader might view the strikethrough as an occlusion to transparency, even a

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<sup>96</sup> Rothenberg, J. “Amy Catanzano: 'The Imaginary Present,' a poem & a commentary from Quantum Poetics.” *Jacket2*, September 12, 2012, Web. Accessed 15. Jan 2020.  
[www.jacket2.org/commentary/amy-catanzano-imaginary-present-poem-commentary-quantum-poetics](http://www.jacket2.org/commentary/amy-catanzano-imaginary-present-poem-commentary-quantum-poetics)

metaphor for difficulty, but in my poem I confront it as a tired typographical gimmick. There's a quantum poetics to my logic, a Schrödinger's cat I am embedding into my poem... Schrödinger's cat is alive and dead at the same time. The poem is readable and not. The strikethrough is simultaneously a gesture and a gimmick.”<sup>97</sup>

In the case of “World Lines: A Quantum Supercomputer Poem”, we have the possibility if not to recreate, at least to imagine that we possess a quantum mind while we read the poem. Because of the entanglement principle in quantum computing, we might have to consider a “simultaneous reading” of the page. Louis Armand defines this “Constellation effect” in *Literate Technologies* as “... a flattening out of depth-of-field in the simultaneous vision of the page and the typographics of visual *intensity*, such that the mimesis of *linear evolution of a meaning* is broken apart, replaced by a generalised transversality.”<sup>98</sup> He explains that unlike events are connected in time and space, in a montage way, and these connections or communications are possible because there is not an “objective present”, and like so, there are no degrees of structural “revelation”, only degrees of *constellation*.<sup>99</sup> For instance the Chinese characters that appealed to Ezra Pound can be seen to function as constellated fragments read simultaneously, keeping trace of the marks that compose it. This prototypical *Constellation Effect*, which was implied in Mallarmé’s poem “A Throw of the Dice” (1897),<sup>100</sup> operates between a static view of the text (Two-dimensional image of a

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<sup>97</sup> Ibid. par. 3.

<sup>98</sup> Armand, Louis. *Literate Technologies*. Litteraria Pragensia, 2006. p.102.

<sup>99</sup> Ibid. p.102

<sup>100</sup> Stéphane Mallarmé (1842-1898) was a French poet of the Symbolic movement, which also inspired W.B. Yeats and T.S. Elliot. Mallarmé's late poem “A throw of the Dice” pursued the implication of the spacing of language experimenting with typographical space and layout. “The poem opens once again Mallarmé's protracted meditation on language and change: here a shipmaster has to decide whether to throw the dice which, unyielding a definite number, will overcome chance and the chaos of the raging sea. But the act of throwing the dice depends upon chance and the knowledge that the ship must perish is mitigated only by the appearance of a constellation whose stars seem to be imaged in the lapidary words strung out across the white space of Mallarmé's pages. A Throw of the Dice would predict many of the discoveries of later avantgarde writing, with its ‘simultaneous vision of the Page’”. In Nicholls, Peter. *Modernisms: A Literary Guide*. University of California Press, 1995. p. 41.



constellation), and the dynamics of a multidimensional constellation of meanings across several space-time degrees, operating somehow like Pound's Chinese character, working in a lexical organization (the individual meaning of a word in a sentence), parallel to syntactic organisation (the arrangement of word in a sentence); Armand's view is that, in methodological terms, the constellation effect that stemmed from Mallarmé's simultaneous vision of a page, only began to be realized with the advent of hypertext.<sup>101</sup> This is relevant because at first glance, "World Lines: A Quantum Supercomputer Poem" is reminiscent of hypertext poetry, but because quantum computers are still implemented in analogue or digital ways, this is just a two-dimensional image representing four qubits. Ideas of constellation bring forth the transversal characteristic of hypertext -and the multiverse of Catanzano's work-, where *transversality* is the idea of certain kind of punctuations (such as the "knot word"), mark a kind of bifurcation, discontinuity, alternative paths, a type of interaction in the structure that suggests a "network."<sup>102</sup> This transversality of Catanzano's poem may be seen as textual surface that preserves the stratification of "difference" between textual events that intersect, but in "Quantum Poetics: Writing the Speed of Light", Catanzano expresses her ideas of Multiversality as follows: "In his theory of general relativity, Einstein illustrated how the world would look to someone with access to multiple, and all, perspectives at the same time... In quantum theory, the relationship between the observed and the observer is one in which the observer affects observed reality. In quantum theory, matter at the molecular level swerves in and out of observation and can appear in multiple states of time and space simultaneously... In proposals such as string theory, spacetime is an ambiguous ecology, and the known universe is thought to be part of a larger wilderness, a multiverse comprised of multiple and perhaps infinite dimensions of space and time that are created by collisions

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<sup>101</sup> Armand, L. *op.cit.* 2006. p.103.

<sup>102</sup> *Ibid.* p.173-174.

between subatomic, vibrating membranes of energy... Poems and other innovative languages also seem to be multiversal, invoking invisible ecosystems outside eye-level, molecular and astronomical scales, ambiguous spacetimes, and collisions between membranes or borders.”

<sup>103</sup> No matter what we do, “World Lines: A Quantum Supercomputer Poem” as it’s written, will remain unaffected, but depending on how each reader approaches, the poem that it’s being read will depend of the reader, but how do we position ourselves as readers, if we know the relation between observer and observed will affect the observed poem? If we wanted to reduce “World Lines” into a “poem-diagram” just for the sake of analysis, we would need to consider, similar to the use of a map, how we navigate the poem. It’s important to clarify that there’s a difference between a map representing a “motionless” territory, and a map that records one’s steps. Catanzano presents a “generator” that produces a poem only after the reader’s intervention, which seems to be more like a map of the second kind. In her essay “Mapping Fluid Spaces: Semiotic bodies and Cyberart,” Christina Ljungberg writes about the importance of “mapping” the new fluid spaces that are rising as technology advances, to not get lost in a cyber and anthropo-technical space. She explains that diagrams --which always refer to something--, makes us put our attention to what it is referring to, and look on the formal similarities of the relation between objects, becoming vital for “map reading.”<sup>104</sup> Catanzano’s poem is not a diagram, and although Ljungberg ideas were meant to map cyber and post-digital art,<sup>105</sup> ideas like these could aid to find the necessary tools for thought, for this poem to have the creative potential in our minds, and to experiment with it as a reader.

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<sup>103</sup> Catanzano, Amy. “Quantum Poetics: Writing the Speed of Light” (Excerpt, Part One), In Rothenberg, J. (ed.) *Poems and Poetics*, June 2009. Web. Accessed 15 Jan 2020.

[www.poemsandpoetics.blogspot.com/2009/07/amy-catanzano-excerpt-from-quantum.html](http://www.poemsandpoetics.blogspot.com/2009/07/amy-catanzano-excerpt-from-quantum.html)

<sup>104</sup> Ljungberg, Christina. “Mapping Fluid Spaces: Semiotic bodies and Cyberart.” In Louis Armand, Pavel Cernovský (eds.), *Language Systems*. Literaria Pragensia 2007. p. 102.

<sup>105</sup> In Ljungberg’s essay, Postdigital art refers to art expression that uses digital media and analogue or non-digital alternatives. Postdigital then is an area with an inclination towards new synthesis of art and literary delivery through traditional and digital media.

One of the functions of the map is to interact with the reader, who has to locate themselves within it -either real or imaginary-, becoming a part of the map, or in this case, the poem, which maps the possible paths of four qubits. Catanzano's poem is not a map if we understand a map as a fixed representation of a terrain overlooked by a sovereign subject that's not necessarily locating itself in the map.<sup>106</sup> Nevertheless, it structures a literary space by giving limited options or paths to follow, and with reader's intervention or entry into a poem, it produces paths that are being recorded (mapped) as a final poem. The poem is helping us see the path a qubit makes through time, and as it's proposing dynamics of quantum computing, we must therefore consider new understandings of time and space, which are characterized as being "more plastic, constantly mobile and dynamic,"<sup>107</sup> even if the poem is presenting possible structures, and not an infinite number of options. Keeping in mind ideas as how we could locate ourselves in the poem, how we could "walk through" it, the constellation effect that each knot word creates, and using our imagination to comprehend the multiverse,<sup>108</sup> might help us to find alternative ways to read "World Lines: A Quantum Supercomputer Poem".

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<sup>106</sup> Ljungberg, Christina. *op.cit.* 2007. p. 102.

<sup>107</sup> *Ibid.* p. 102.

<sup>108</sup> Here multiverse means the attempt of the poet to reflect the "multiverse" as the hypothesis how it is being delivered by the physicists.

# AMY CATANZANO'S DEVELOPMENT OF QUANTUM POETICS

Amy Catanzano (born 1974) is an American poet, who has been developing since 2009 the writing praxis of quantum poetics. She received the PEN USA Literary Award in Poetry and was selected for the POL Poetry Prize at Fordham University Press for her work *Multiversal* where she explores language, science and consciousness proposing a theory of quantum poetics. She is also the author of “World Lines: A Quantum Supercomputer Poem”, published by the Simons Center for Geometry and Physics at Stony Brook University. Her research, both creative and academic, range from the avantgarde, contemporary literature and artistic subcultures, to physics and its under-acknowledged relationship to poetics and the philosophy of language.<sup>109</sup> Catanzano deliberately works within a field called quantum poetics, and her fiction and poetry is of cross-genre forms, where she “explores the historical and contemporary intersections of literature and science, particularly theoretical physics but also biotechnology, cosmology, genomics, and beyond.”<sup>110</sup>

Unlike our previous examples of Modernist poets, the goals of Catanzano are clearer, as she is aware of the language problematic that early theorists of quantum encountered, actively trying to develop methods for a more “accurate” quantum expression. In “Symbolic

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<sup>109</sup> “Simons Center Poet in Residence, Amy Catanzano, April 16 – 20,” published on April 12, 2018 Web. Accessed 06 Jan 2020. [www.scgp.stonybrook.edu/archives/25297](http://www.scgp.stonybrook.edu/archives/25297)

<sup>110</sup> Catanzano, Amy. “Commentary of Quantum Poetics.” in *Jacket2*. Web. Accessed 10. Jan 2020, [www.jacket2.org/commentary/amy-catanzano](http://www.jacket2.org/commentary/amy-catanzano)

Multiplication” she wrote: “Quantum mechanics changed the discourse about physical reality from ‘what is the truth about nature?’ to ‘what is nature?’ in much the same way, perhaps, as L=A=N=G=U=A=G=E writing changed the discourse from ‘what is the meaning of poetic language?’ to ‘what is poetic language?’ In this regard, I see quantum mechanics functioning as a kind of imaginative eco-poetics in physics through its proposal that at subatomic scales, the future position and momentum of particles can only be measured in terms of probability.”

<sup>111</sup> In this article, she explains that in her opinion, the Uncertainty Principle postulated by Heisenberg, which invalidates causality and attempts at measuring subatomic phenomenon without certainty, marked the swift when science became philosophy.<sup>112</sup> “Many writers and readers of poetry consider poetry to be a philosophical activity, one that inhabits its claims through formal properties and contextual frameworks. If physics is the study of physical reality, what happens when physics becomes philosophy and when poetry, as a philosophical activity and symbolic language, becomes a physics?”<sup>113</sup> These questions remind us of the “division” that Snow observed, which have drastically changed since the 1950’s, and Catanzano believes that these kind of questions are relevant for contemporary practitioners of both science *and* literature. “Heisenberg, whose Uncertainty Principle was part of his development of matrix mechanics, was concerned that quantum theory does not have an adequate language beyond mathematics to describe it... Heisenberg, while arguing that science must be as attentive to imagination as to logic, also seems to be suggesting that novel sciences must be described by novel languages.”<sup>114</sup> She has written several poems in different media and with different structures departing from classic poetry, such as “Wavicle” on the

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<sup>111</sup> Catanzano, Amy. “Symbolic Multiplication” *Jacket2*, March 6, 2014. Web. Accessed 13 Jan 2020. [www.jacket2.org/commentary/symbolic-multiplication](http://www.jacket2.org/commentary/symbolic-multiplication)

<sup>112</sup> *Ibid.* par. 3.

<sup>113</sup> *Ibid.* par. 4.

<sup>114</sup> Catanzano, Amy. “Quantum Poetics: Writing the Speed of Light” (Excerpt, Part Four), In Rothenberg, J. (ed.) *Poems and Poetics*, June 2009. Web. Accessed 14 Jan 2020 [www.poemsandpoetics.blogspot.com/2012/01/amy-catanzano-excerpt-from-quantum.html](http://www.poemsandpoetics.blogspot.com/2012/01/amy-catanzano-excerpt-from-quantum.html)

wave and particle duality created using “digital couplets”, and a 3D editor for visualization,<sup>115</sup> or “Borealis: Time signatures”, a visual poem that explores the theories of time in the context of quantum poetics, and which is only part of a series of poems working with the image of a tesseract (a four-dimensional analogue of a three-dimensional cube that represents the fourth dimension in geometry).<sup>116</sup> In 2009, she wrote speculative essays on quantum poetics where she expresses that “the multiverse”<sup>117</sup>, a concept rooted in science fiction, is now an accepted theory of physical reality in theoretical physics. Poems and other innovative languages also seem to be multiversal, invoking invisible ecosystems outside eye-level, molecular and astronomical scales, ambiguous spacetimes, and collisions between membranes or borders. One problem of the quest for a single theory of everything is the reductive nature of its premise. How can a single theory of physical reality describe a universe composed of multiple dimensions? It seems multiple theories would be needed to describe the complexity of the multiverse, multiple quantum and relative theories (like poems) that are mutable, relational, and paradoxical.”<sup>118</sup> She writes that one hypothesis of quantum poetics is that “poetry, as a multiversal technology, ricochets between pattern and the swerve toward novelty within multiple scales of physical reality through known and unknown dimensions.”<sup>119</sup> She argues that the complexity of matter is not missing quantum reality, but we rely on our

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<sup>115</sup> The gravity of words Exhibition. *Poetry International Festival in Rotterdam 2017*. Web. Accessed 14 Jan 2020, video-visualization available in [www.3dpoetryeditor.art/](http://www.3dpoetryeditor.art/)

<sup>116</sup> Catanzano, Amy. “Borealis Tesseract in the Fourth Dimension” *Perfect Wave*, Vol.4, 2017. Web. Accessed 14 Jan 2020. [www.perfectwave.org/vol-4/](http://www.perfectwave.org/vol-4/)

<sup>117</sup> The multiverse is “a hypothetical collection of potentially diverse observable universes, each of which would comprise everything that is experimentally accessible by a connected community of observers... The multiverse idea has arisen in many versions, primarily in cosmology, quantum mechanics, and philosophy, and often asserts the actual physical existence of different potential configurations or histories of the known observable universe.” In “Multiverse”, *Encyclopædia Britannica*. November 28, 2019. Web. Accessed 13 Jan 2020 [www.britannica.com/science/multiverse](http://www.britannica.com/science/multiverse)

<sup>118</sup> Catanzano, Amy. “Quantum Poetics: Writing the Speed of Light” (Excerpt, Part One), In Rothenberg, J. (ed.) *Poems and Poetics*, June 2009. Web. Accessed 13 Jan 2020 [www.poemsandpoetics.blogspot.com/2009/07/amy-catanzano-excerpt-from-quantum.html](http://www.poemsandpoetics.blogspot.com/2009/07/amy-catanzano-excerpt-from-quantum.html)

<sup>119</sup> Catanzano, Amy. “Quantum Poetics: Writing the Speed of Light” (Excerpt, Part Four). In Rothenberg, J. (ed.) *Poems and Poetics*, June 2009. Web. Accessed 14 Jan 2020 [www.poemsandpoetics.blogspot.com/2012/01/amy-catanzano-excerpt-from-quantum.html](http://www.poemsandpoetics.blogspot.com/2012/01/amy-catanzano-excerpt-from-quantum.html)

mechanical and biological instruments, that might be unsuitable to receive all these details.<sup>120</sup>

We are constantly developing technologies to improve our interaction with physical reality, and as such technology advances, so will our capacities to create through alternative mediums.

### 3.1 World Lines: A Quantum Supercomputer Poem

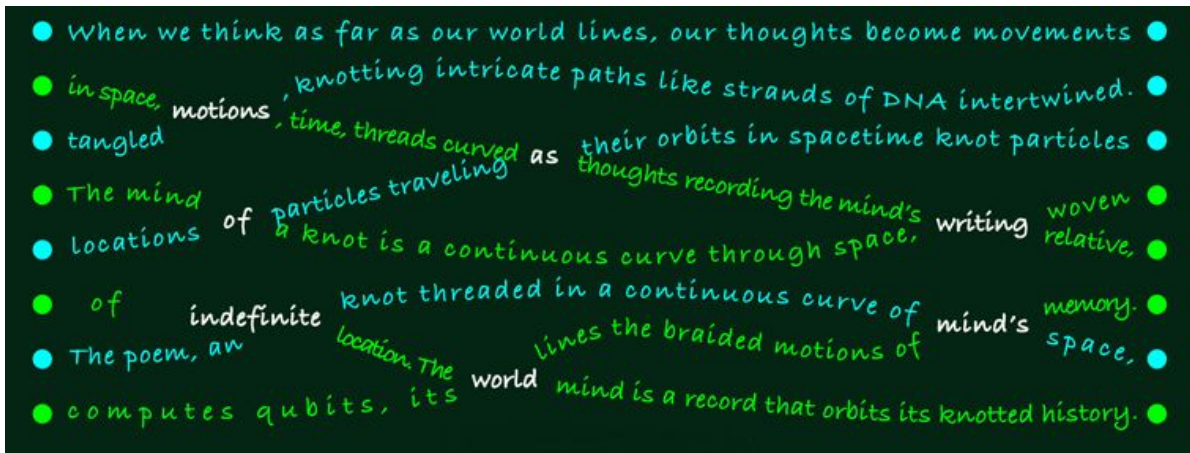
Amy Catanzano's "World Lines: A Quantum Supercomputer Poem" not only was inspired by quantum, but also incorporates the physics of a topological quantum computer. The poem is a design of a possible architecture of quantum computing, a diagram containing four qubits, each consisting in two "quasiparticles" called anyons, which was discussed in Chapter 2. Katherine Wright, a senior editor of American Physical Society's online magazine *Physics* explains "Calculations are performed by swapping the positions of adjacent anyons in a predetermined sequence. The output of the computation is then contained in the so-called knots and braids created by the intertwining of the anyons' paths—or, more technically, their world lines."<sup>121</sup> Catanzano then replaces the anyons with poetic couplets crossing over one another, and in each intersection, there's a word that it's a literary device to represent an anyon knot; those are the "forks" that the reader encounters; it can be read following linear sequence, or the reader can jump to other "world lines" when a knot is met. Each path leads to unique outcomes, and these calculations are similar to the ones a topological quantum computer does.

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<sup>120</sup> Catanzano, Amy. "Quantum Poetics: Writing the Speed of Light" (Excerpt, Part Two). In Rothenberg, J. (ed.) *Poems and Poetics*, June 2009. Web. Accessed 14 Jan 2020

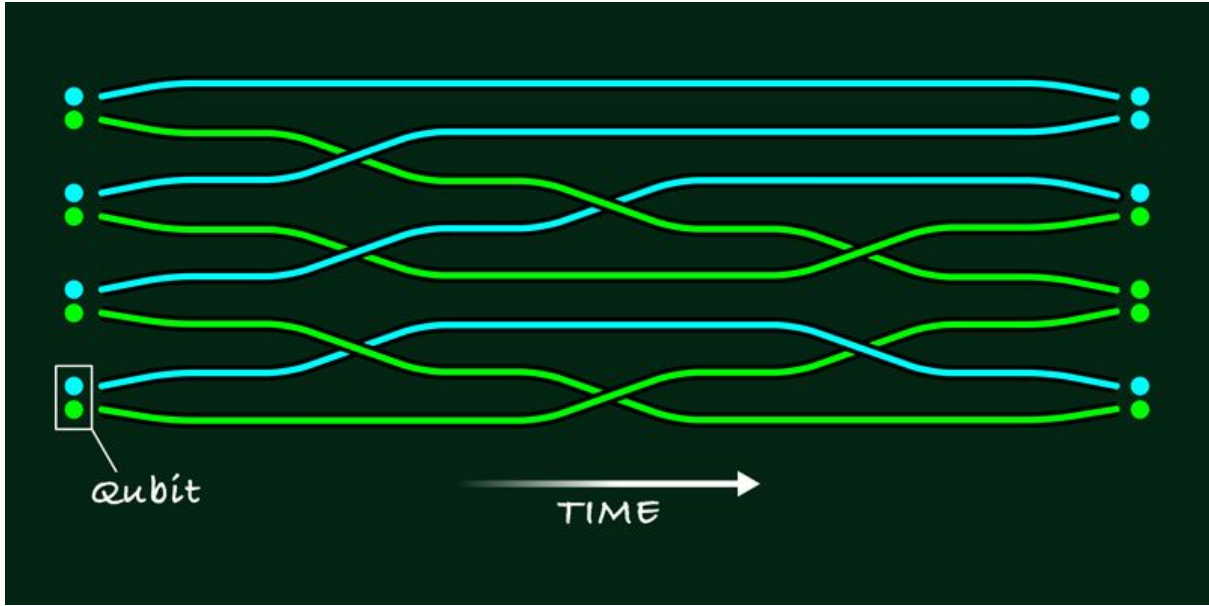
[www.poemsandpoetics.blogspot.com/2009/08/amy-catanzano-excerpt-from-quantum.html](http://www.poemsandpoetics.blogspot.com/2009/08/amy-catanzano-excerpt-from-quantum.html)

<sup>121</sup> Wright, Katherine. "Arts & Culture: Poetry Takes on Quantum Physics." *Physical Review Journals*, Published by the American Physical Society, 2018. Accessed 14 Jan 2020. [www.physics.aps.org/articles/v11/103](http://www.physics.aps.org/articles/v11/103)



Amy Catanzano; APS/Alan Stonebraker “Anyon knot” or “knot word” (in white). Each qubit has two anyons, one blue and one green.”

The following diagram shows a possible design of a topological quantum computer containing four qubits, which contains two anyons. While calculating, these anyons are swapped creating “braids”, and at the end of this calculation, the anyon pairs of each qubit is measured.



Amy Catanzano; APS/Alan Stonebraker  
 Catanzano’s “translation” of theory behind quantum computing is achieved by the words used and the visual structure, with the expectation that the poem served as an



“imaginative and rigorous site” for the interaction of science and arts.<sup>122</sup> Entanglement is an example of this tricky interaction, because the word itself suggests that these particles are interconnected or overlapped, when in the experiments, this communication takes places without any actual physical connection; metaphor may be dangerous, in the sense that it would be a recursion of “ordinary language”, capturing inaccurately the mathematics of quantum theory, which might lead to misunderstandings. Luis Álvarez-Gaumé, the Director of the Simons Center for Geometry and Physics at Stony Brook University New York, where Catanzano wrote this poem, says “If you try to extrapolate ordinary language to a world that humans have never directly experienced, it’s very difficult to find expressions that can express this particular reality.”<sup>123</sup> This hasn’t stopped either scientists nor artists from having fun, but from the view of Álvarez-Gaumé, we have failed so far to find a quantum language that is true.

The motivation for Catanzano to write this poem was to propose a solution, or at least a search towards a new language that could describe more precisely the apparently indescribable quantum world. She says that the qualities of poetry are suitable for “taking on” quantum physics, “Poetic language is a hyperbolic language that can inspire fresh ways of seeing and being. It can deconstruct and challenge our assumptions.” She believes that poetic language is compatible with quantum dynamics, and she thinks that the general public could avoid confusions if poetry were more assimilated.<sup>124</sup> Poems use a wide range of literary devices to explore invisible worlds, and play with the flow of time, as we saw in our examples of Modernists poets, and maybe it’s possible for a poet to feel as the first physicist who encounter the quantum world must have felt: discovering unthinkable things. We can see

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<sup>122</sup> Ibid. par. 5.

<sup>123</sup> Ibid. par. 7.

<sup>124</sup> Ibid. par. 8.

then that the meaning of *poetic method* that we find in our example of Ezra Pound's Chinese character, or the methods of Amy Catanzano, are not a mere mechanical application as a "technologisation of literacy", but as Louis Armand writes, this *poetic method* is a way of knowing about the technological *condition* of literacy, where *methodos* (*μέθοδος*) literally means: *the path of a change of condition*.<sup>125</sup>

### 3.2. Walking the lines<sup>126</sup>

Because of the entanglement principle in quantum computing, we might have to consider a "simultaneous reading" of the page, where linear meaning is replaced by transversality. At a first glance, the reader can spot the knot words by themselves "Motions, of, indefinite, world, as, mind's, writing." The reader might also notice how the anyons (one blue, one green) will end up, and that one can read each line as a wave, and still have a particle there, either as a knot word, or as the word with meaning itself, like in "tangled motions, time, threads curved as their orbits in spacetime knot particles". The first anyon (blue), for instance, follows a "straight" line, but it's other anyon (green), which comprise the whole qubit, entangles with another qubit (third anyon), that will change that first line anyway: "When we think as far as our world lines, our thoughts become movements/ in space, motions, time, threads curved as their orbits in spacetime knot particles" or "When we think as far as our world lines, our thoughts become movements/ in space, motions, knotting intricate paths like strands of DNA intertwined." Once we have a simultaneous view of a page, we can locate, and just walk any line. Now we can better understand how Catanzano's poem is intended to work. No matter what we do, "World Lines" as it's written, will remain unaffected, but depending on how each reader approaches, the poem that it's being read will depend on the observer.

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<sup>125</sup> Armand, Louis. *Literate Technologies*. Litteraria Pragensia, 2006. p.105.

<sup>126</sup> All lines are taken from Amy Catanzano's World Lines, and were randomly read by a human.

# CONCLUSION

As brief as this thesis has been, this essay has had two purposes: The first, was to serve as an introduction to the problems with quantum language and imagery, beginning with a brief historical background of the quantum revolution, which challenged classical concepts, the gap between science and art, moving into an overview on how Modernist poets, in light of their studies in physics, consciously or unconsciously addressed this gap, making an emphasis on their methods and metaphors. The second purpose was to analyze Amy Catanzano's "World Lines: A Quantum Supercomputer Poem" to find a potential solution for the quantum poetry to write *within* scientific quantum dynamics, instead of writing *about* popular quantum conceptions.

Based on the literature chosen to tackle this analysis, it is more feasible to conclude that Catanzano's poem bears the potential of a poem written to exemplify certain quantum traits through language, yet it does not accurately portray the contradictions of the quantum physics. However, I do not dare to state that this study is totally conclusive as I have carried out a brief formal analysis, a limitation stated at the beginning. These conclusions are solely based on the analysis presented on this thesis. More research would be needed and I would like to encourage fellow colleagues to expand on this experimental study.

Let us clarify some of the findings and relevant points about this study, specifically about Catanzano's poem. We reviewed the problems of language that scientists encountered when writing about these systems, a problem that came along with the difficulty of describing accurately what they were developing in theory and observing in experiments. Even if we accepted, just for the sake of the argument, that poetic language provides tools to describe a counter-intuitive reality, and that there might be a wide range of poetic literary devices to

explore invisible worlds and play with the flow of time, then the work of the artists don't seem to keep up with contemporary quantum physics. As we noted in the beginning of this essay, to prove or quantify how "quantum" a poem can be, further intensive research would be required, and even if we adapted a scientific method into poetry, we must ask ourselves how effectively a poem could provide an experiment for physics. Consequently, I would like to make some criticism in order to potentially aid further research in this field of study. In "World Lines: A Quantum Supercomputer Poem", some aspects of the quantum theory were addressed, but we must consider that this is a poem working closer with computing, rather than just superposition and entanglement -which is an important concept in quantum computing-; to have a single work to encompass all these concepts successfully and remain scientifically accurate is in itself a challenge, so "World Lines" seems to be a poem working with words on the possible structure of four qubits in a computer. Nonetheless, she translated into a poem the concepts of world-lines and anyons; this could somehow be considered a thought-experiment, but the experiment isn't working how she thinks it is -when "poetry" becomes "a physics",-<sup>127</sup> but rather seemed to be a poem inspired by the possible qubit paths with values already assigned by the poet (words), letting the reader experience how their observation affects the final result, yet ultimately, it doesn't serve as an experiment for computer scientists working with qubits. One other thing to consider is how the poet works with superposition, the poem is not encompassing infinite possibilities, instead it delimits the number of words and of combinations, following the design of a topological quantum computer. These words aren't only words, and when used in discourse (a poem or sentence) serve functions that make them something more than themselves when considered in isolation, carrying meaning and content. Now, this work examined the metaphors and

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<sup>127</sup> Catanzano, Amy. "Symbolic Multiplication" *Jacket2*, March 6, 2014. Web. Accessed 13. Jan 2020, <http://jacket2.org/commentary/symbolic-multiplication>

methods of Modernists poets, but in the case of Catanzano we focused on the structure, and what it told us about qubits with little scientific knowledge about them. This was with the purpose of clarifying how quantum poetry is not only about terms and metaphors, but also about structures and quantum contradictions, that as readers without the specific scientific literacy we can only begin to fathom, so I presume there is something of an ontological or existential level that quantum poetry is trying to achieve, other than simply enabling people without scientific training to grasp quantum concepts, something that quantum poetry can provide that mathematical language or other “scientific” concepts cannot, otherwise people could just study mathematics and quantum physics. Nonetheless, despite all the complications on this analysis, we can see the achievements of “World Lines,” such as how the *observer effect* plays an important role in the measurement of the event (a line): without a reader there is no quantum poem, since it’s the reader creating the disturbance that is unmistakably linked to the interference pattern. This provides by itself an experiment, both for the reader and the writer. During the 20th Century, from the beginning of quantum theory, some artists and academics realized the compatibility of quantum and poetic language, and these attempts aided to close the gap between science and art, which became a necessity in order to comprehend more holistically the human experience, and it’s something the quantum poetry can bring about that “science” alone cannot. Nowadays, Amy Catanzano continues to advocate for the search towards solving the language problem of quantum ideas through poetic expression.

To finish this conclusion chapter and the thesis, I would like to end with a reflection: Technology plays an important role in our lives, and we use technologies such as the word for the preservation of our experiences, to enhance them, and largely to make our lives easier, but we must consider how technology has been developing at a higher speed than our

understanding of its implications in our human experience. Quantum computers may be far from being commercially accessible, and their potential impact remains largely theoretical. However, because of their potential applications -cybersecurity, financial modelling, weather forecasting and climate change, artificial intelligence, quantum-resistant cryptographic algorithms, protein folding simulation, etc.- humanities should not fall behind in the study of how theoretical science and technology may affect humanity, as we live during its development. Nevertheless, the language problem of quantum ideas has not been properly addressed by academics observant of the language, or has only remained in avantgarde circles. Poets and artists have integrated science and technology as part of the Zeitgeist, but a lot of their observations fall into so-called pseudo-sciences. Quantum theory showed us how science challenges itself, questioning structures and concepts that are centuries old; perhaps these leaps are reflected in our conception of reality, and these leaps reflect our conception of reality, that is, the leaps change -and in that sense show themselves - in our conception of reality, and our conception of reality bring about these leaps, simultaneously. This contradictory challenge encounters resistance, just as quantum theory encountered resistance within the scientific spheres. The process of integrating novel scientific discoveries into a society takes time, no matter how challenging it is at the beginning, but nowadays we see tech giants in a race to improve quantum computers and solve problems that no classical computer can feasibly solve,<sup>128</sup> making it relevant for us to start comprehending the science behind it, within the scope of the field of humanities. If we imagine, just for the sake of knowledge, the quantum leaps our perception of reality could make, not only in our general worldview, and what we conceive the nature of things to be about our beliefs, ways of thinking or

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<sup>128</sup> Lichfield, Gideon. "Inside the race to build the best quantum computer on Earth". *Technology Review*, Published by the MIT, Feb 26, 2020. Web. Accessed 07 April 2020, <https://www.technologyreview.com/s/615180/quantum-computer-race-ibm-google/>

conceptions, but also more strictly speaking perception (as in our experience of reality as it is) and not simply accuracy of thought, we could pose more radical questions. Then we would have to ask ourselves if the answer to the problems presented by the quantum world is in language, or if its ontological, or if it's in both at the same time. Food for thought, at least.

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