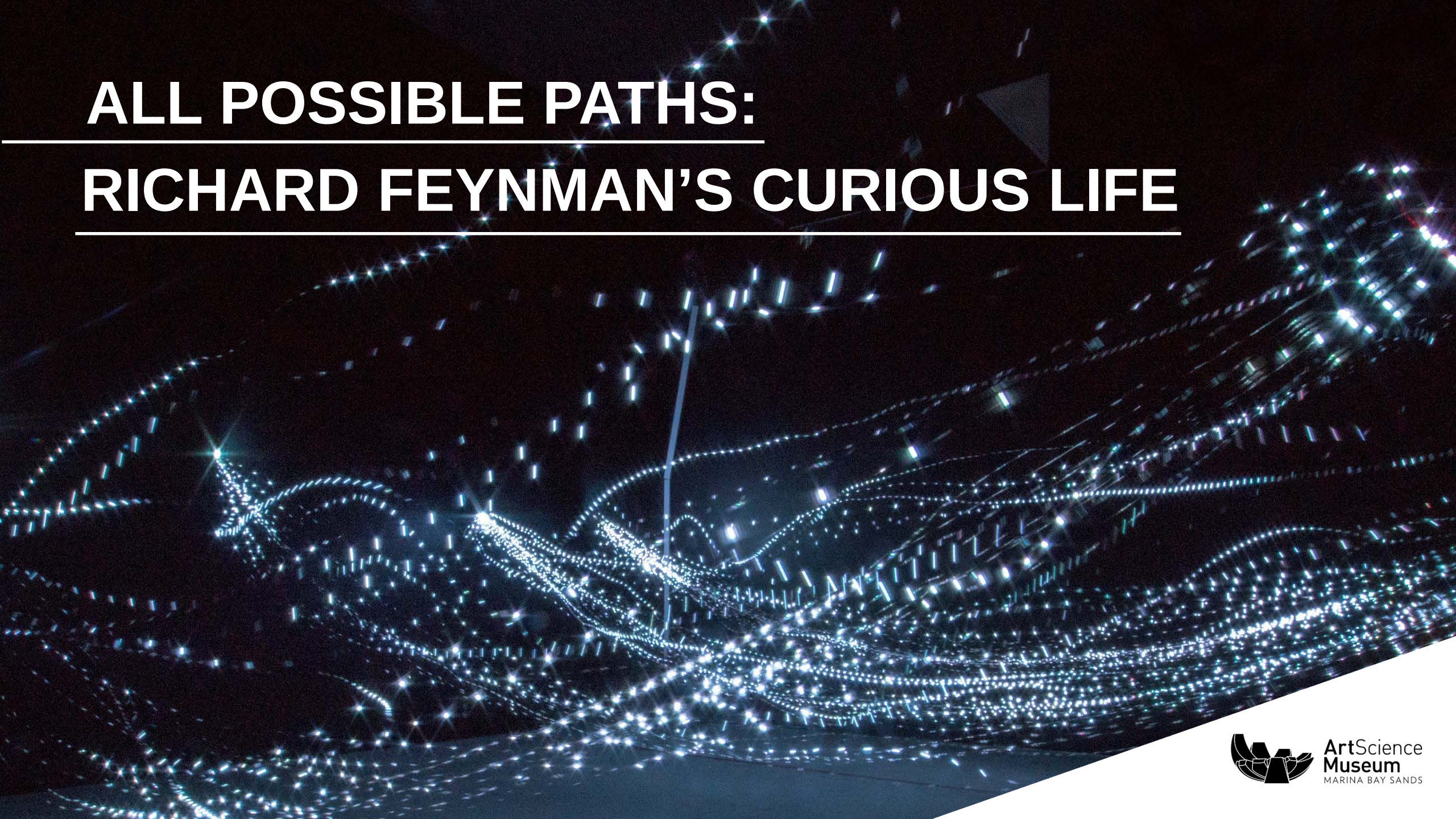
ALL POSSIBLE PATHS: RICHARD FEYNMAN'S CURIOUS LIFE

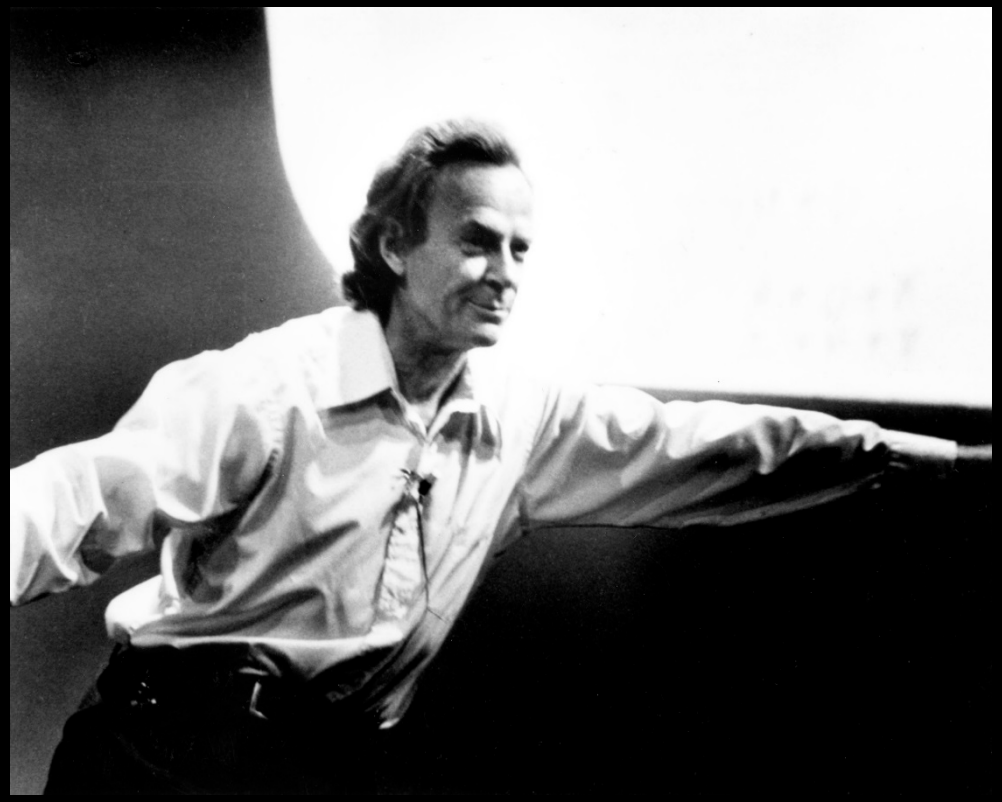


ArtScience Museum
MARINA BAY SANDS

ABOUT ARTSCIENCE MUSEUM

ArtScience Museum is an iconic cultural landmark in Singapore.
Our mission is to explore the intersection of art, science, culture and technology.

RICHARD FEYNMAN



Richard Feynman was an American theoretical physicist known for his work in quantum mechanics – the basis of modern physics and of many technological advances that support our everyday lives. He received the Nobel Prize in 1965 and his work changed the way physicists think forever.

ARTSCIENCE MUSEUM™ PRESENTS

ALL POSSIBLE PATHS

RICHARD FEYNMAN'S CURIOUS LIFE

In collaboration with Nobel Museum,
California Institute of Technology and
Michelle Feynman

ALL POSSIBLE PATHS

Spanning 800m^2, the exhibition features over a hundred

- original artefacts
- scientific papers
- audio-visual materials
- artworks
- interactive educational activities
- animations

All Possible Paths goes beyond being a traditional biographical exhibition. It uses both art and science, as well as striking contemporary design to convey the vitality of Feynman's ideas for today's audiences.

A CURIOUS LIFE

I don’t know anything but I do know that everything is interesting if you go into it deeply enough.

Richard Feynman

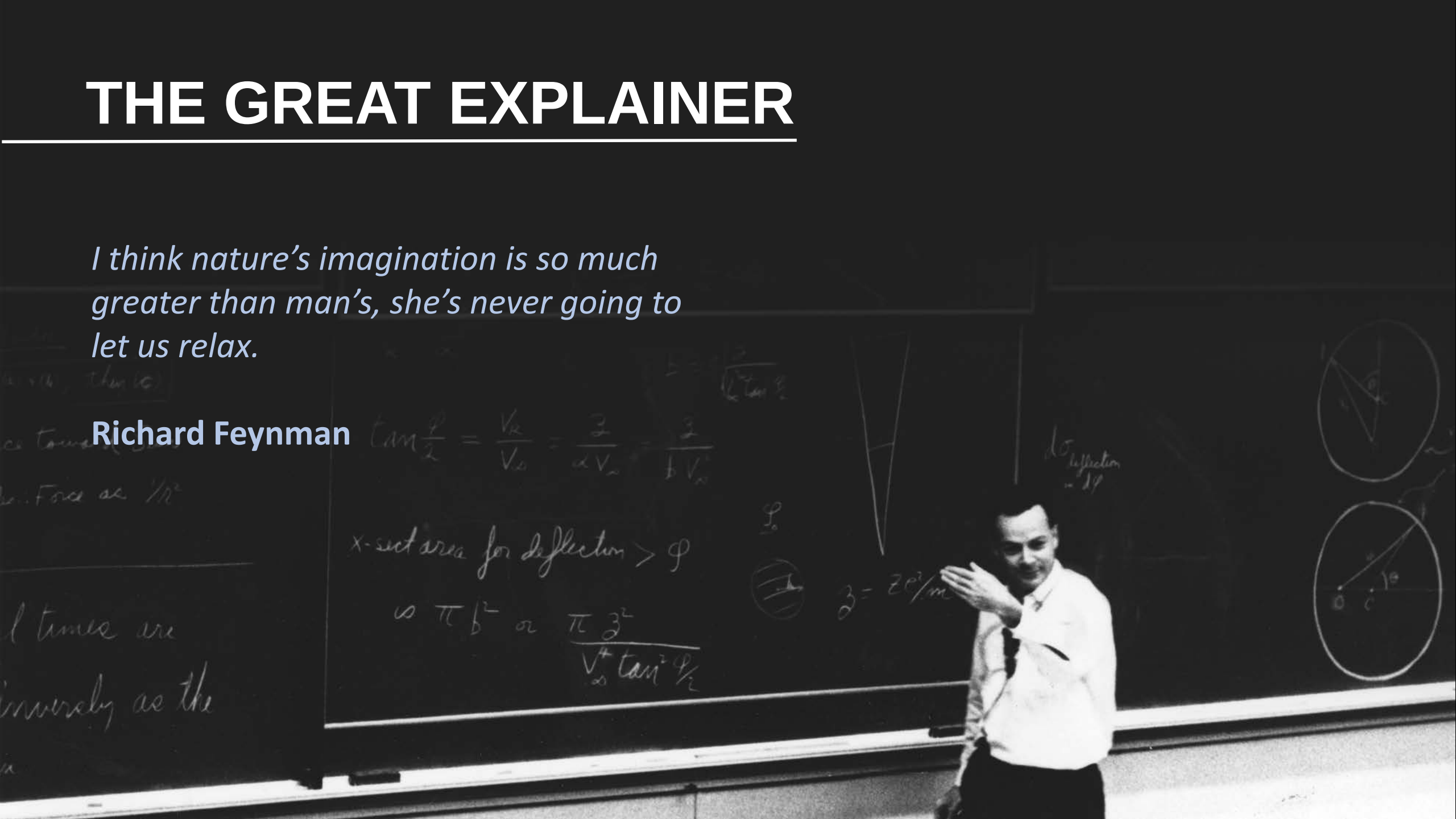

A CURIOUS
LIFE


Traveller 200

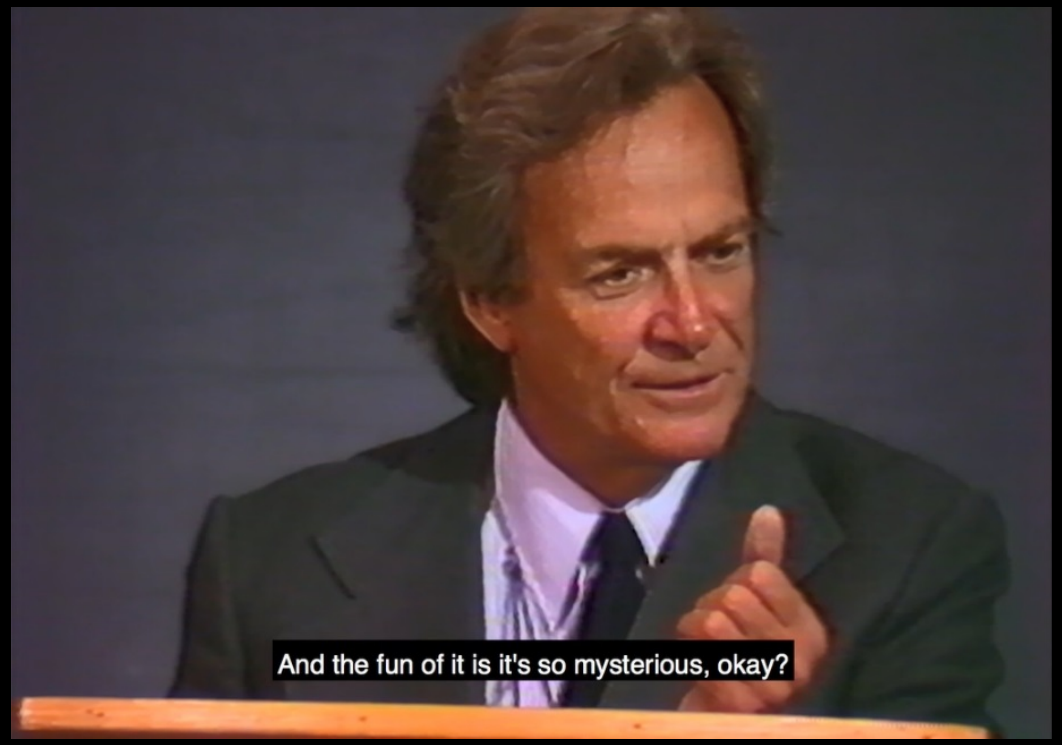
THE GREAT EXPLAINER

I think nature's imagination is so much greater than man's, she's never going to let us relax.

Richard Feynman



THE GREAT EXPLAINER



Feynman’s infectious passion for thinking and learning is brilliantly conveyed in the second section of the exhibition, through a series of lectures he gave at the University of Auckland in New Zealand.

THE PLEASURE OF FINDING THINGS OUT

Our imagination is stretched to the utmost, not, as in fiction,
to imagine things which are not really there, but just to comprehend those things which are there.

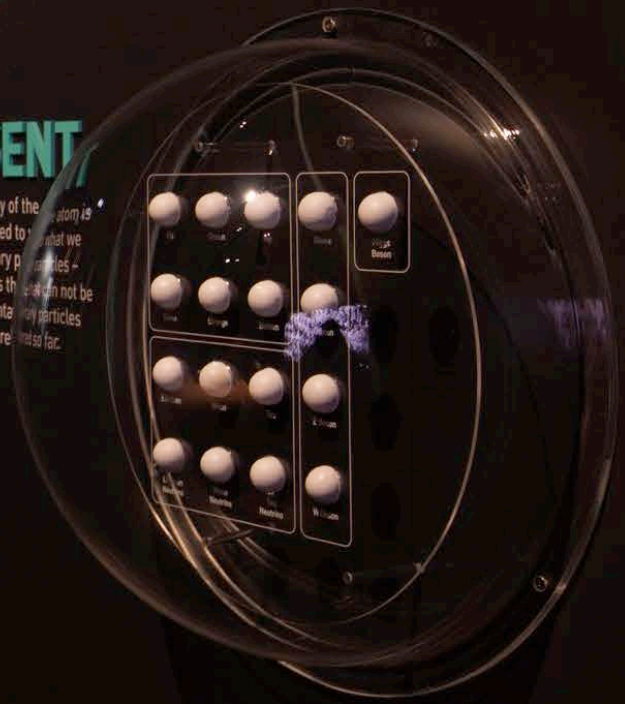
Richard Feynman

THE PLEASURE OF
FINDING
THINGS OUT

1964

PRESENT

Democritus' theory of the atom is more closely related to what we now call elementary particles – these are particles that can not be divided. 17 elementary particles have been discovered so far.



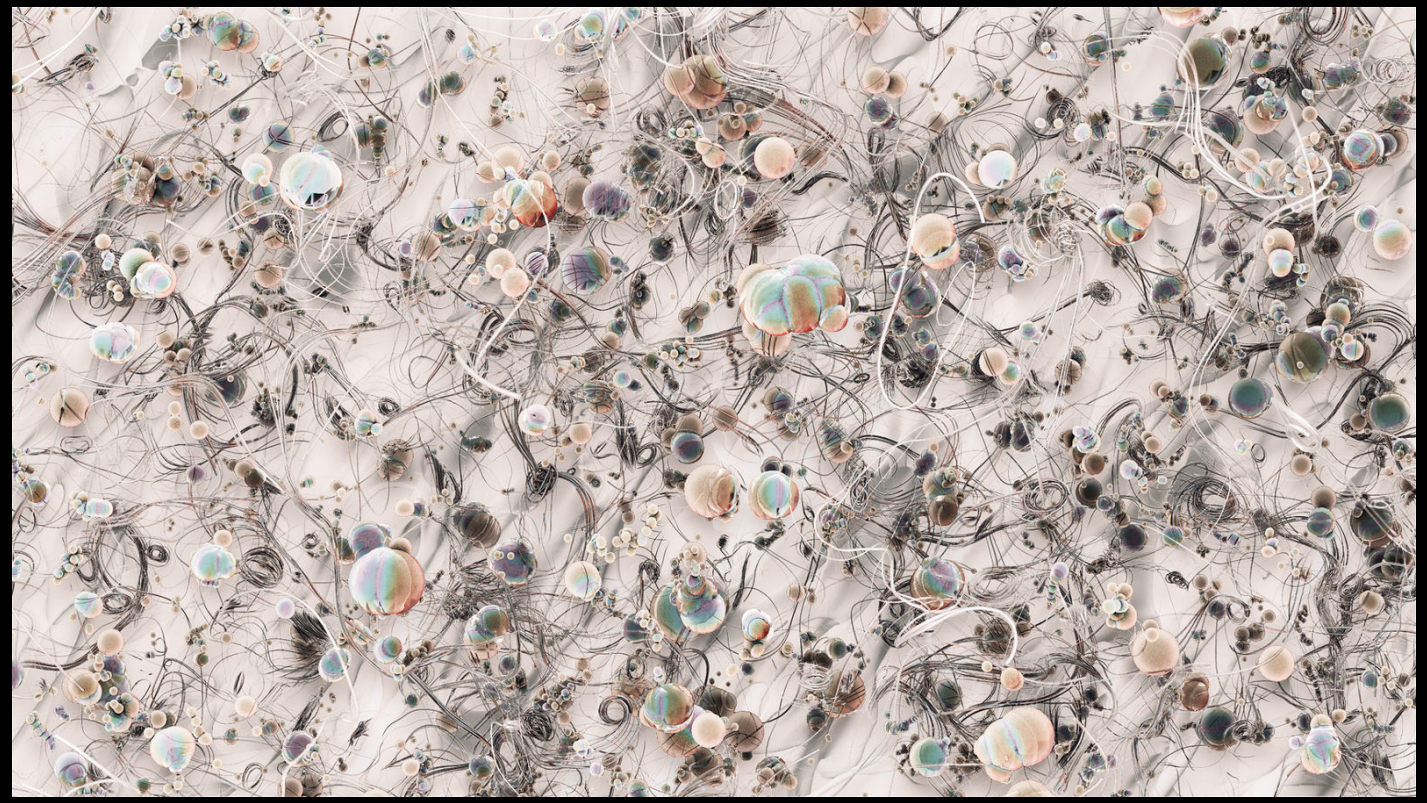
THE PLEASURE OF FINDING THINGS OUT

The emergence of quantum mechanics in the 20th century enabled scientists like Feynman to understand nature's secrets in new way, leading to striking technological breakthroughs.

Frederik De Wilde, *Quantum Foam #2*, 2018, 3D printed polyamide

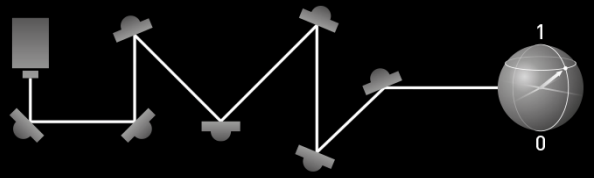
THE PLEASURE OF FINDING THINGS OUT

Taking inspiration from Feynman's own highly visual way of thinking, the third section of the exhibition explores quantum physics and its applications through the visual medium of art.

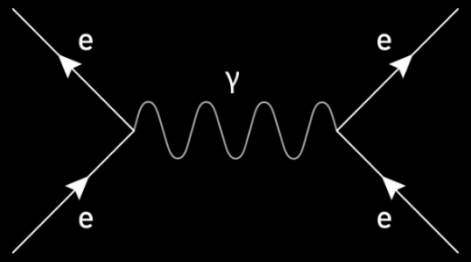


Markos Kay, *Quantum Fluctuations*, 2017, Digital video

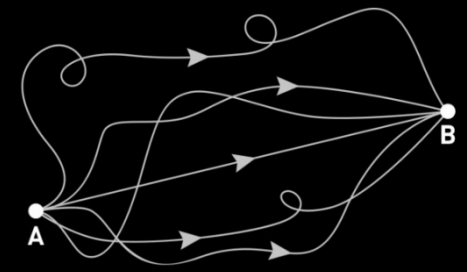
THE PLEASURE OF FINDING THINGS OUT



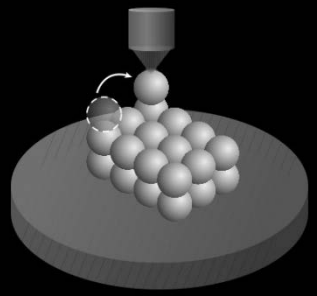
Quantum Computers



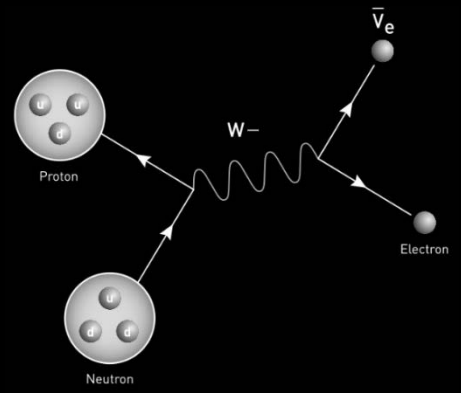
Feynman Diagrams



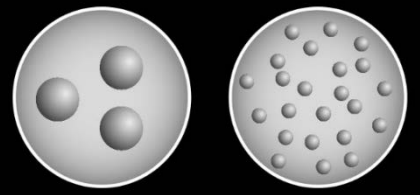
Quantum Electrodynamics



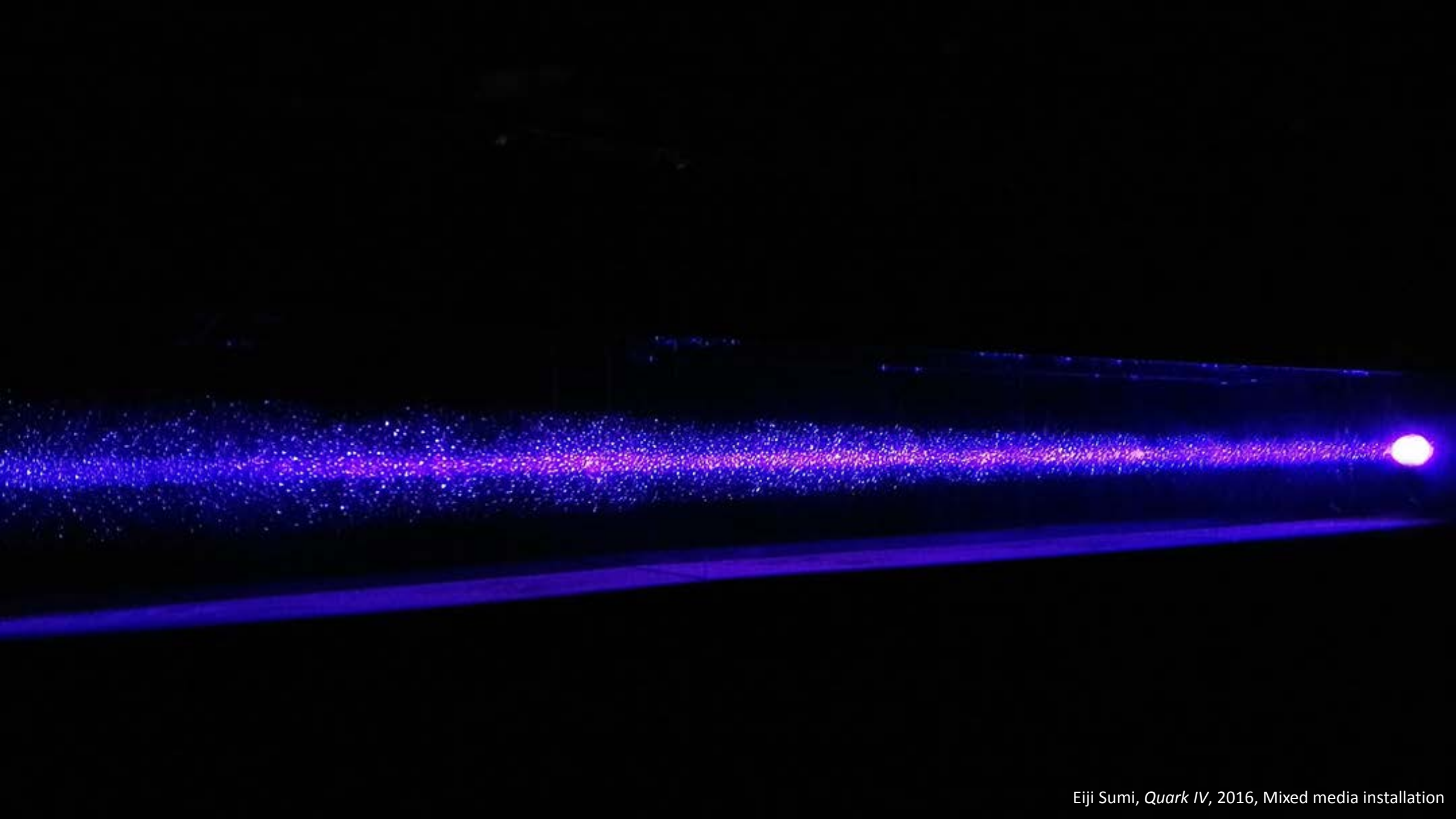
Nanotechnology



Weak Force

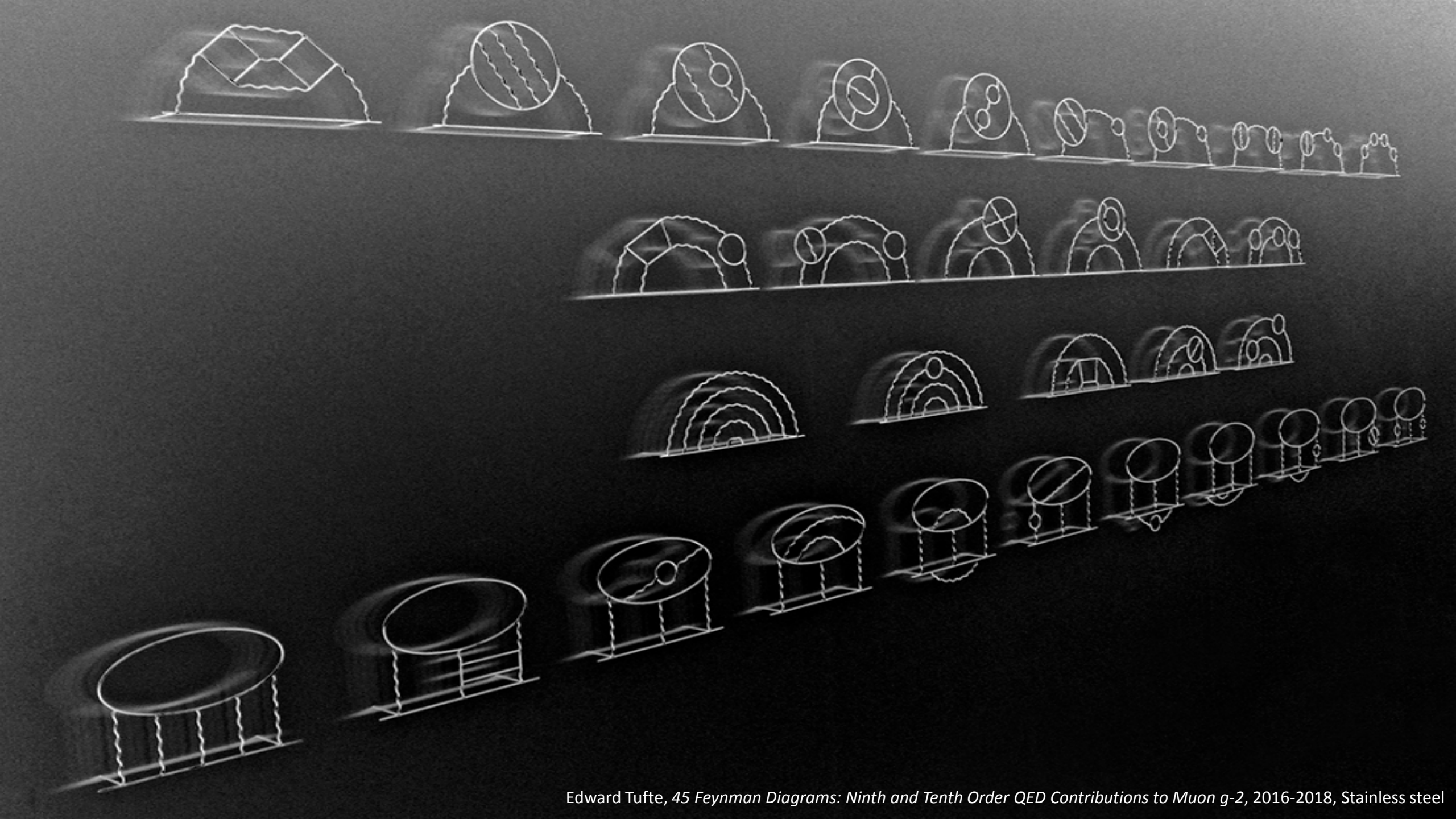


Parton Theory

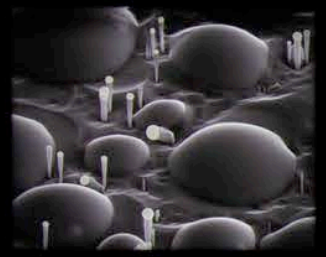


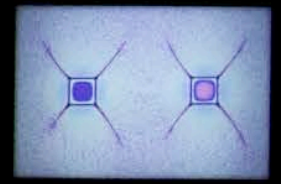
Eiji Sumi, *Quark IV*, 2016, Mixed media installation

::vtol::, *wave is my nature*, 2015, Mixed media installation

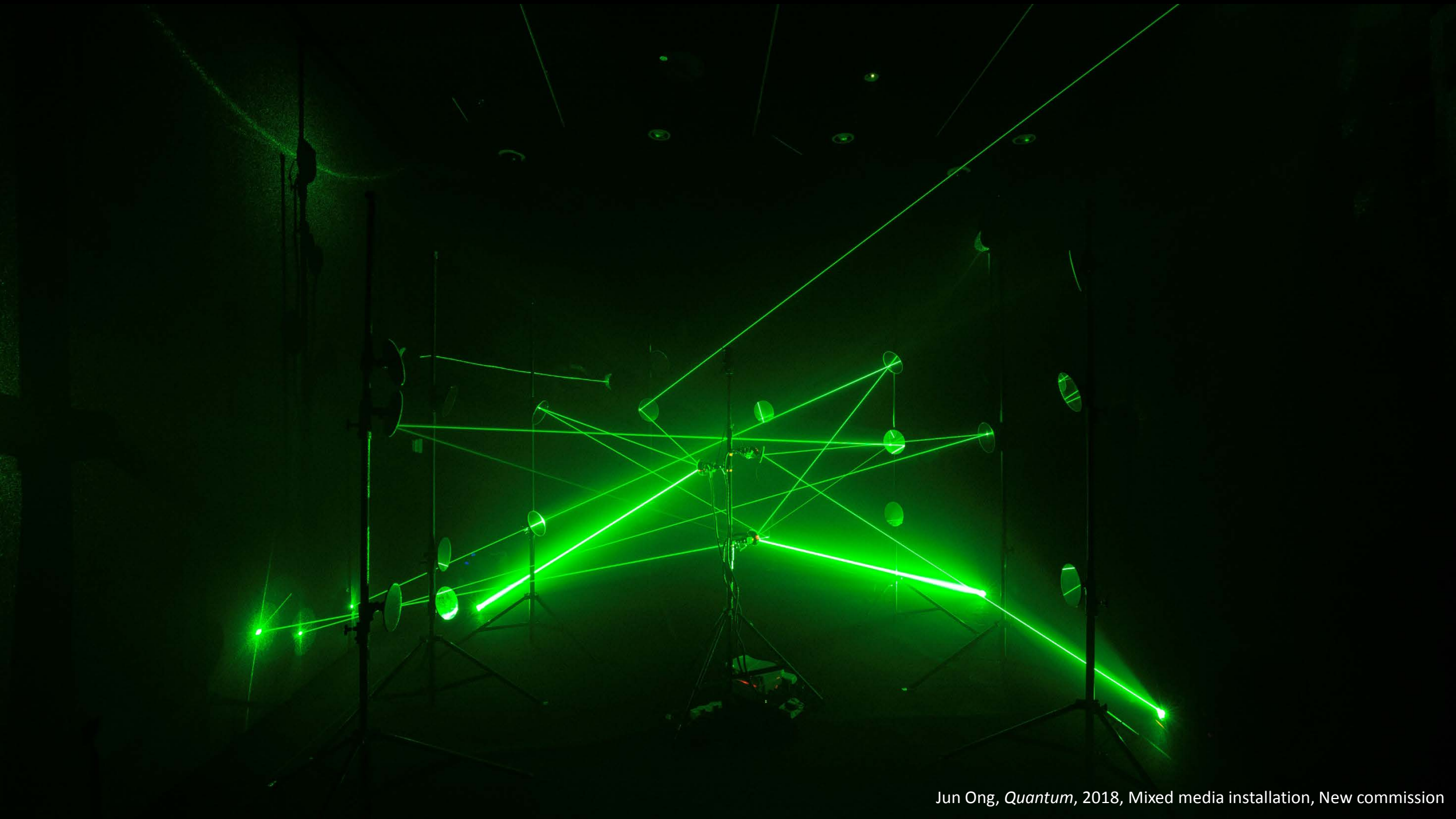


Edward Tufte, *45 Feynman Diagrams: Ninth and Tenth Order QED Contributions to Muon g-2*, 2016-2018, Stainless steel





Images by German nanotechnologists, 2005-2010, Backlit vinyl sticker

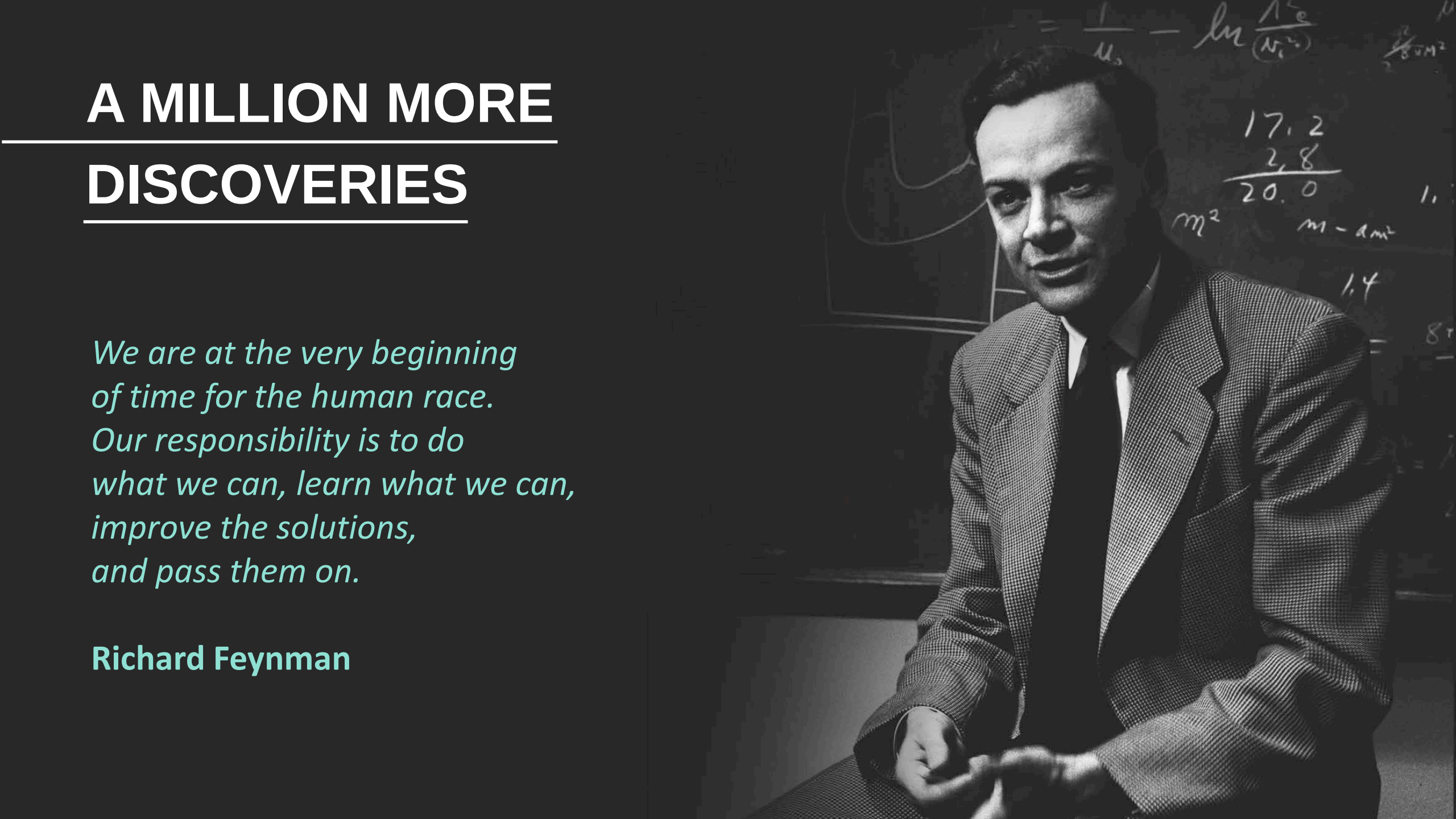


Jun Ong, *Quantum*, 2018, Mixed media installation, New commission

A MILLION MORE DISCOVERIES

We are at the very beginning
of time for the human race.
Our responsibility is to do
what we can, learn what we can,
improve the solutions,
and pass them on.

Richard Feynman




A MILLION MORE
DISCOVERIES
Richard Feynman's brilliant mind and wonderfully curious personality have inspired scientists from all around the world. Not only did he win the Nobel Prize himself in 1965, but many of those he taught or influenced, went on to win Nobel Prizes of their own.
One of the ways that Feynman has influenced physicists is through the development of Feynman Diagrams. These diagrams act as a visual dictionary for processes that take place in the microscopic world, helping scientists visualise complex ideas.
In this section, the influence of Feynman's approach to physics is demonstrated in a series of original Feynman Diagrams drawn by fellow Nobel Laureate, Frank Wilczek. The diagrams depict several scientific discoveries which went on to receive Nobel Prizes in Physics. Animations, commissioned for this show, bring the Feynman Diagrams to life, vividly illustrating discoveries which have helped shape our understanding of the universe.

NEUTRINO OSCILLATION

The 2015 Nobel Prize in Physics was awarded jointly to Takaaki Ka
and Arthur B. McDonald *"for the discovery of neutrino oscillations, which
shows that neutrinos have mass"*.

Most particles called neutrinos found passing through Earth,
in nuclear reactions that take place in our nearest star
However, as neutrinos rarely interact with matter, de
extremely challenging. After years of research, scien
types of neutrinos that transform from one type to a
through space. In the language of Feynman Diagra
particle turn into another, without any interaction
of this phenomenon, named neutrino oscillatio
the history, structure and future of the Universe.

RICHARD FEYNMAN
NOBEL PRIZE

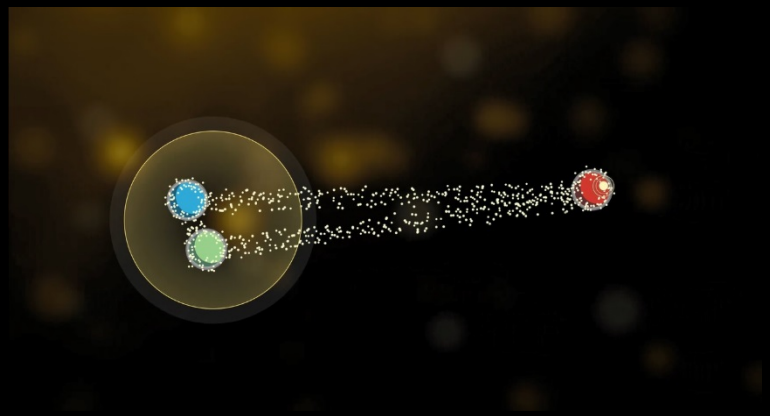
NEW TYPE OF PULSAR

The 1993 Nobel Prize in Physics was awarded jointly to Russell A. Hulse and Joseph H. Taylor Jr. *"for the discovery of a new type of pulsar, a discovery that has opened up new possibilities for the study of gravitation"*.

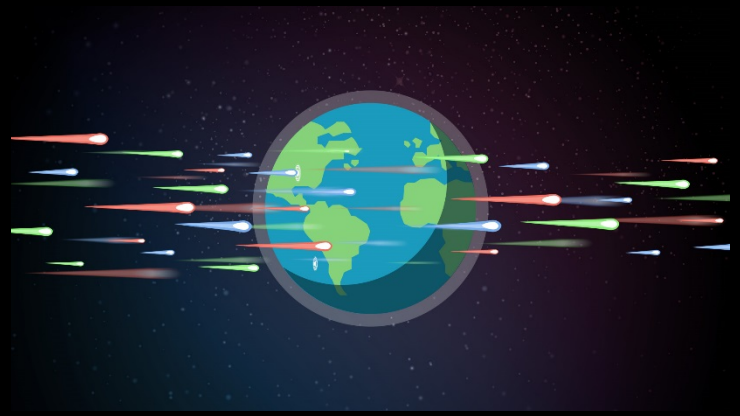
Pulsars are compact spherical objects with a radius of about ten kilometers that contain more mass than our Sun. Albert Einstein predicted that pairs of pulsars produce gravitational waves — ripples in spacetime as they rotate around each other. Scientists now believe that gravitational waves are actually caused by a hypothetical particle, known as the graviton. This Feynman Diagram shows gravitons being emitted by a pulsar. Such diagrams can help us explore particles which may still only exist in theory, before actually observing them.

A MILLION MORE DISCOVERIES

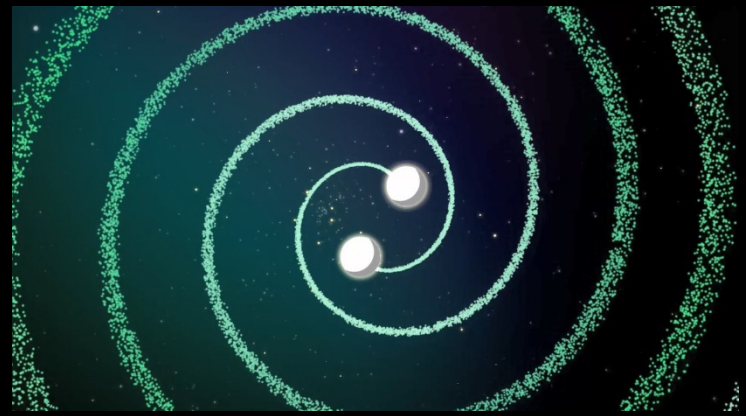
Animations commissioned for this exhibition bring Feynman Diagrams to life, vividly illustrating discoveries which have helped shape our understanding of the universe.



Strong Force,
2004 Nobel Prize in Physics



Neutrino Oscillation,
2015 Nobel Prize in Physics



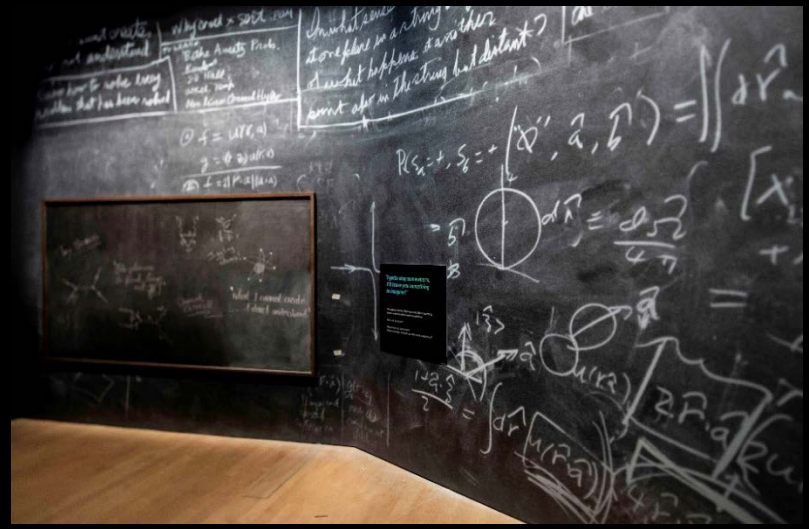
New Type of Pulsar,
1993 Nobel Prize in Physics

INTERACTIVE STATIONS

The in-gallery educational components of *All Possible Paths* primarily take the form of a series of interactive stations which offer an entry level to cater to the varied background of visitors.

Particle Physics Brick by Brick

Feynman Pinball Machine



Feynman's last blackboard

ESSAYS

As part of the exhibition, Feynman's friends and colleagues contributed essays to share their memories of him.

11 essays in total can be made available as printouts in the exhibition space or as downloadable files from the exhibition website.

ARTSCIENCE MUSEUM™ PRESENTS

ALL POSSIBLE PATHS

RICHARD FEYNMAN'S CURIOUS LIFE

Freeman J. Dyson
Institute for Advanced Study, Princeton, New Jersey

This Side Idolatry

Foreword to: "The Pleasure of Finding Things Out: The Best Short Works of Richard Feynman" edited by Jeffrey Robbins

"I did love the man this side idolatry as much as any", wrote the Elizabethan dramatist Ben Jonson. "The man" was Jonson's friend and mentor William Shakespeare. Jonson and Shakespeare were both successful playwrights. Jonson was learned and scholarly, Shakespeare was slapdash and a genius. There was no jealousy between them. Shakespeare was nine years older, already filling the London stage with masterpieces before Jonson began to write. Shakespeare was, as Jonson said, "honest and of an open and free nature", and gave his young friend practical help as well as encouragement. The most important help that Shakespeare gave was to act one of the leading roles in Jonson's first play, "Every Man in his Humour", when it was performed in 1598. The play was a resounding success and launched Jonson's professional career. Jonson was then aged 25, Shakespeare 34. After 1598, Jonson continued to write poems and plays, and many of his plays were performed by Shakespeare's company. Jonson became famous in his own right as a poet and scholar, and at the end of his life he was honored with burial in Westminster Abbey. But he never forgot his debt to his old friend. When Shakespeare died, Jonson wrote a poem, "To the Memory of my Beloved Master, William Shakespeare", containing the well-known lines:

> "He was not of an age, but for all time."
>
> "Nature herself was proud of his designs,
> And joyed to wear the dressing of his lines, ...
> Yet I must not give Nature all: Thy art,
> My gentle Shakespeare, must enjoy a part.
> For though the poet's matter nature be,
> His art doth give the fashion; and, that he
> Who casts to write a living line, must sweat, ...
> For a good poet's made, as well as born."

What have Jonson and Shakespeare to do with Richard Feynman? Simply this. I can say as Jonson said, "I did love the man this side idolatry as much as any". Fate gave me the tremendous luck to have Feynman as a mentor. I was the learned and scholarly student who came from England to Cornell University in 1947 and was immediately entranced by the slapdash genius of Feynman. With the arrogance of youth, I decided that I could play Jonson to Feynman's Shakespeare. I had not expected to meet Shakespeare on American soil, but I had no difficulty in recognising him when I saw him.

Before I met Feynman, I had published a number of mathematical papers, full of clever tricks but totally lacking in importance. When I met Feynman, I knew at once that I had entered another world. He was not interested in publishing pretty papers. He was struggling, more intensely than I had ever seen anyone struggle, to understand the workings of nature by rebuilding physics from the bottom up. I was lucky to meet him near the end of his eight-year struggle. The new physics that he had imagined as a student of John Wheeler seven years earlier was finally coalescing into a coherent vision of nature, the vision that he called "the space-time approach". The vision was in 1947 still unfinished, full of loose ends and inconsistencies, but I saw at once that it had to be right. I seized every opportunity to listen to Feynman talk, to learn to swim in the deluge of his ideas. He loved to talk, and he welcomed me as a listener. So we became friends for life.

For a year I watched as Feynman perfected his way of describing nature with pictures and diagrams, until he had tied down the loose ends and removed the inconsistencies. Then he began to calculate numbers, using his diagrams as a guide. With astonishing speed he was able to calculate physical quantities that could be compared directly with experiment. The experiments agreed with his numbers. In the summer of 1948 we could see Jonson's words coming true: "Nature herself was proud of his designs, and joyed to wear the dressing of his lines".

During the same year when I was walking and talking with Feynman, I was also studying the work of the physicists Schwinger and Tomonaga who were following more conventional paths and arriving at similar results. Schwinger and Tomonaga had independently succeeded, using more laborious and complicated methods, in calculating the same quantities that Feynman could derive directly from his diagrams. Schwinger and Tomonaga did not rebuild physics. They took physics as they found it, and only introduced new mathematical methods to extract numbers from the physics. When it became clear that the results of their calculations agreed with Feynman, I knew that I had been given a unique opportunity to bring the three theories together. I wrote a paper with the title "The Radiation Theories of Tomonaga, Schwinger and Feynman", explaining why the theories looked different but were fundamentally the same. My paper was published in the Physical Review in 1949, and launched my professional career as decisively as "Every Man in his Humour" launched Jonson's. I was then, like Jonson, 25 years old. Feynman was 31, three years younger than Shakespeare had been in 1598. I was careful to treat my three protagonists with equal dignity and respect, but I knew in my heart that Feynman was the greatest of the three and that the main purpose of my paper was to make his revolutionary ideas accessible to physicists around the world. Feynman actively encouraged me to publish his ideas, and never once complained that I was stealing his thunder. He was the chief actor in my play.

One of the treasured possessions that I brought from England to America was "The Essential Shakespeare" by J. Dover Wilson, a short biography of Shakespeare containing most of the quotations from Jonson that I have reproduced here. Wilson's book is neither a work of fiction nor a work of history, but something in between. It is based on the first-hand testimony of Jonson and others, but Wilson used his imagination together with the scanty historical documents to bring Shakespeare to life. In particular, the earliest evidence that Shakespeare acted in Jonson's play comes from a document dated 1709, more than a hundred years after the event. We know that Shakespeare was famous as an actor as well as a writer, and I see no reason to doubt the traditional story as Wilson tells it.

Luckily, the documents that provide evidence of Feynman's life and thoughts are not so scanty. The present volume *[The Pleasure of Finding Things Out: The Best Short Works of Richard Feynman]* is a collection of such documents, giving us the authentic voice of Feynman recorded in his lectures and occasional writings. These documents are informal, addressed to general audiences rather than to his scientific colleagues. In them we see Feynman as he was, always playing with ideas but always serious about the things that mattered to him. The things that mattered were honesty, independence, willingness to admit ignorance. He detested hierarchy and enjoyed the friendship of people in all walks of life. He was, like Shakespeare, an actor with a talent for comedy.

Besides his transcendent passion for science, Feynman had also a robust appetite for ordinary human pleasures. A week after I first got to know him, I wrote a letter to my parents in England describing him as "half genius and half buffoon". Between his heroic struggles to understand the laws of nature, he loved to relax, to play his bongo drums, to entertain everybody with jokes and tricks and stories. In this too he resembled Shakespeare. Out of Wilson's book I take the testimony of Jonson:

"When he hath sat himself to writing, he would join night to day; press upon himself without release, not minding it till he failed: and when he left off, remove himself into all sports and looseness again; that it was almost a despair to draw him to his book: but once got to it, he grew stronger and more earnest by the ease".

ArtScience Museum
MARINA BAY SANDS

EXHIBITION DETAILS

Tour dates:	**Available from June 2019**
Size of exhibition:	**Approximately 800m2**
Target audience:	**Adults and young adults, science enthusiasts**
Hire fee or revenue share:	**Hire fee**
Hire fee (if appropriate):	**75,000 euro**
Minimum hire period:	**3 months minimum**

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