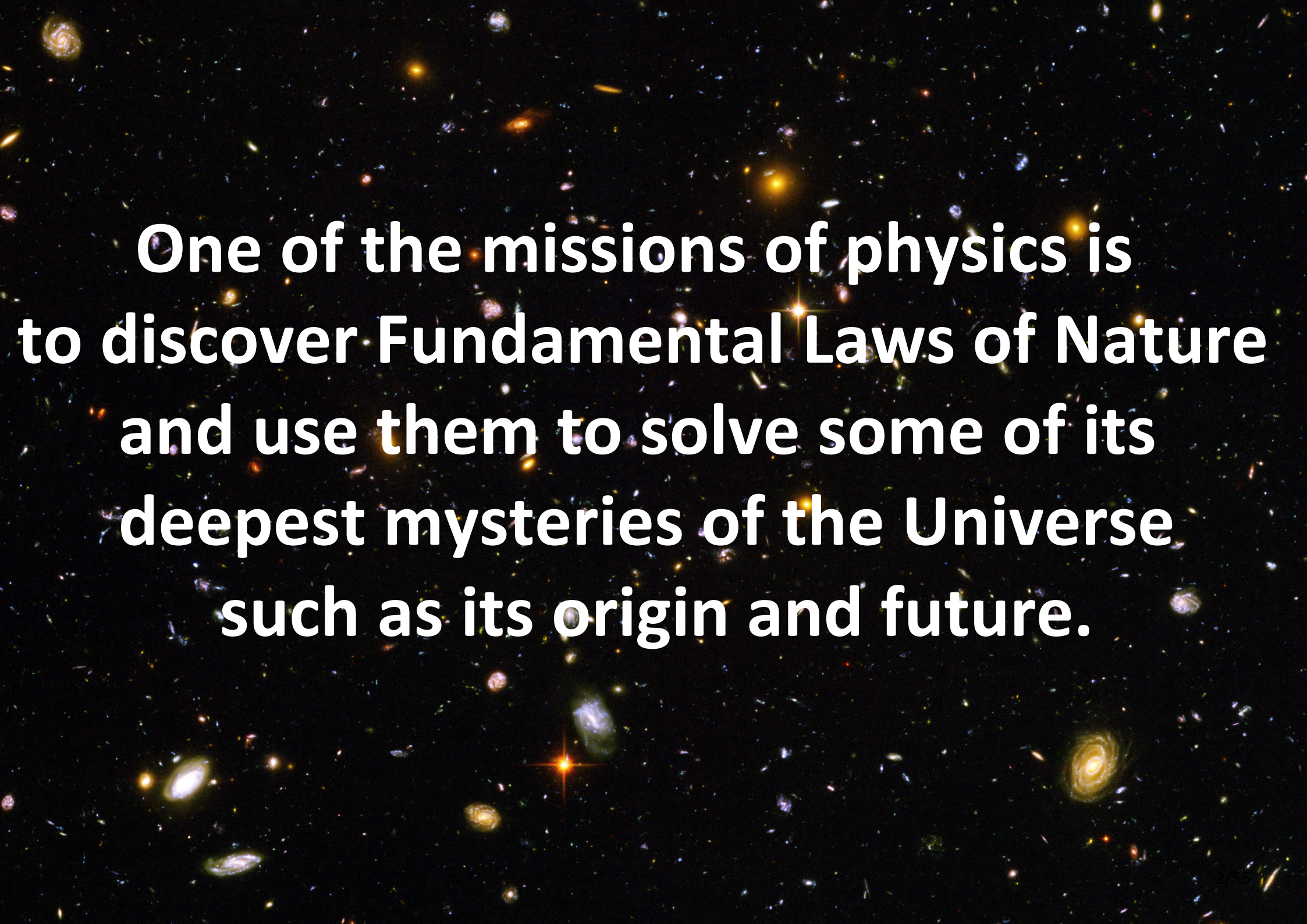


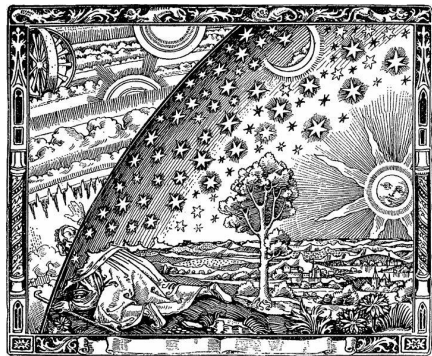
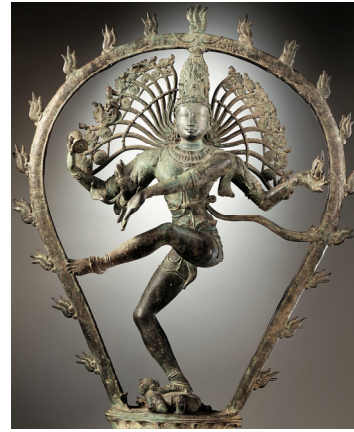
The Science of *The Man from the 9 Dimensions*

Hiroshi Ooguri

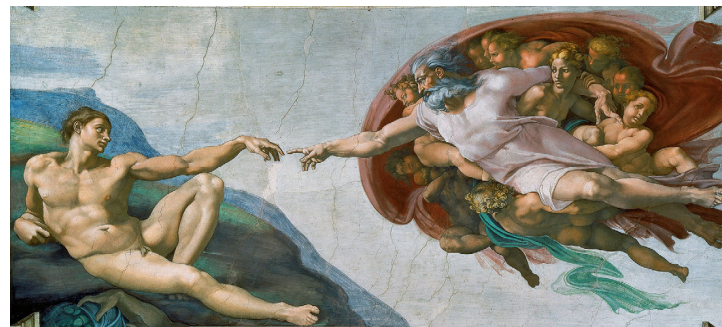
Twenty-eighth Arnold Sommerfeld Lectures
Ludwig Maximilian University of Munich / ESO Planetarium, Garching
30 June 2023

A deep field image of the universe, showing a vast field of galaxies in various colors (yellow, orange, blue, purple) and shapes (spiral, elliptical, irregular) against a dark background. The galaxies are scattered across the frame, with some appearing as bright, distinct objects and others as faint, distant points of light.

One of the missions of physics is to discover Fundamental Laws of Nature and use them to solve some of its deepest mysteries of the Universe such as its origin and future.



Since ancient times, humans have been interested in finding out how the Universe began, how it works, and what our place is in it.



Four centuries ago, Galileo Galilei pointed his telescope at a night sky and opened a new window to the Universe. This initiated the scientific revolution and enabled us to address some of mysteries of the Universe by the scientific method.

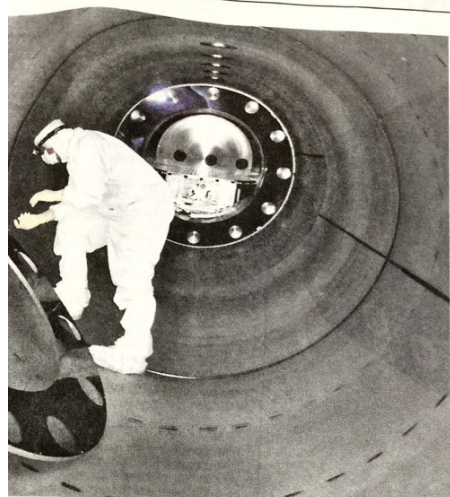


Starry Messenger
published on 13 March 1610

We have made remarkable success in deciphering the Universe over the last 400 years, and the progress is continuing strongly.

New York Times

FRIDAY, FEBRUARY 12, 2016



CALTECH-MIT LIGO LABORATORY

Interferometer Gravitational-Wave Observatory in Hanford, Wash.

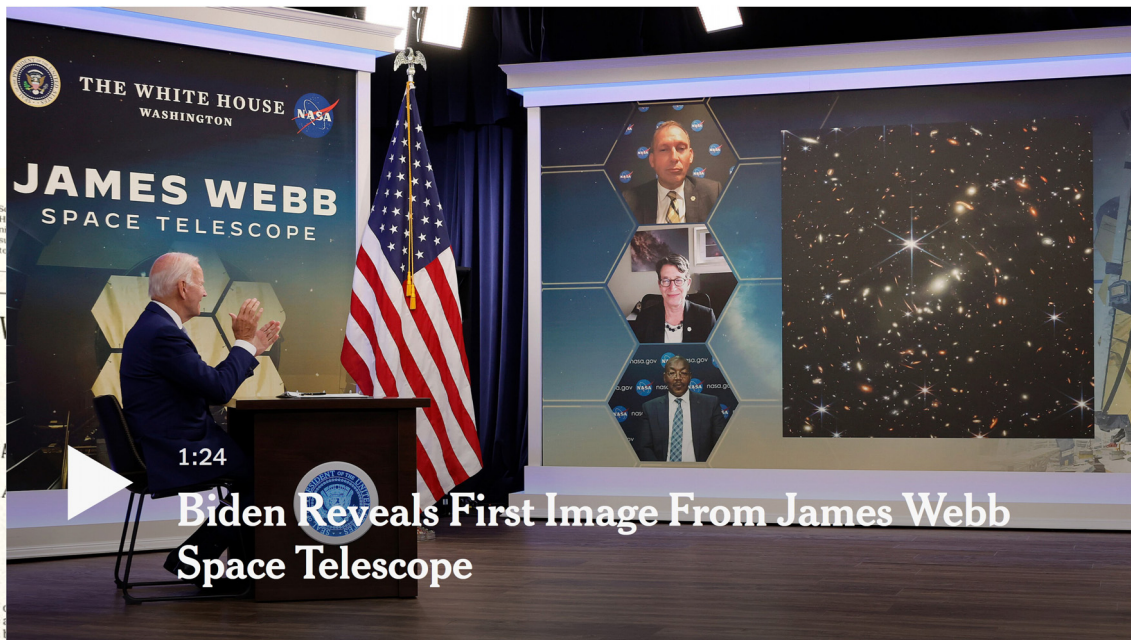
Notice Sanders

candidate she barely knew. "It makes me feel good," she said, chucking, "that young people are listening to the elderly people." She now said she was an undecided voter and planned to do some homework on Mr. Sanders.

Last Occupier In Rural Oregon Is Coaxed Out

This article is by Dave Semnara, Richard Pérez-Peña and Kirk Johnson.

PRINCETON, Ore. — They in-



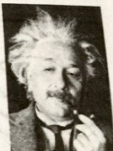
THE WHITE HOUSE WASHINGTON NASA

JAMES WEBB SPACE TELESCOPE

1:24

Biden Reveals First Image From James Webb Space Telescope

Eight-years away, a fleeting chirp that fulfilled the last prediction of Einstein's general theory of relativity. That faint rising tone, physicists say, is the first direct evidence of gravitational waves, the ripples in the fabric of space-time that Einstein predicted a century ago. It completes his vision of a universe in which space and time are interwoven and dynamic, able to stretch, shrink and jiggle. And it is a ringing confirmation of the nature of black holes, the bottomless gravitational pits from which not even light can escape, which were the most foreboding (and unwelcome) part of his theory. More generally, it means that a century of innovation, testing, questioning and plain hard work



Frankfurter Allgemeine

ZEITUNG FÜR DEUTSCHLAND

VERBANDSGESAMEN VON WENDEL GÖNKA, BERTRAND BÜHLER, DÜSTERER HÖCHENHEIMER, FRANK SCHREIBERMEIER, BILGISE STREITNER

Ganz früher war alles besser

Versprechen

Recht auf Einmischung

Best wishes! Peter Higgs

New York Times

Late Edition Today, sunny to partly cloudy, rather hot, high 82. Tonight, mostly clear, low 72. Tomorrow, mostly sunny, hot and humid, high 86. Weather map appears on Page B16.

PHYSICISTS FIND ELUSIVE PARTICLE SEEN AS KEY TO UNIVERSE

重力波を初観測

米研究チーム発表

100年前にアインシュタインが存在を予言し、世界の研究が電線を目標にしていた「重力波」について、米国の研究チームが11日、初の観測に成功した。最終的に確認されれば理論が実証されたこととなり、物理の歴史的な成果となる。光や電波ではわからない宇宙の姿を新たな天文観測にも活用する。

重力波は、時間や空間がわずかにゆがみ、時空のひずみ「がさ」が波のように伝わる現象。物体が加速して動くときに伝わるアインシュタインが1916年、一般相対性理論から予言していた。その観測は最後の宿願とされ、物理学の長年悲願でもあった。

重力波はあらゆる運動で生じるとされるが、極めて微弱で通常は観測できない。このため、星の合体などで生じた大きな重力波をとらえることになる。研究チームは米国のワシントンにある装置「LIGO」の性能を大幅に高めた。昨年9月から今年1月上旬まで観測、分析作業を進めていた。

発表によると、昨年9月11日、地球を3億3千万キロ離れた「2つのブラックホール」が衝突したとされた。重力波は十分に強度で検出できたとされている。物理学史上、この

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朝日新聞

2月12日 金曜日

号外

朝日新聞 朝日新聞 朝日新聞

連報も詳細もデジ

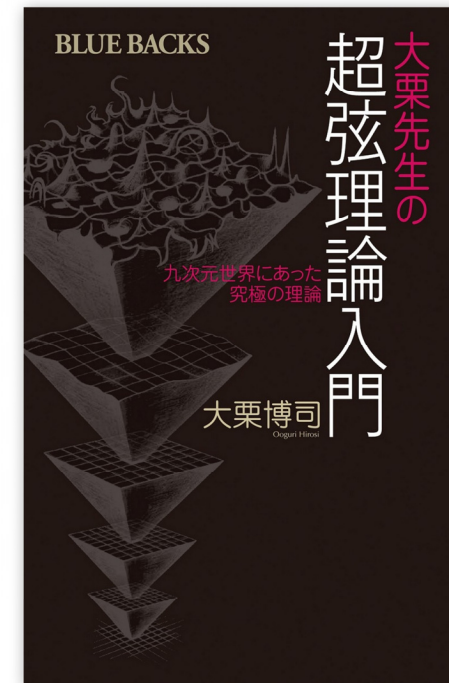
I have written 8 popular science books in Japanese to communicate some of recent excitements in this area.



"What is Gravity"



"Strong and Weak Forces"

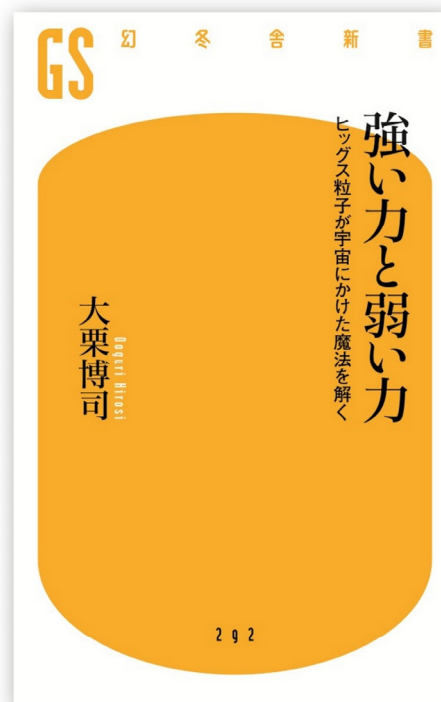


"Superstring Theory"

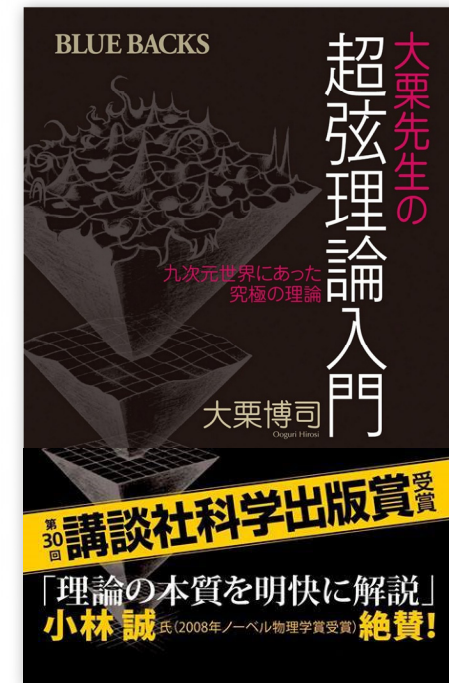
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"What is Gravity"



"Strong and Weak Forces"



"Superstring Theory"

2014
Kodansha
Prize for
Science Book

Sold over 300,000 copies in Japan.
Translated into Chinese and Korean.

15 May 2013



We want to make
a 3D dome theater movie
based on your books.
Can you help us?



Dimitris Kontopolous
Science Communicator at Miraikan

Visual Image Wizard

"Professor"

Science Guy

"Assistant"

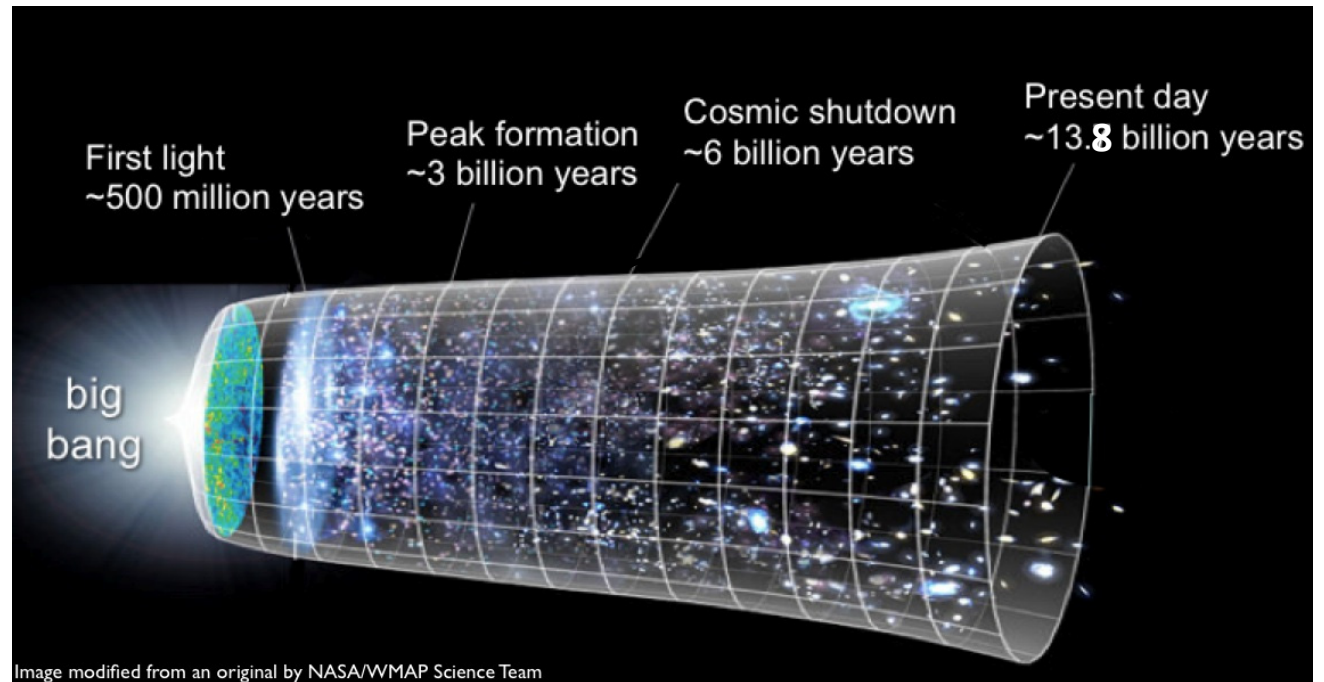
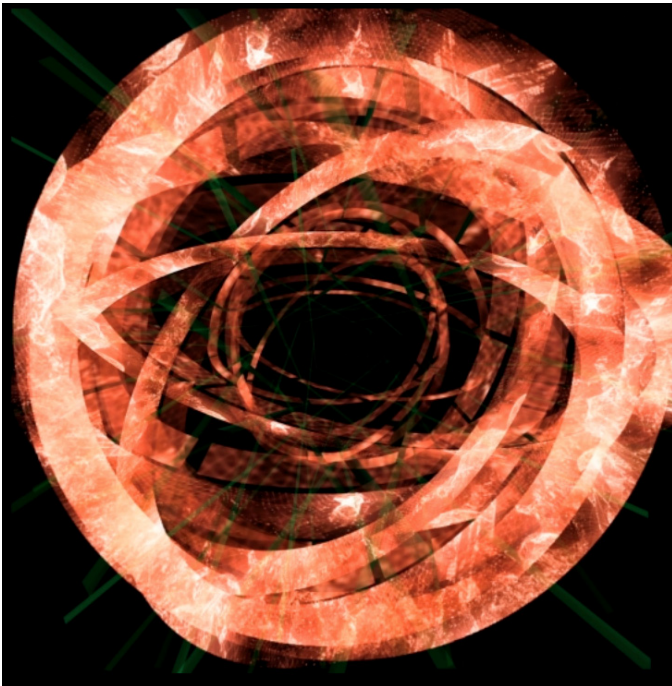
Horror Movie Director

**"The Man from the
9 Dimensions"**

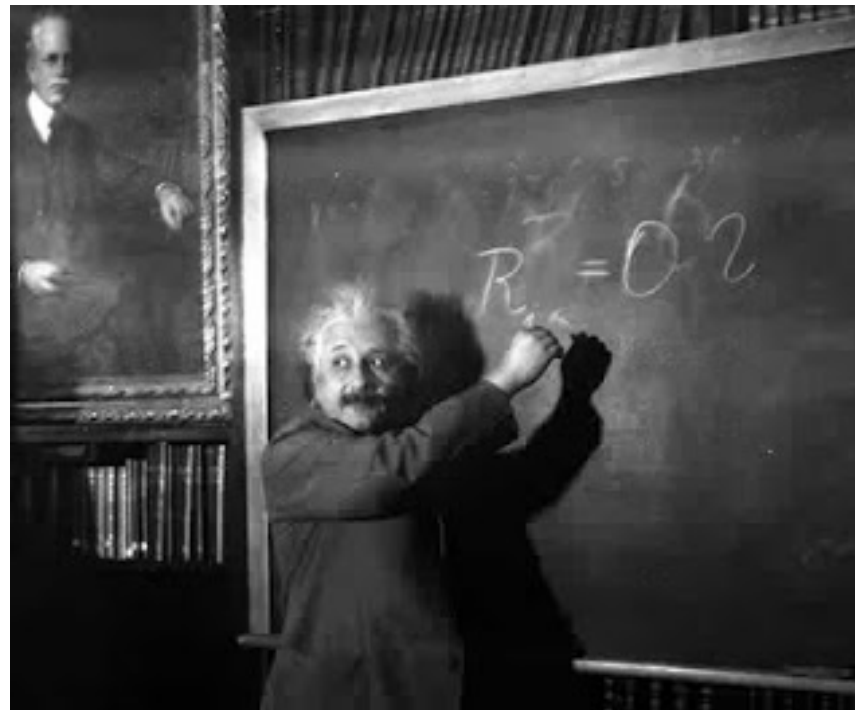


The Science of ***The Man from the 9 Dimensions***

The Universe was born 13.8 billion years ago.



1915: Einstein completed his theory of gravity. He applied it to the whole universe, found an expanding solution, and abandoned it.

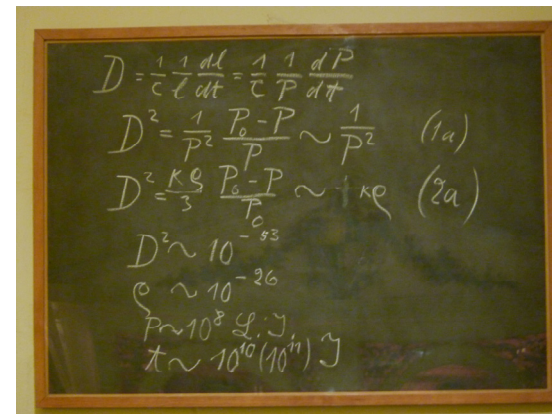


1915: Einstein completed his theory of gravity. He applied it to the whole universe, found an expanding solution, and abandoned it.

1929: Hubble at Mt. Wilson discovered that the universe is expanding.



Pasadena, 1931



Oxford, 1931

3 minutes after the birth:

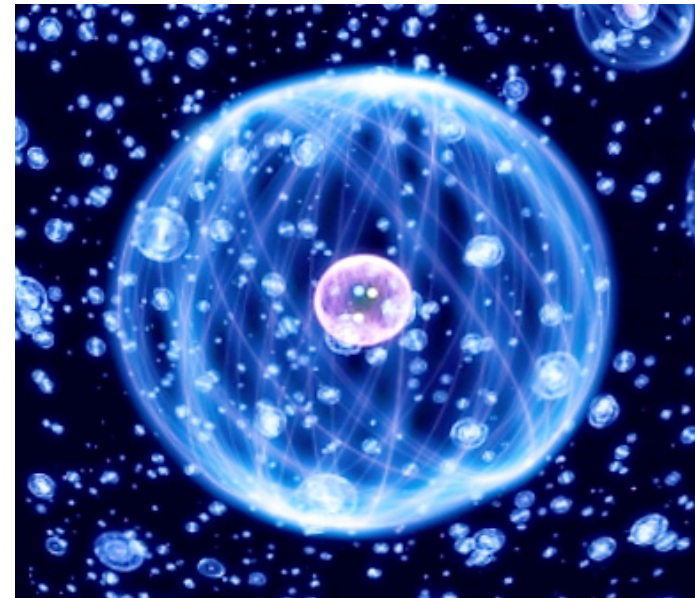
Protons and neutrons combined to make hydrogen and helium nuclei.

Theoretical calculations showed 12:1 ratio.

Precisely agreed with astrophysical observations.



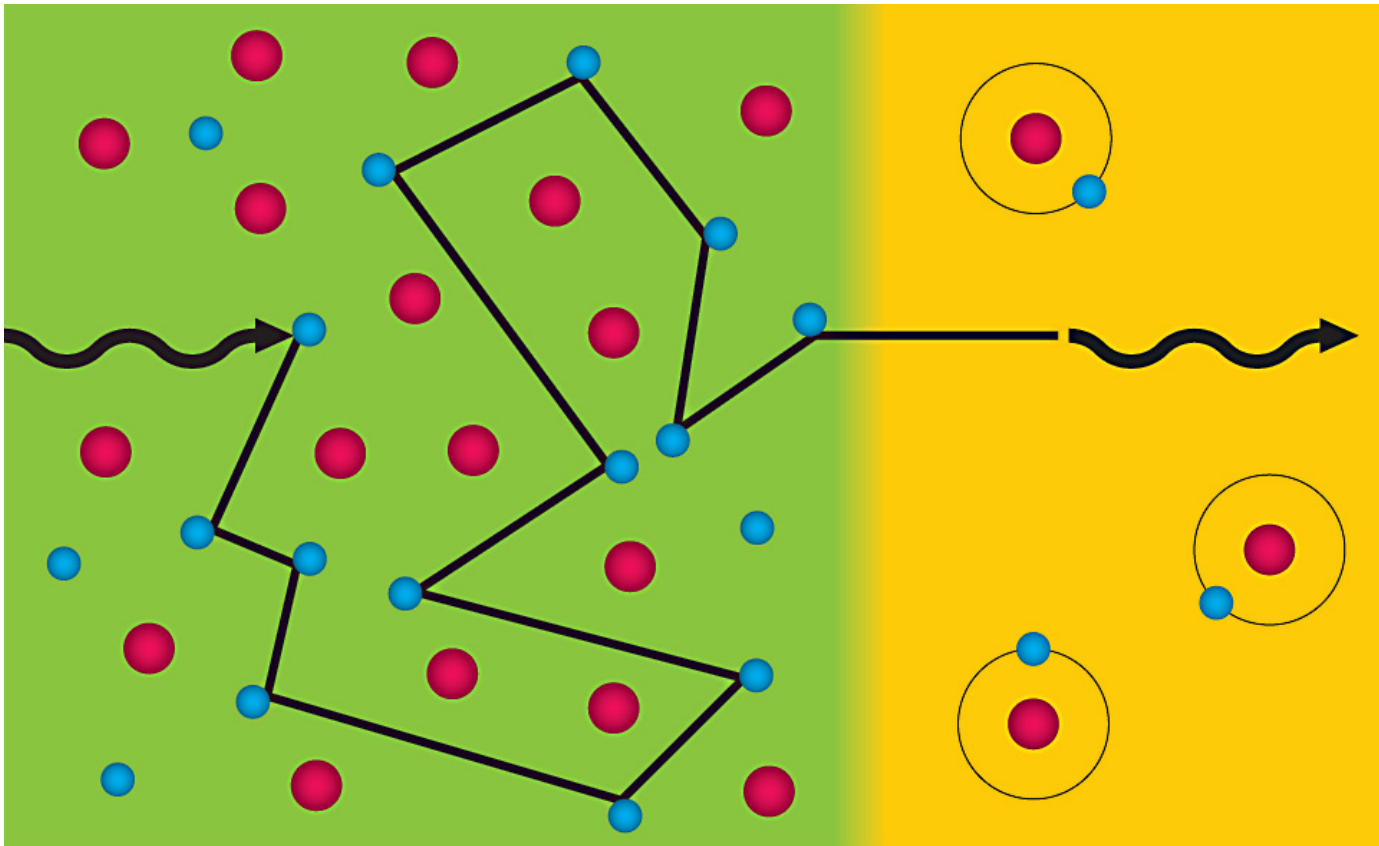
George Gamov, et al. (1948)



400,000 years after the birth:

Electrons and atomic nuclei combined to form neutral atoms.

The Universe became transparent.

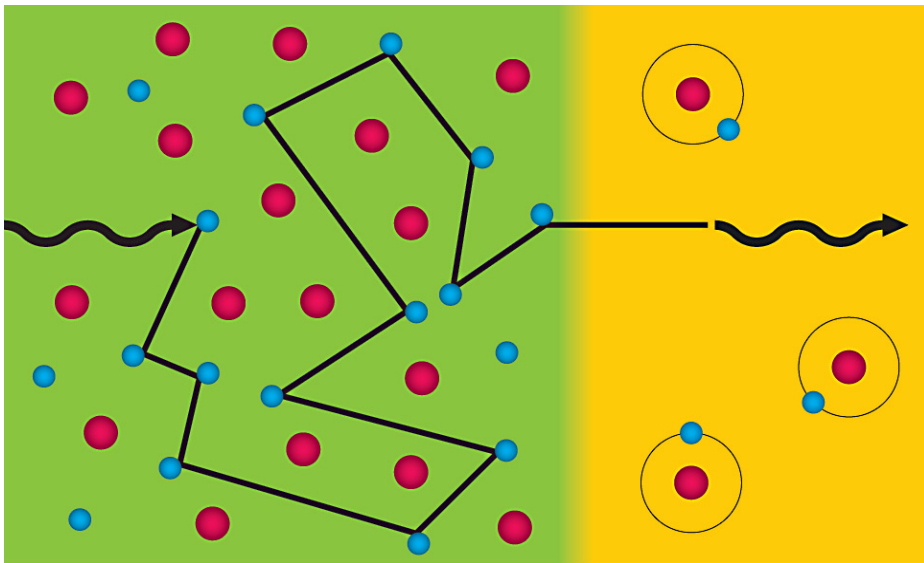


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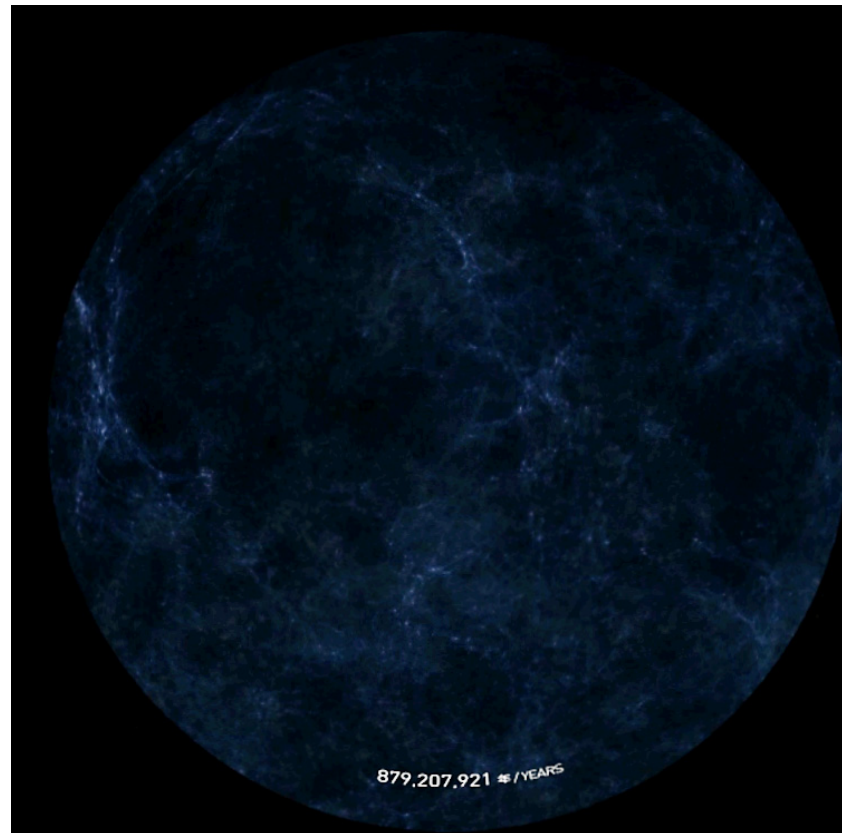
In 1964, Penzias and Wilson detected the primordial light.



Until 100,000,000 years later:

No new light had been emitted.
Stars and galaxies were still to be born.

Dark Age of the Universe



100,000,000 years later:

Atoms scattered by the Big Bang began to come together by gravity. Clumps began to form and became seeds for stars and galaxies.



100,000,000 years later:

The first star was born.



100,000,000 years later:

The New York Times

© 2022 The New York Times Company

NEW YORK, TUESDAY, JULY 12, 2022

Biden and NASA Share First Webb Space Telescope Image

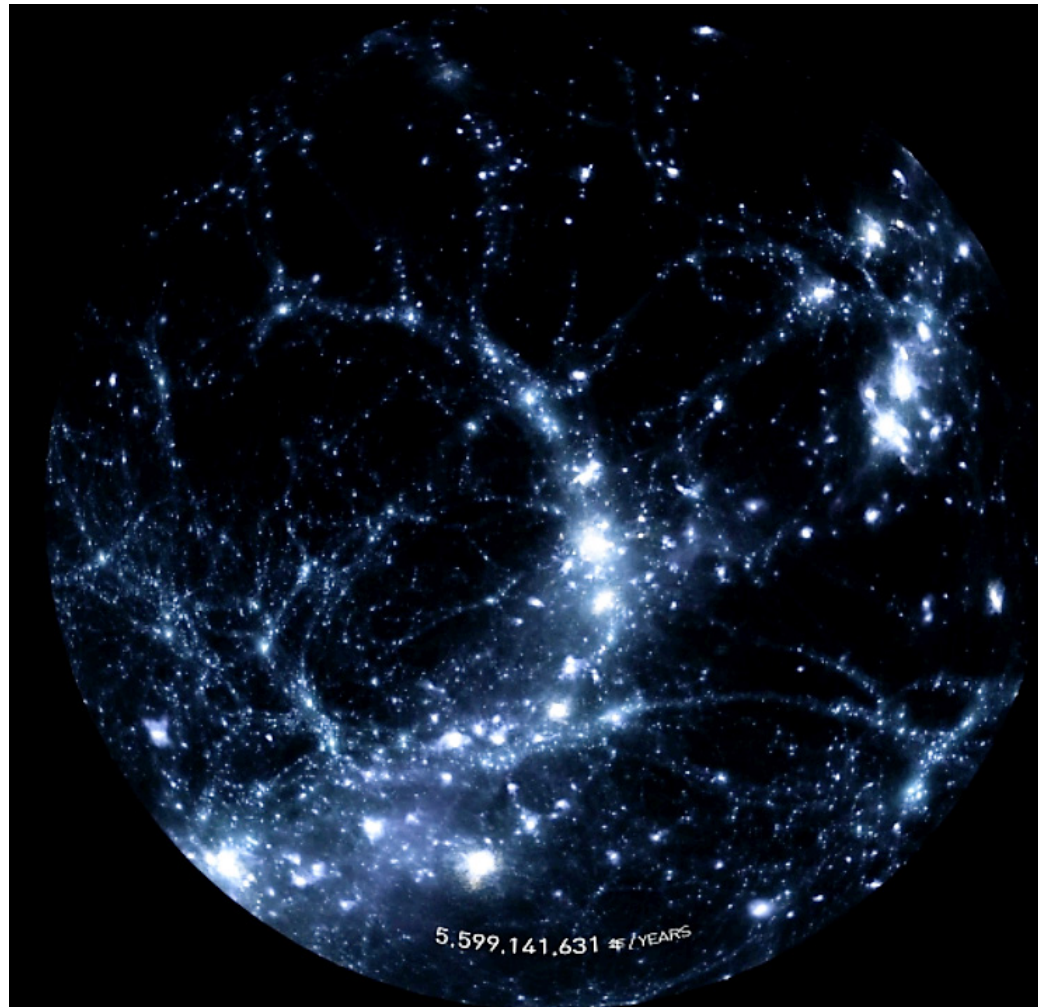
From the White House on Monday, humanity got its first glimpse of what the observatory in space has been seeing: a cluster of early galaxies.



The James Web Space Telescope enables us to see images of stars born 13 billion years ago.

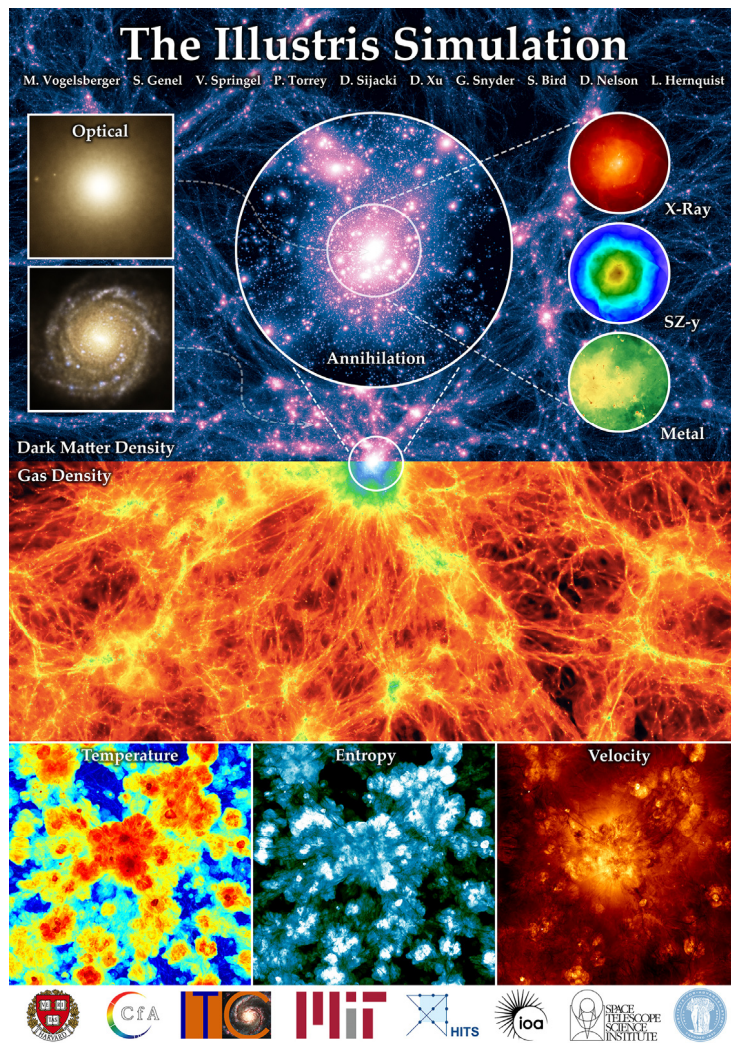
1,000,000,000 years later:

Galaxies started forming.



1,000,000,000 years later:

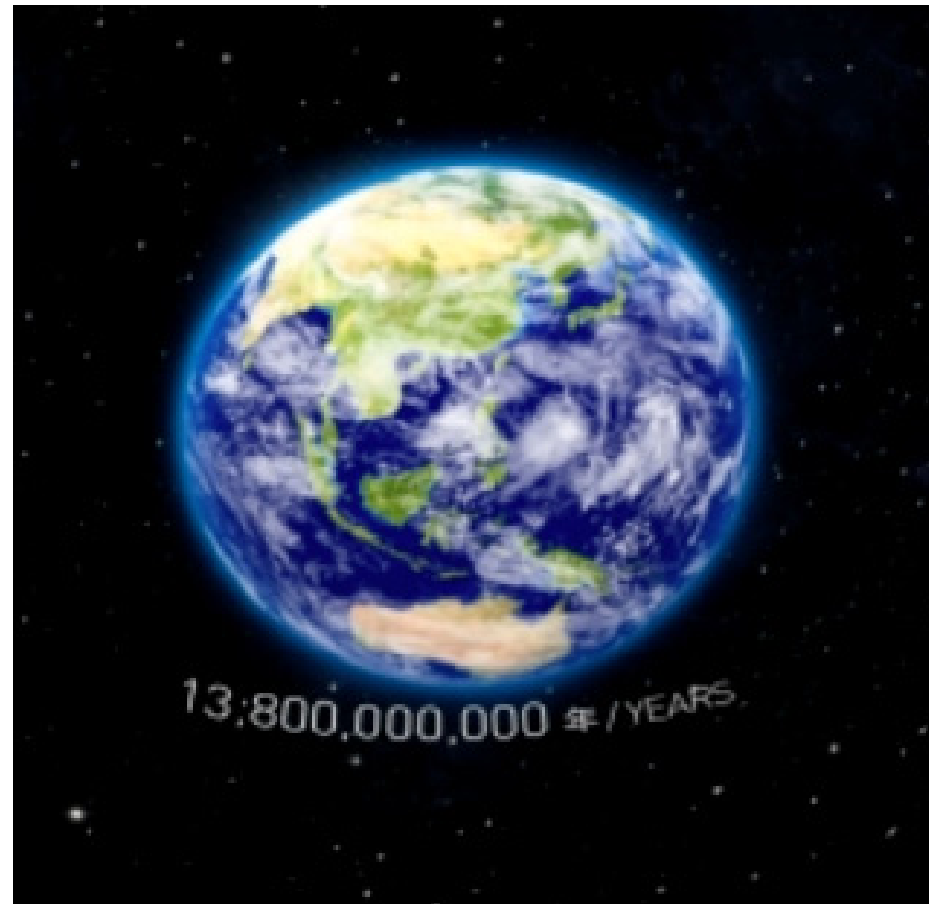
Galaxies started forming.



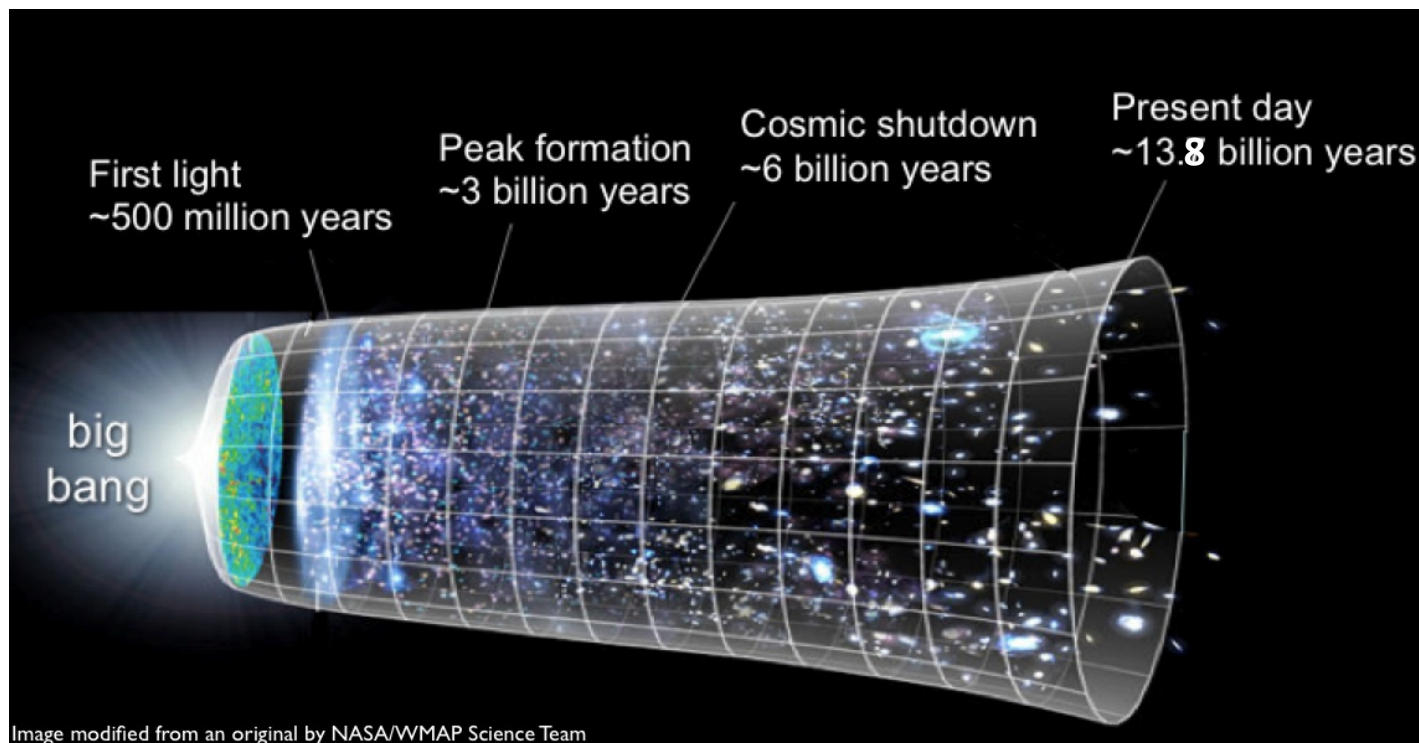
To show an accurate picture of the evolution of the Universe, we worked with the *Illustris Project*, a cosmological simulation of galaxy formation using a state of the art numerical code.

9,000,000,000 years later:

The Sun and the Earth formed.



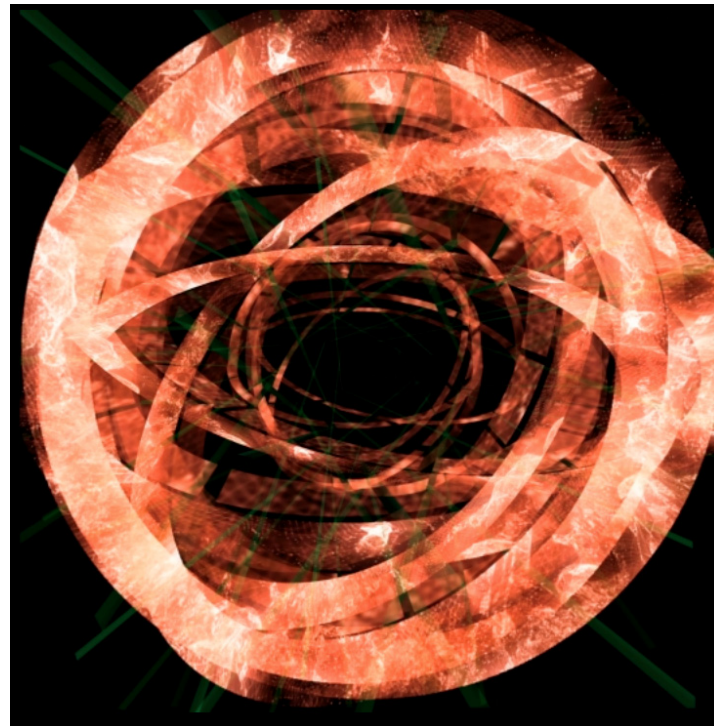
The Universe gave us home on this beautiful planet and 3.5 billion years to evolve from microbes to homo sapiens intelligent enough to ask: "How does the Universe work?"



A deep field image of the universe, showing a vast field of galaxies and stars against a black background. The galaxies are of various colors, including yellow, orange, blue, and purple, and are scattered across the frame. Some are bright and clear, while others are faint and distant. The stars are also scattered, with some appearing as bright points of light and others as smaller, dimmer dots. The overall scene is a rich and diverse representation of the universe's structure and composition.

**Why is the Universe the way it is?
How did it come to existence?**

Let us go back to the Big Bang.



3 minutes after the birth:

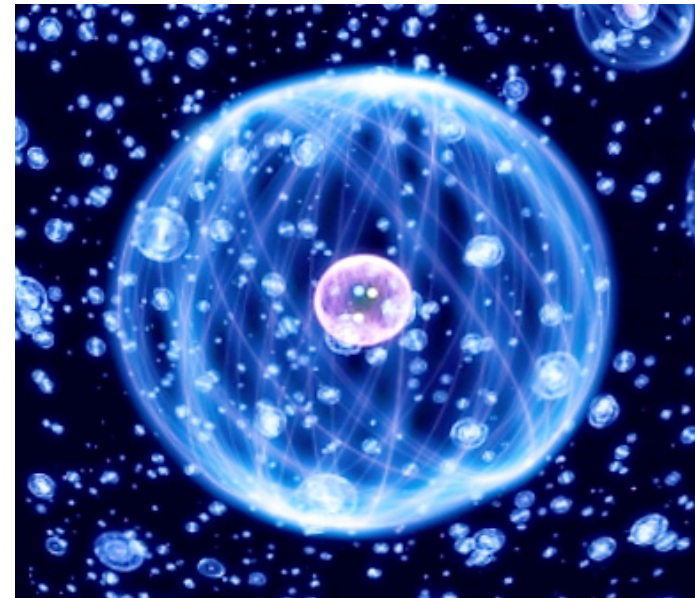
Protons and neutrons combine to make hydrogen and helium nuclei.

Theoretical calculations showed 12:1 ratio.

Precisely agreed with astrophysical observations.



George Gamov, et al. (1948)



Until 0.0001 seconds after the birth:

Protons and neutrons were
broken apart into quarks



Until 0.000000000001 seconds after the birth:

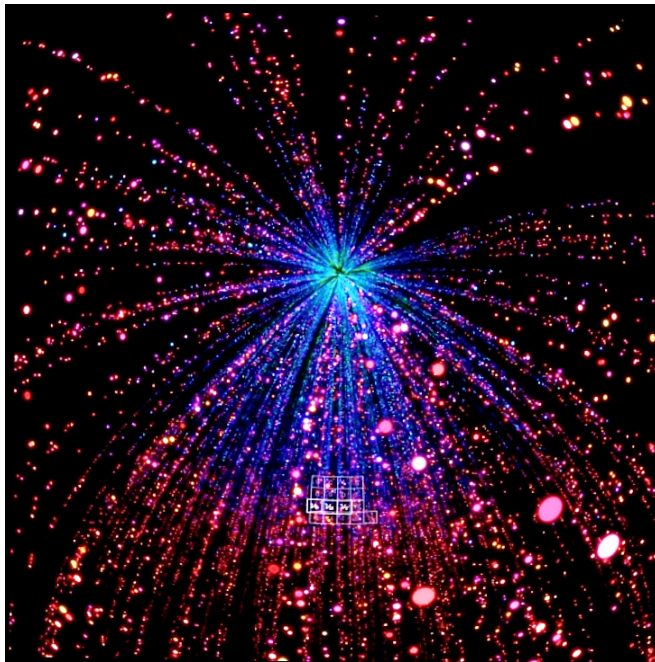
The Universe can be accurately described by the Standard Model of Particle Physics.



The Standard Model represents our best understanding of the microscopic world, verified by experiments.

Until 0.0000000000001 seconds after the birth:

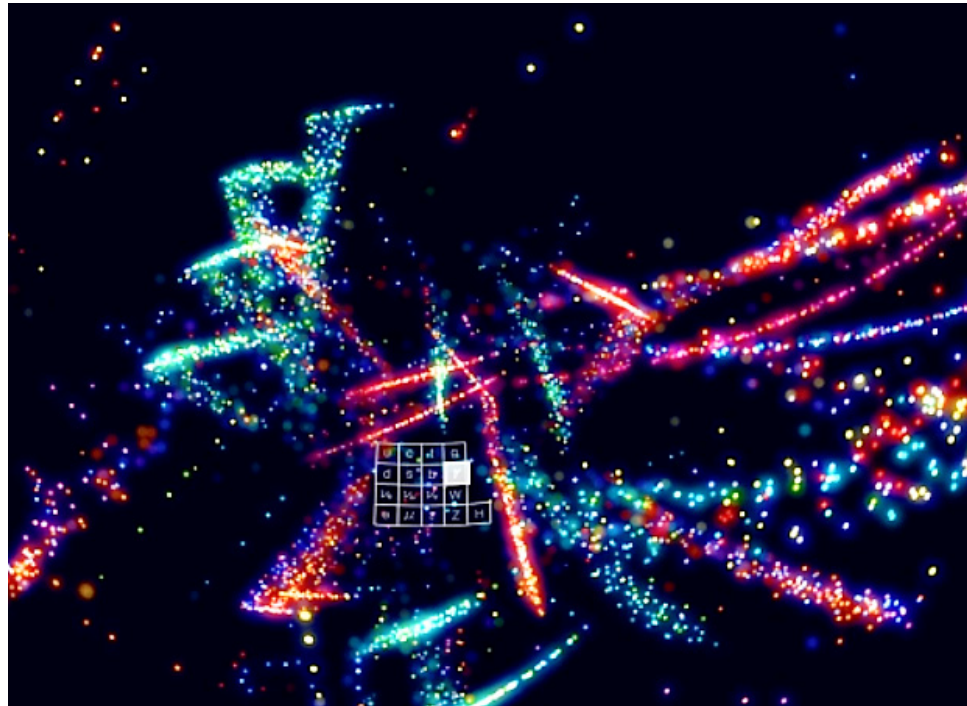
The Universe can be accurately described by the Standard Model of Particle Physics.



Neutrinos [ν] change their flavors as they fly.
(Neutrino Oscillation)

Until 0.000000000001 seconds after the birth:

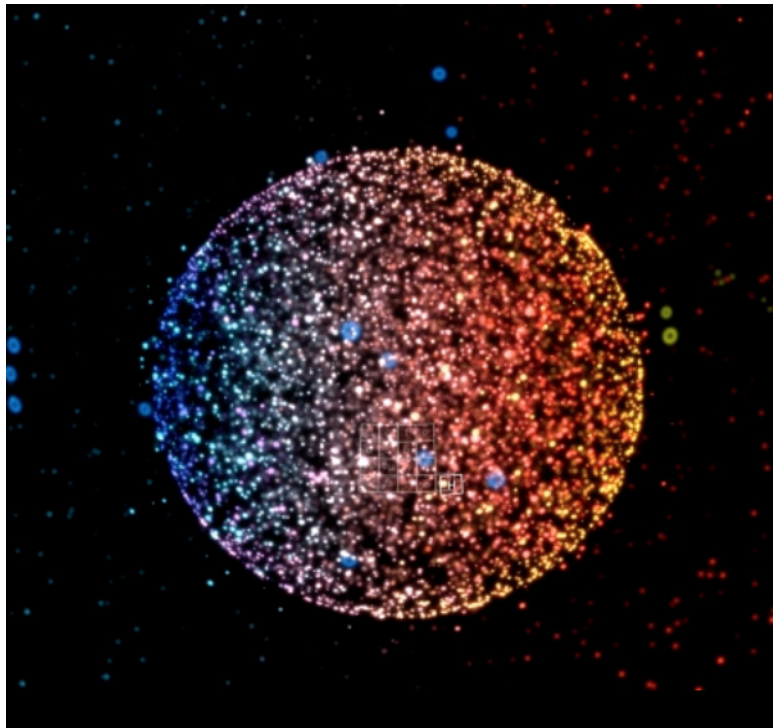
The Universe can be accurately described by the Standard Model of Particle Physics.



Photons [γ] mediates electric and magnetic forces.

Until 0.000000000001 seconds after the birth:

The Universe can be accurately described by the Standard Model of Particle Physics.



The Higgs particle [H] gives masses to elementary particles.



Until 0.000000000001 seconds after the birth:

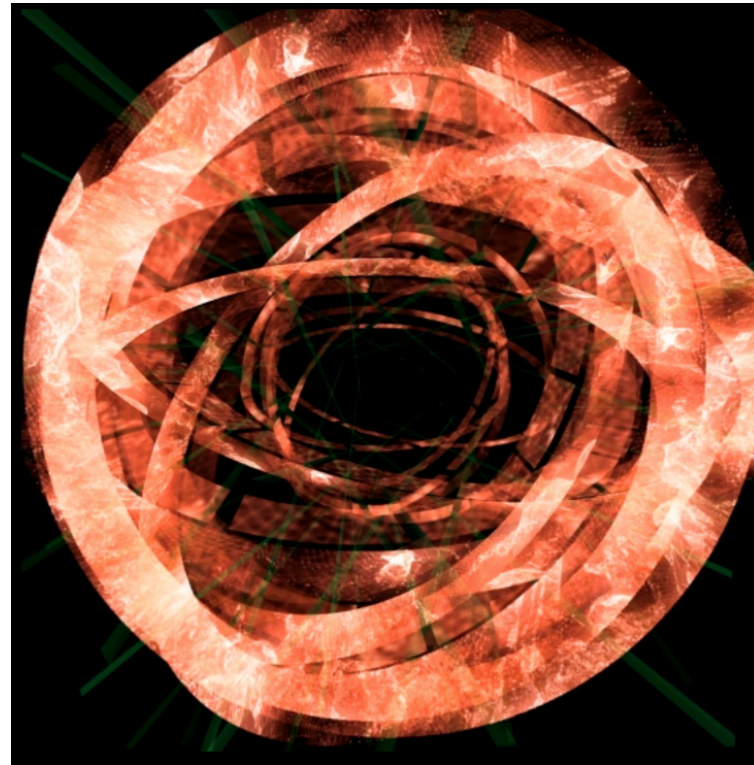
The Universe can be accurately described by the Standard Model of Particle Physics.



How was the Universe like before 0.000000000001 seconds of its birth?

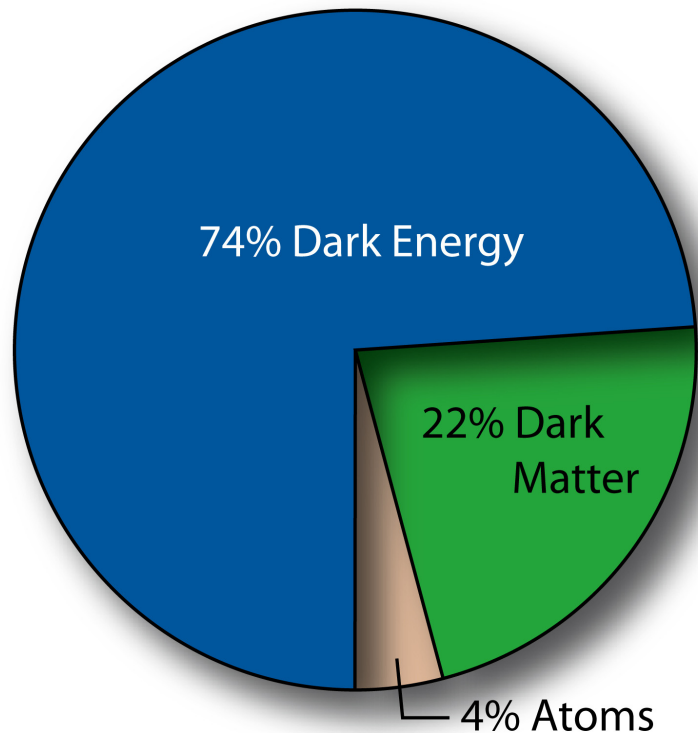
How was the Universe like before 0.000000000001 seconds of its birth?

To answer this question, we need a more fundamental theory that goes beyond the Standard Model.



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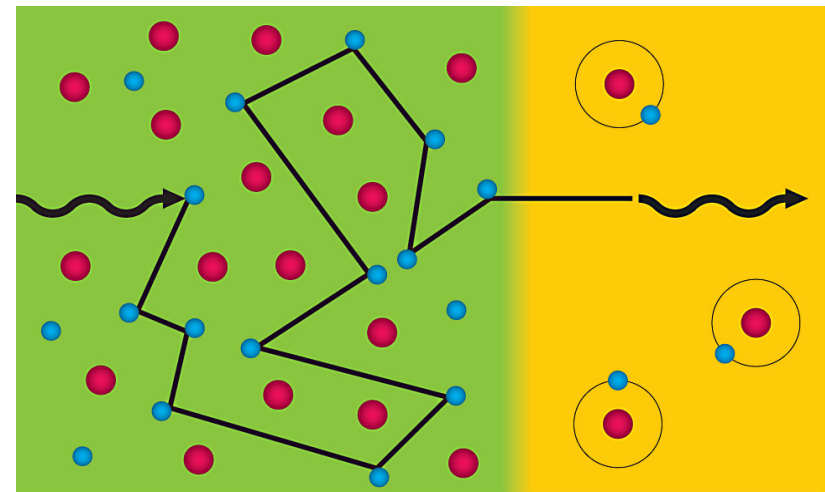


In fact, the Standard Model can explain only 4% of the Universe.



February 1985
Kyoto, Japan

Stephen Hawking (1942 - 2018)
and his collaborators predicted
that the quantum fluctuations
of forces, matter, and space-time
in the early universe can be
observed in the primordial light.



LIGO's detection of gravitational waves opened a new window to the Universe. Gravitational waves may also help us solve mysteries of the early Universe.

New York Times
FRIDAY, FEBRUARY 12, 2016

National Edition
Southern California

2017 NOBEL PRIZE IN PHYSICS

**Rainer Weiss
Barry C. Barish
Kip S. Thorne**

"for decisive contributions to the LIGO detector and the observation of gravitational waves"

Interferometer Gravitational-Wave Observatory in Hanford.

Notice Sanders
candidate she barely knew. "It makes me feel good," she said, chuckling, "that young people are listening to the elderly people." She now said she was an undecided voter and planned to do some homework on Mr. Sanders.

**Last Occupie
In Rural Oregon
Is Coaxed Out**
This article is by Dave Semina, Richard Pérez-Peña and Kirk Johnson.
PRINCETON Ore. — They im

ational pits from which not even light can escape, which were the most foreboding (and unwelcome) part of his theory. More generally, it means that a century of innovation, testing, questioning and plain hard work

Today's News:

New way to detect gravitational waves by observing lights from pulsars

The New York Times

The Cosmos Is Thrumming With Gravitational Waves, Astronomers Find

Radio telescopes around the world picked up a telltale hum reverberating across the cosmos, most likely from supermassive black holes merging in the early universe.

Give this article



The Very Large Array on the Plains of San Agustine that worked with a global consortium to detect the

nature

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nature > news > article

NEWS | 29 June 2023

Monster gravitational waves spotted for first time

Using beacon stars called pulsars, a decades-long effort has found space-time ripples that are light-years-wide.

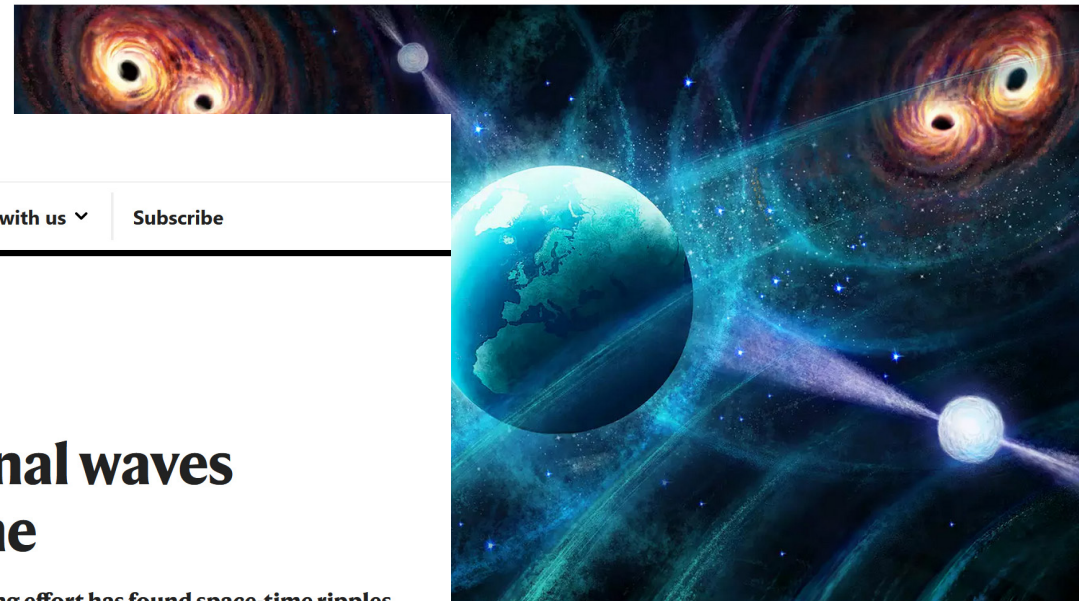
A new access to the universe

Precise as a clock: pulsars in the Milky Way form large-scale observatory for gravitational waves

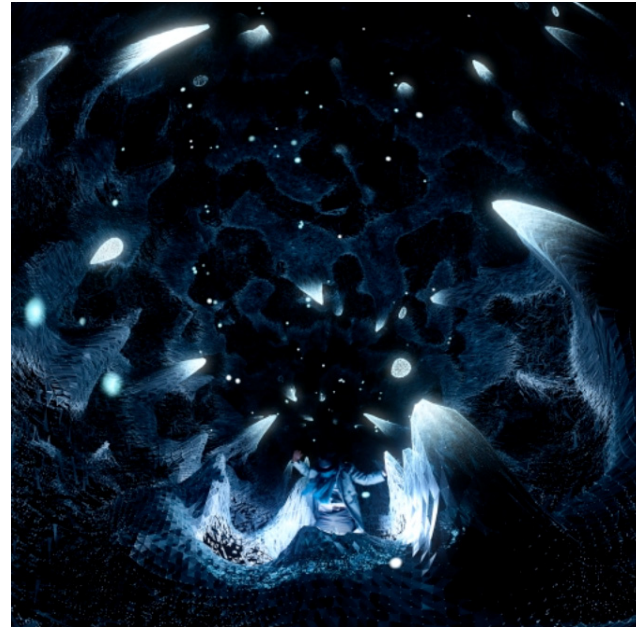
JUNE 29, 2023

Astronomy Astrophysics Black Holes Galaxies Gravitational Waves

Astronomical observatories are usually based on Earth and study the extreme processes in the universe by capturing light as an information carrier. But not all processes in the universe produce light. For example, when galaxies merge and black holes orbit each other, they cause ripples in space-time. To make such gravitational waves measurable, astronomers have used a trick. They observed the light of pulsars, a special class of stars. Together, these stars form an observatory that is almost as large as our Milky Way.



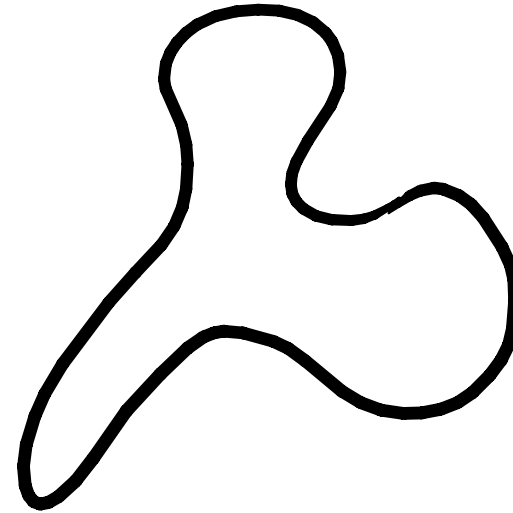
To understand the early Universe, we need a more fundamental theory that unifies the macroscopic world of gravity with the microscopic world of quantum mechanics.





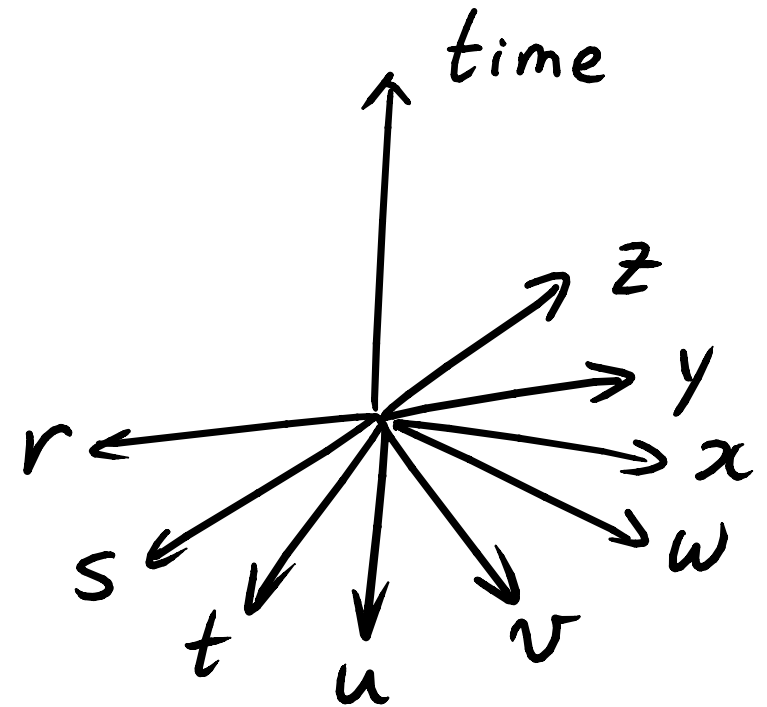
The only consistent way
we know how to do this is

Superstring Theory

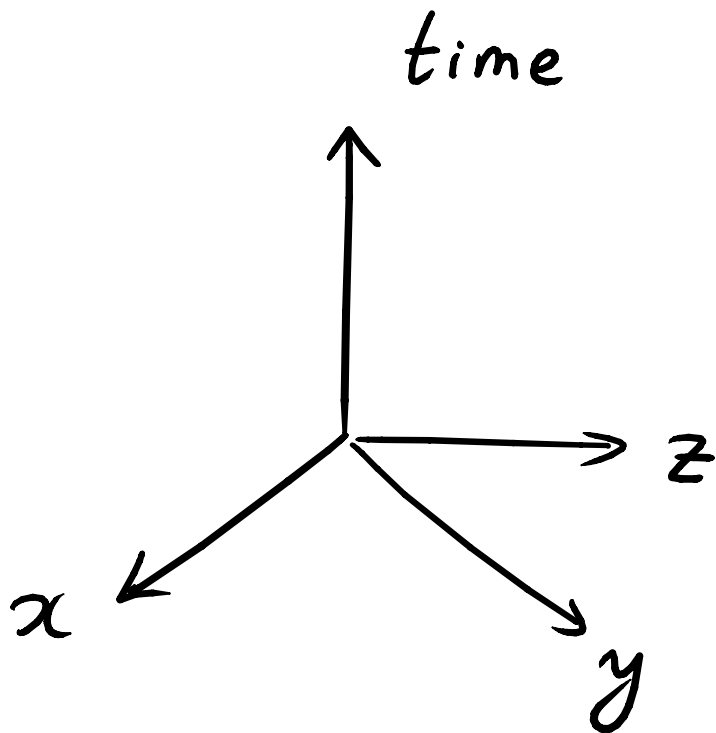


Superstring Theory postulates
fundamental building blocks are
not point particles but strings.

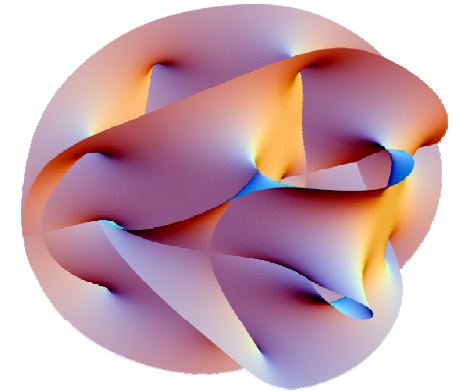
Superstring theory is defined in (9+1) spacetime dimensions.



We live in (3+1) dimensions.
At least we feel so.

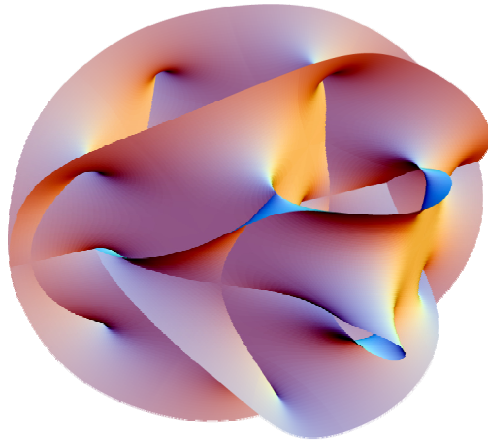


If the extra 6 dimension is a small compact **Calabi-Yau** manifold, it will not be visible to us directly.

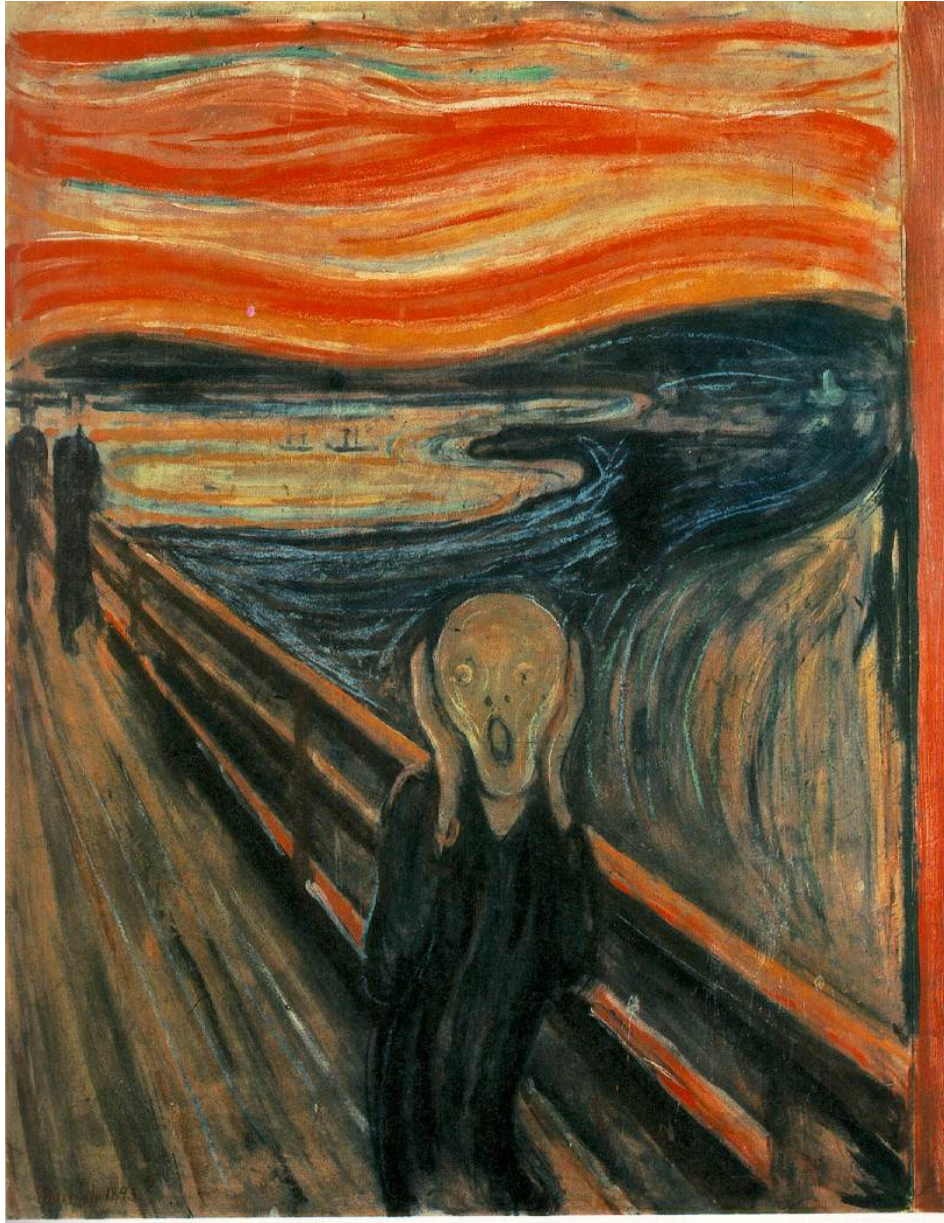


The rich structure in particle physics, such as 17 types of **elementary particles,** gauge **forces,** and **Higgs boson,** **emerges from Calabi-Yau geometry.**

We want to derive quantitative predictions on physics in (3+1) dimensions from the geometry of



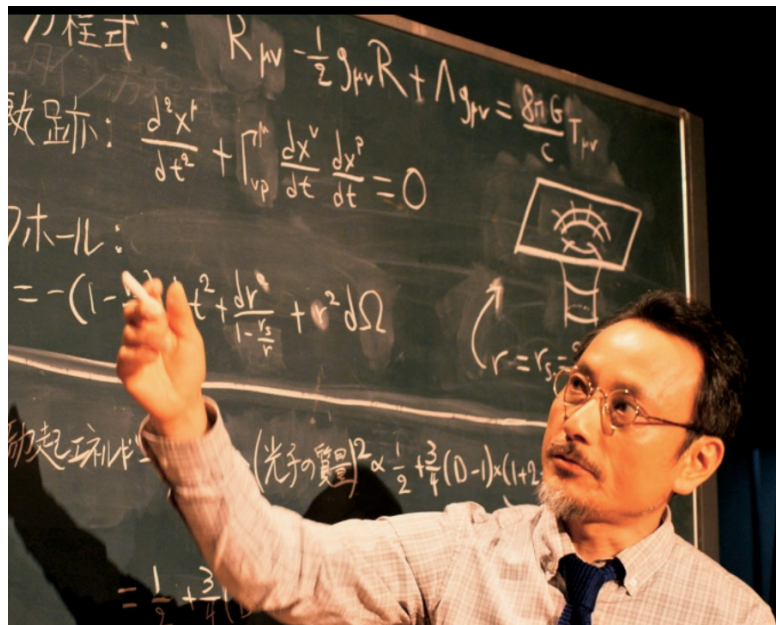
Calabi-Yau manifold



We do not even know
how to measure
distance between
two points on Calabi-Yau.

What can we do ?

Power of Mathematics



Everything is made up of *Strings*?

9次元からきた男

The Man from the 9 Dimensions

Scientific Advisor: **Hirosi Ooguri** Director: **Takashi Shimizu** ("The Grudge" "Kiki's Delivery Service")
Visual Director: **Synichi Yamamoto**

Cast: James Sutherland, Asahi Yoshida, Roza Tachibana, Tabito Okayasu Voice: Rikiya Koyama
Production, CG/VFX: OMNIBUS JAPAN Planning, Production, and Copyright: Miraikan (National Museum of Emerging Science and Innovation)
2016 / 30mins / 3D / 4K Domemaster / 7.1ch surround / Japanese, English versions available



Enjoy the Movie!

From the world of elementary particles to the farthest reaches of the Universe, the journey beyond dimensions starts now.

[INTRODUCTION]

Based on the latest scientific data and hypotheses, Takashi Shimizu, the pioneer of horror movies, visualizes the world as theoretical physicists see it in order to create a new kind of science movie.

A 3D full-dome movie on the "Theory of Everything", the ultimate goal of physics to describe all natural phenomena by a single, consistent theory. Physics is in crisis. Our understandings of the microscopic world of elementary particles and of the macroscopic world of the universe are in contradiction. Scientists are striving to resolve the contradictions and construct the Theory of Everything. Be ready to be surprised by the new world of vibrating strings and hidden dimensions predicted by the most promising hypothesis, the Superstring Theory.

[STORY]

The mysterious man T.o.E. must be caught!

"How does the Universe work? How was it even created?" Growing up, everyone has thought about these fundamental questions, but there are still people who keep searching for the answers — Scientists. Scientists are seeking a certain person. His name is T.o.E. If they catch him, all the mysteries of the physical world will be solved. The scientists are finally able to locate him, but the moment they try to catch him, he escapes with ease. He says "Welcome to my world", and invites us to a fantastical journey. He traverses space and time, from the world of the infinitesimally small to the vastness of the macroscopic world, and from the present day to the distant past, up to the birth of the Universe. What lies at the end of this journey is something that will change how we perceive reality forever.



Scientific Advisor: Hirosi Ooguri (Fred Kottl Professor of Theoretical Physics and Mathematics and Founding Director of the Walter Burke Institute for Theoretical Physics at the California Institute of Technology, and Principal Investigator of the Kavli Institute for the Physics and Mathematics of the Universe at the University of Tokyo) Director: Takashi Shimizu ("The Grudge" "Kiki's Delivery Service")
Visual Director: Synichi Yamamoto Cast: James Sutherland, Asahi Yoshida, Roza Tachibana, Tabito Okayasu Voice: Rikiya Koyama Scenario: Masanori Iuchi Director of Photography: Jun Fujimoto
Lighting: Takao Ichikawa Film editing: Yoshitaka Koyama Music: Taro Inoue Cosmological Simulation Visualization: Takashi Tanaka Data Provided by: The Illustris Collaboration, CERN
Production, CG/VFX: OMNIBUS JAPAN Planning, Production and Copyright: Miraikan (National Museum of Emerging Science and Innovation)

<https://www.miraikan.jat.go.jp/sp/9dimensions/en>



Dome Theater GAI! Equipped with Japan's first super high detail full-dome 3D optical system "Almos", "MEGASTAR-II cosmos" which can project 10million stars, and a 7.1 surround sound system, the diameter of this dome-shaped theater is 15meters. Big screen films and 3D planetarium shows are screened. (112 seats. Seats for wheelchairs also available)

Tickets! Reservations are required for the Dome Theater.

- 1 On-site reservation (Please make a reservation when purchasing admission tickets at the ticket booth.)
Free for the Dome Theater 300 yen for adults, 100 yen for those 18 years old or under.
*Tickets for the Dome Theater can only be purchased along with admission tickets.
- 2 Online reservation <https://domeyoyaku.jp/> (Reservations can be made until 5 p.m. on the previous day of the show)

For inquiries | 9dimensions@miraikan.jat.go.jp