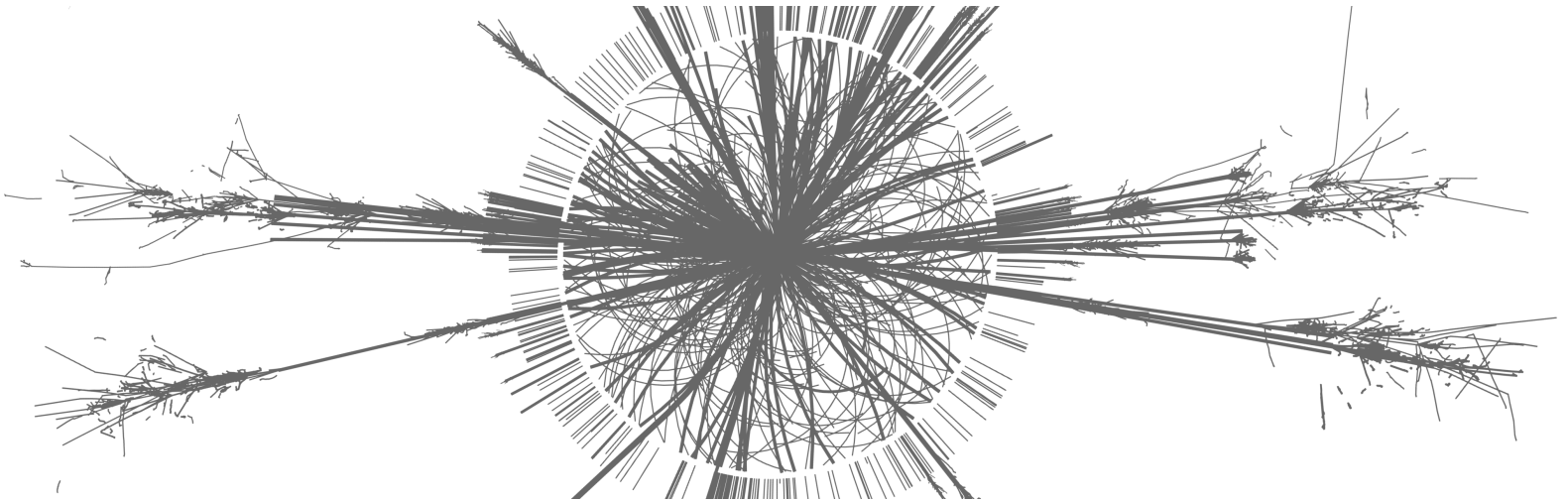
The PhD Guide to the Experiments in HEP



Maciej Trzebiński

Institute of Nuclear Physics
Polish Academy of Sciences
Cracow, Poland

New Trends in High-Energy Physics

Odessa, Ukraine

15th May 2019

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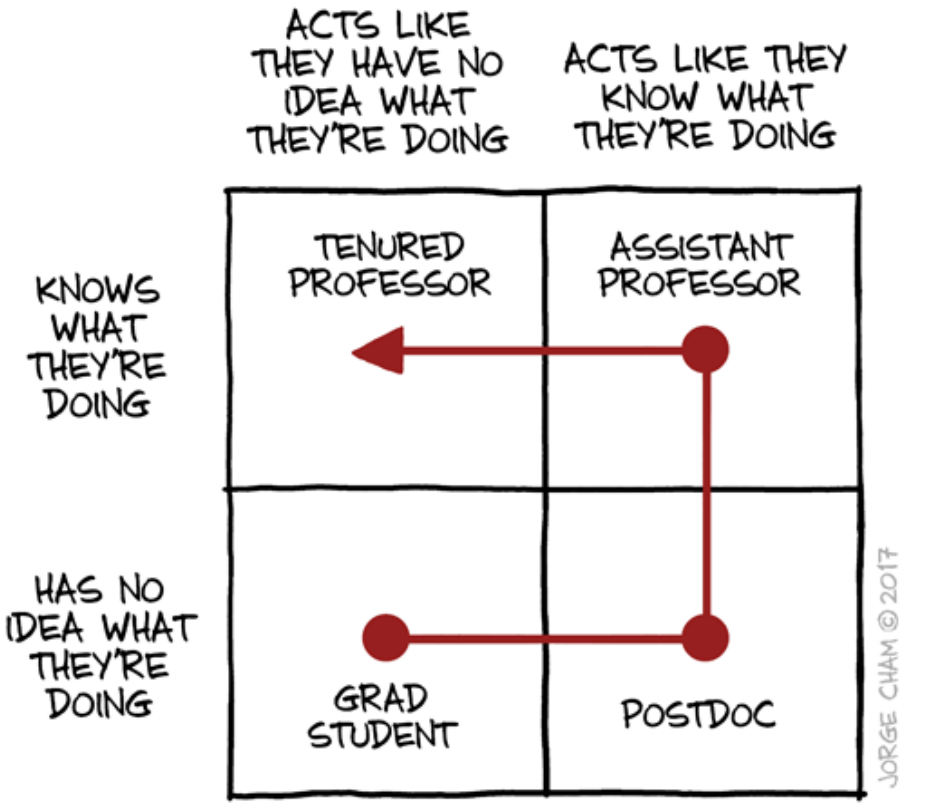
ACTS LIKE THEY HAVE NO IDEA WHAT THEY'RE DOING
ACTS LIKE THEY KNOW WHAT THEY'RE DOING
KNOWS WHAT THEY'RE DOING
HAS NO IDEA WHAT THEY'RE DOING
TENURED PROFESSOR
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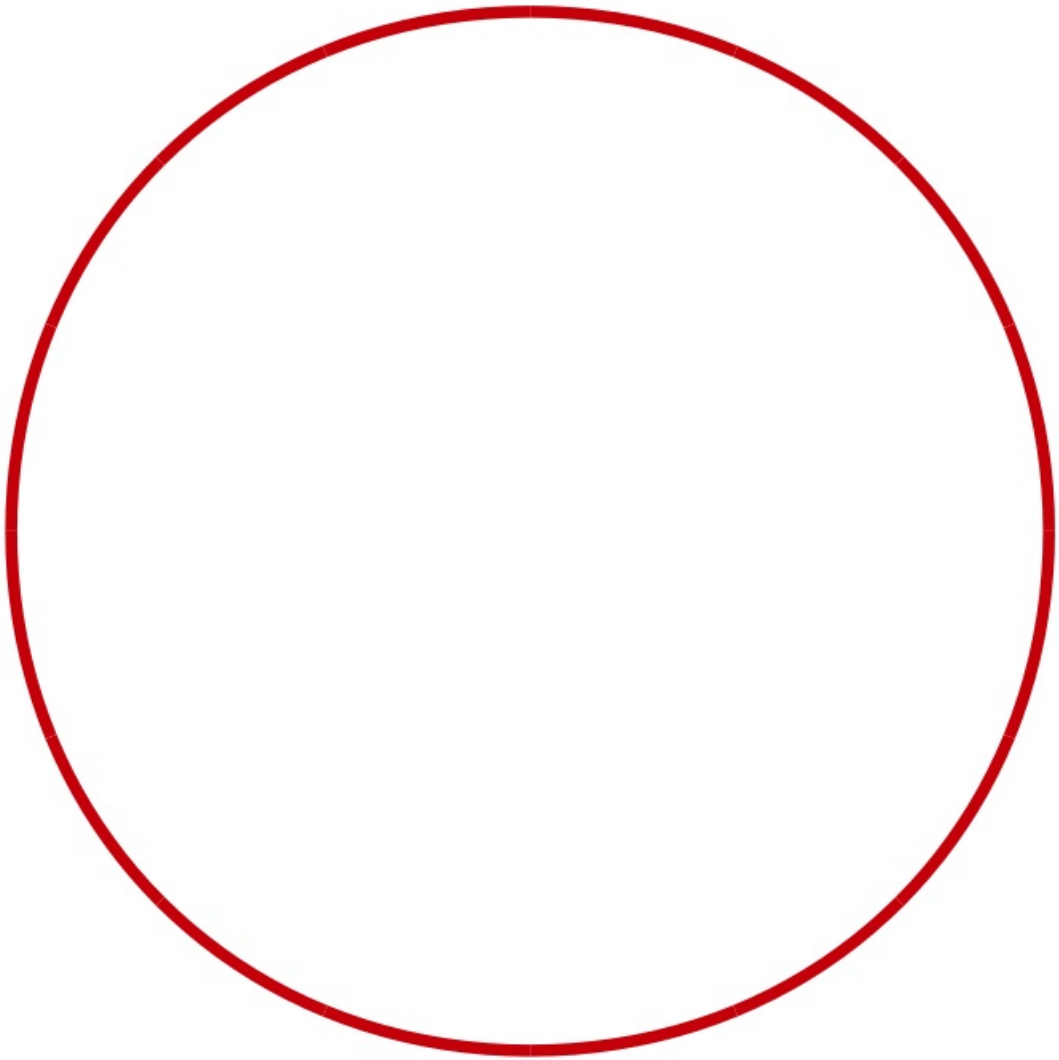
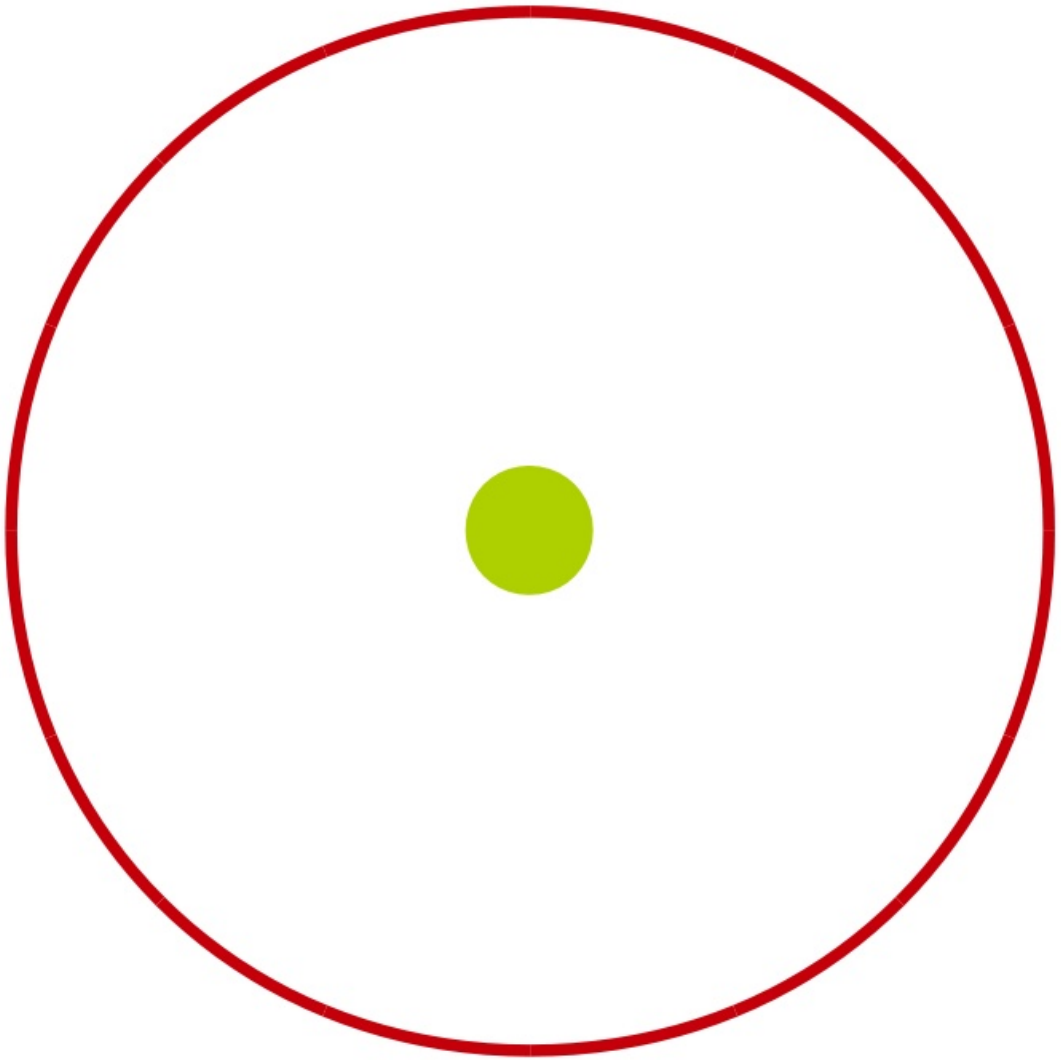
Our Knowledge

Our Knowledge



Everything humanity knows

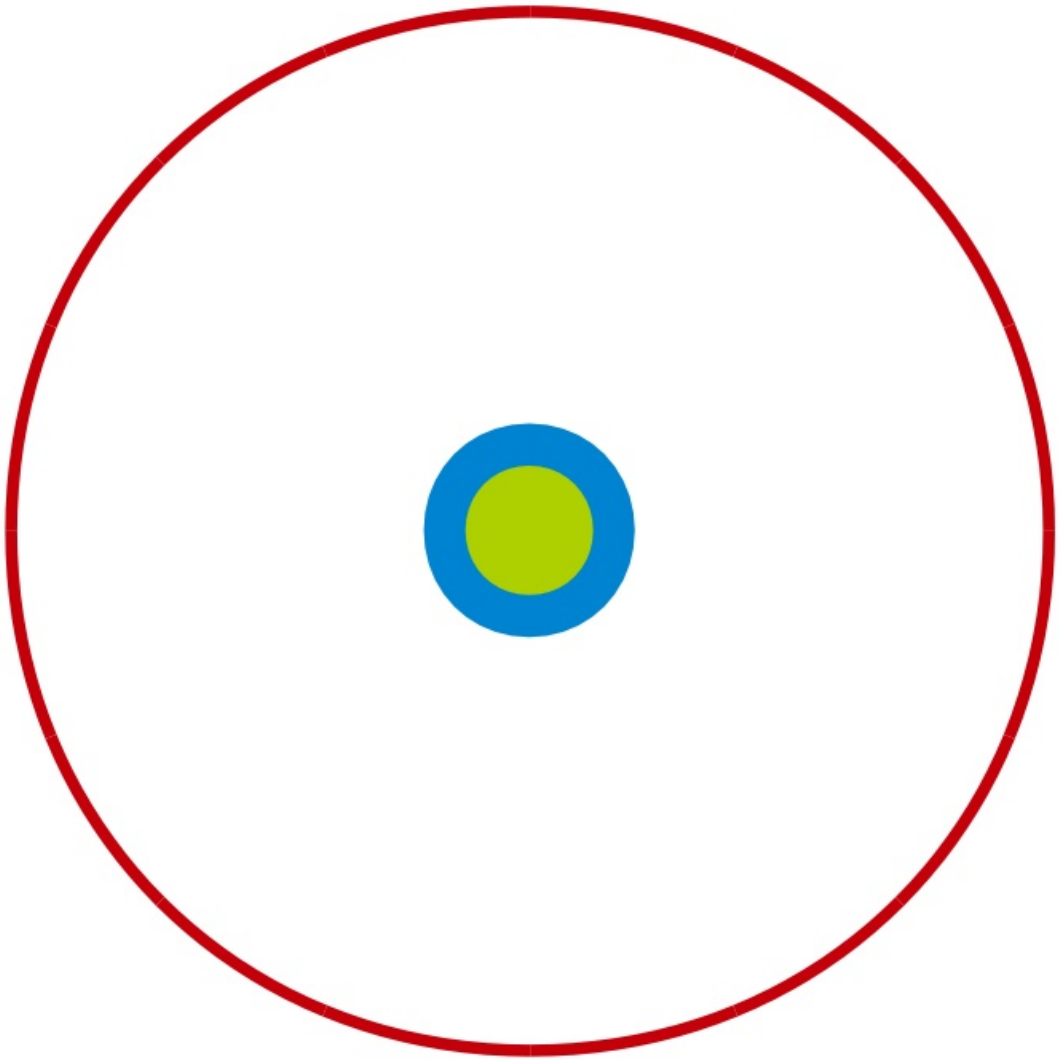
Our Knowledge



Everything humanity knows

Things you learn in primary school

Our Knowledge



Everything humanity knows

Things you learn in primary school

Things you learn in high school

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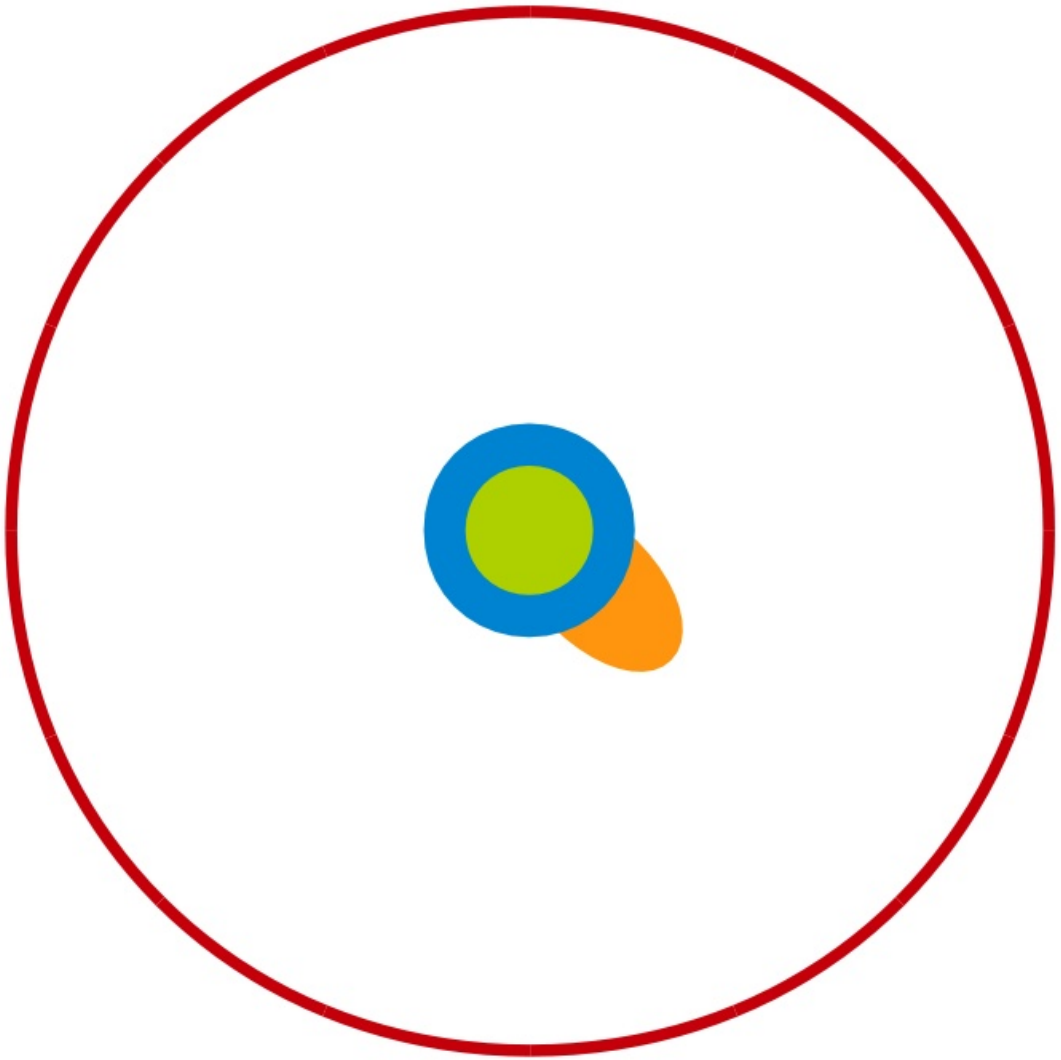

Everything humanity knows

Things you learn in primary school

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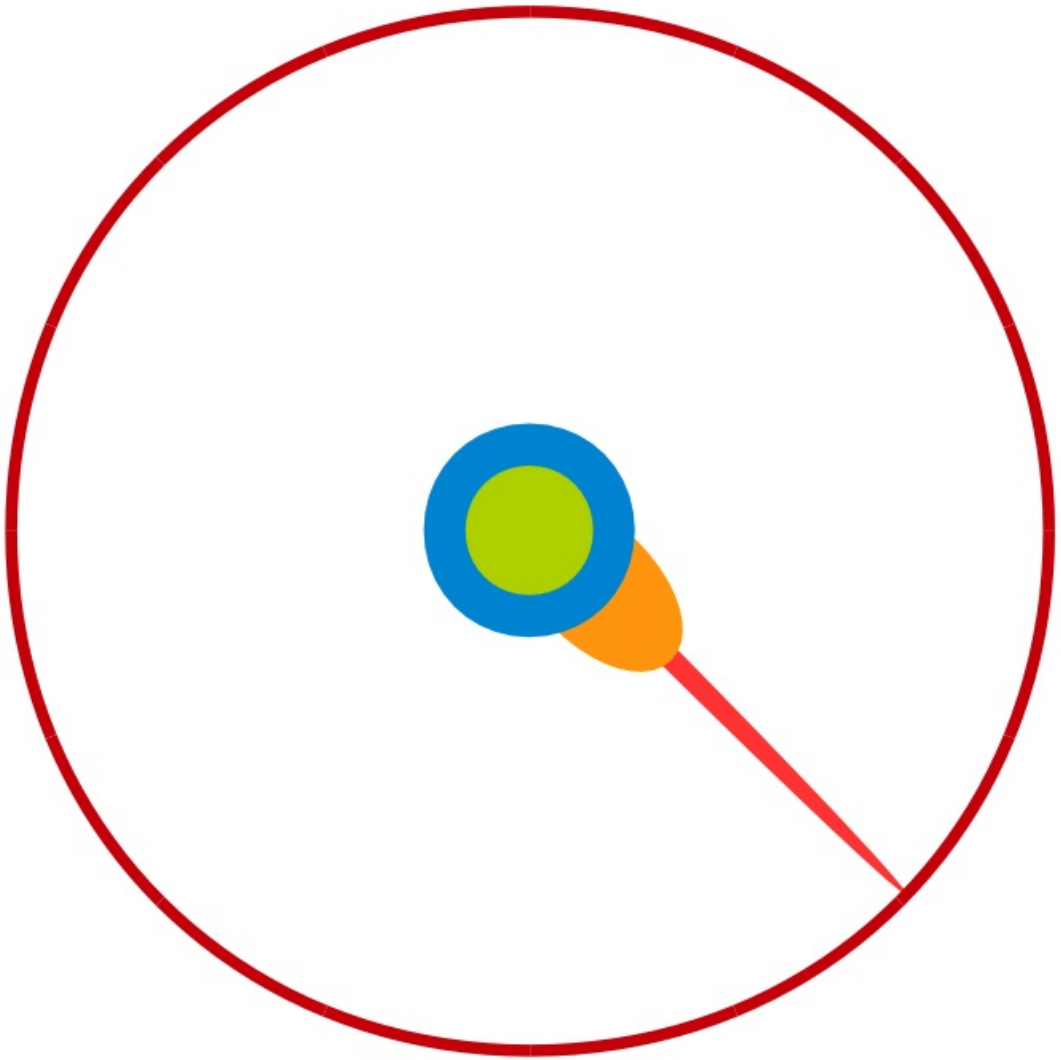
Our Knowledge



Everything humanity knows

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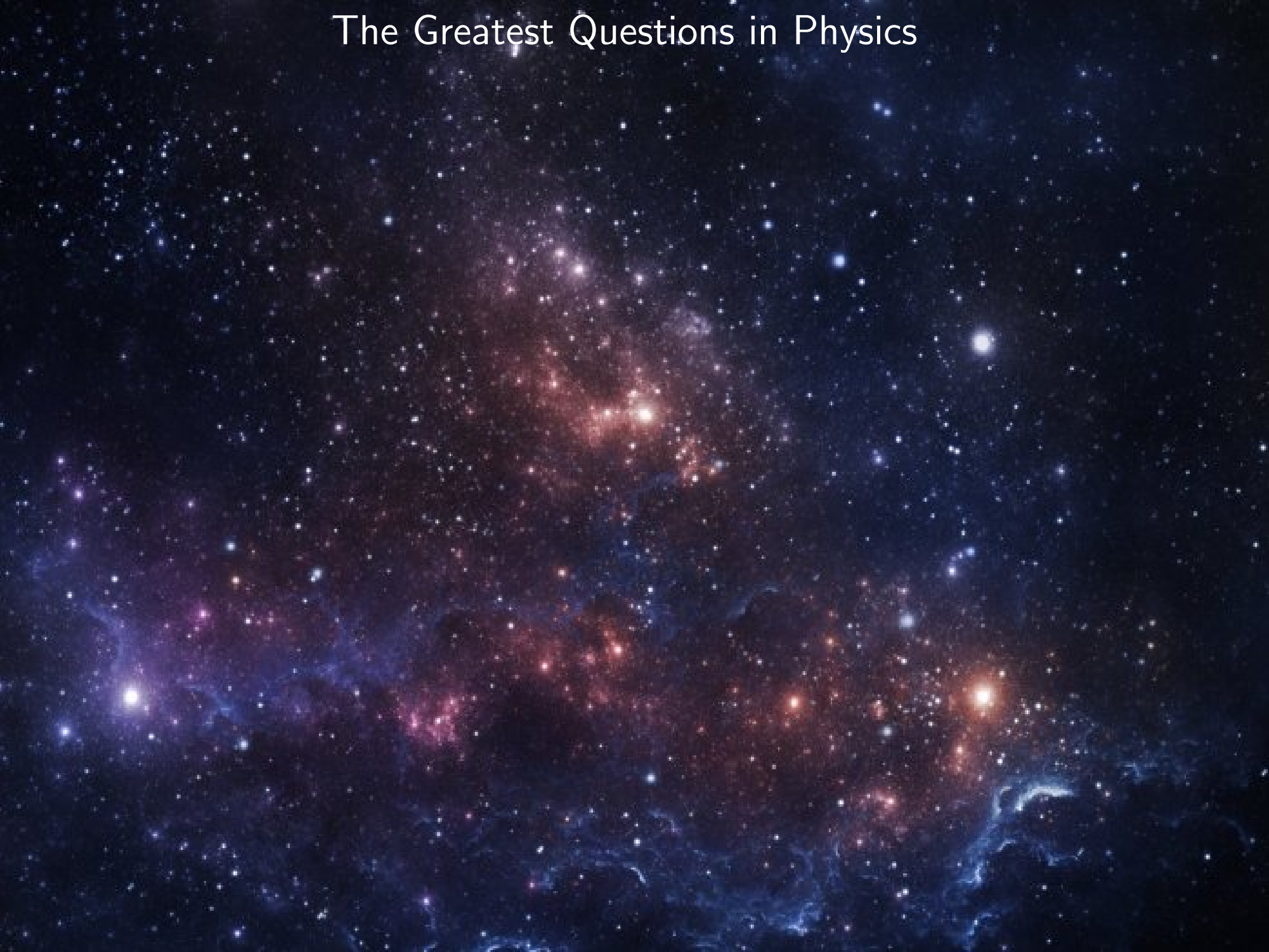
The Greatest Questions in Physics



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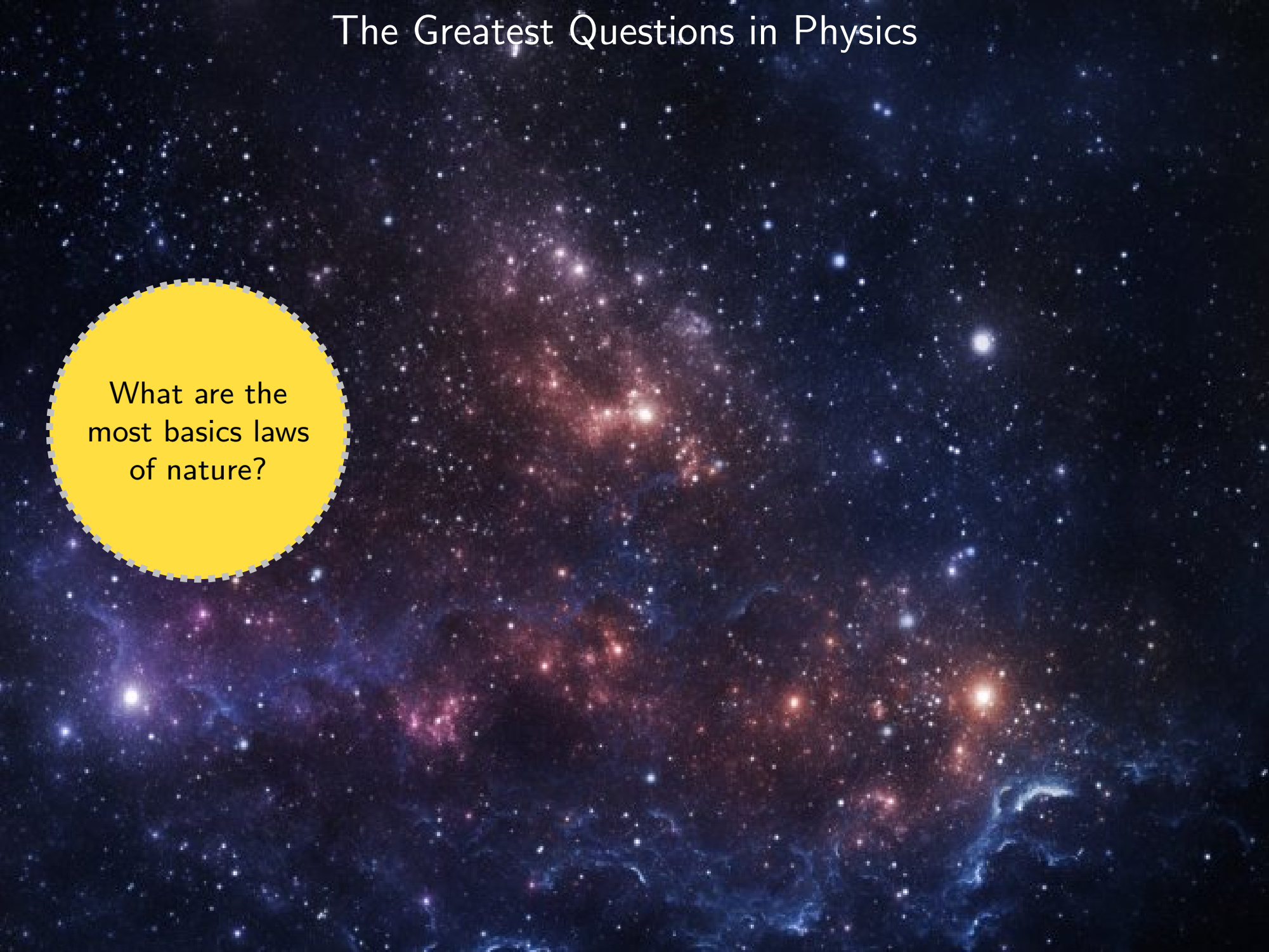

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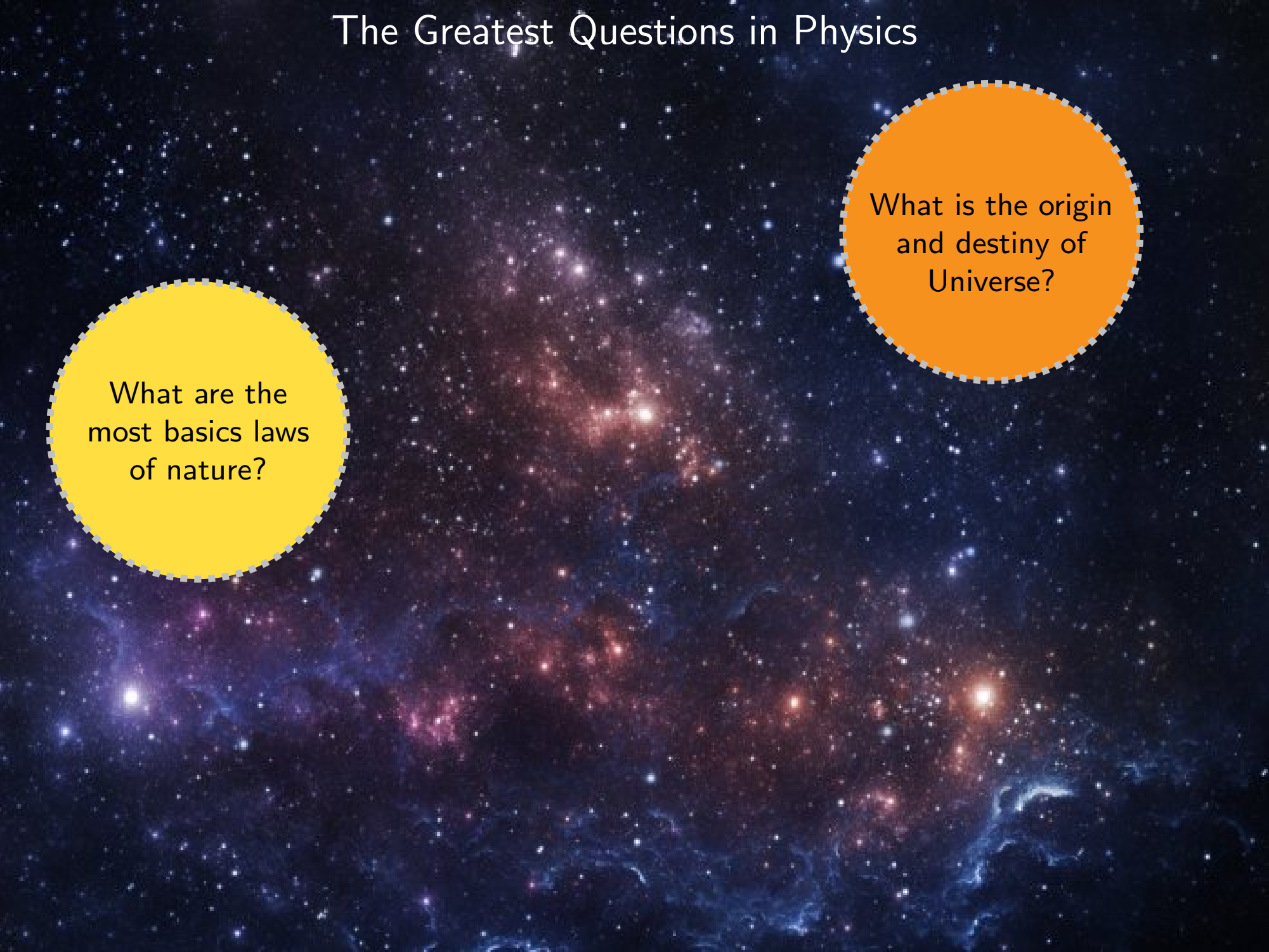

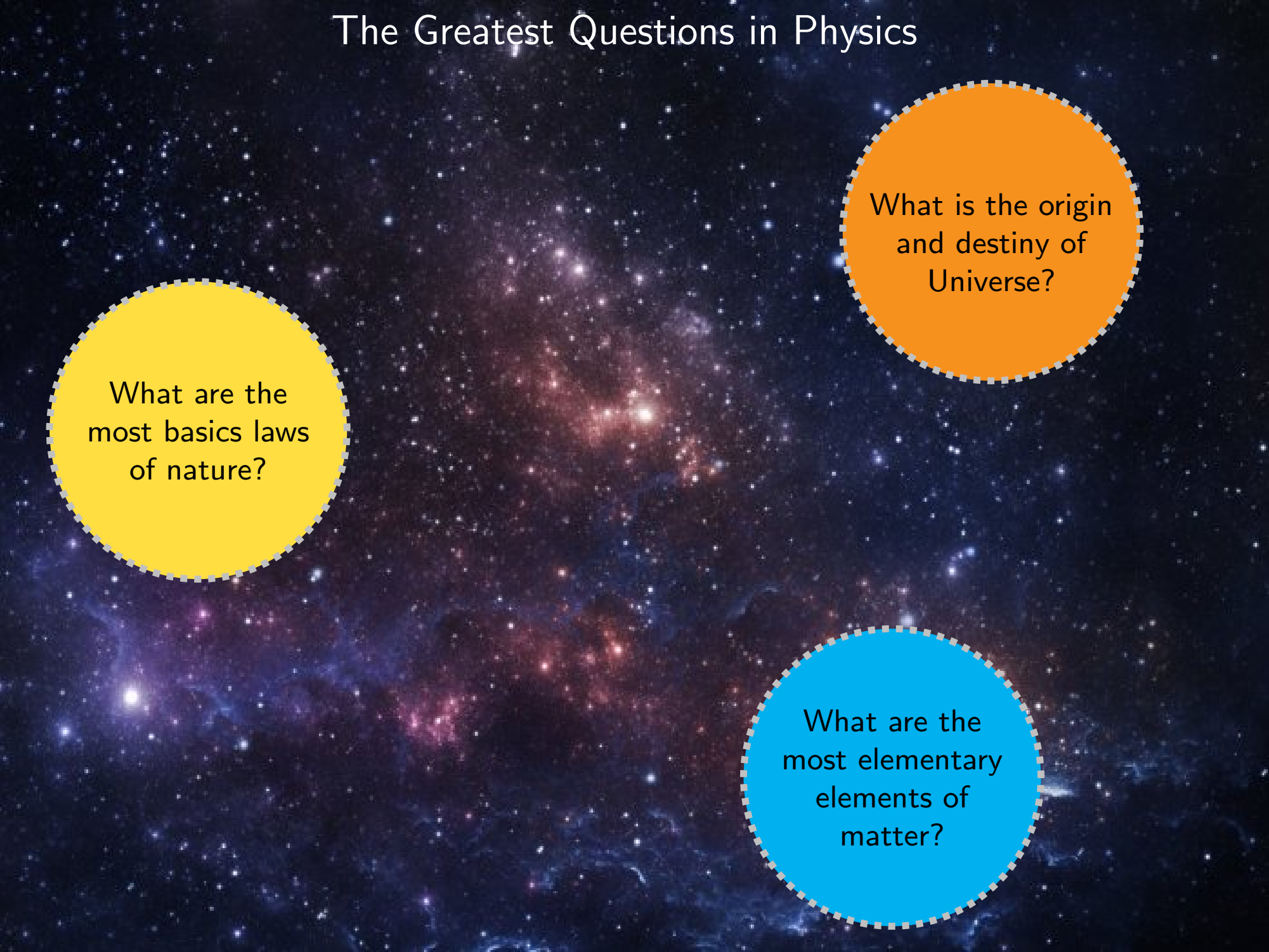
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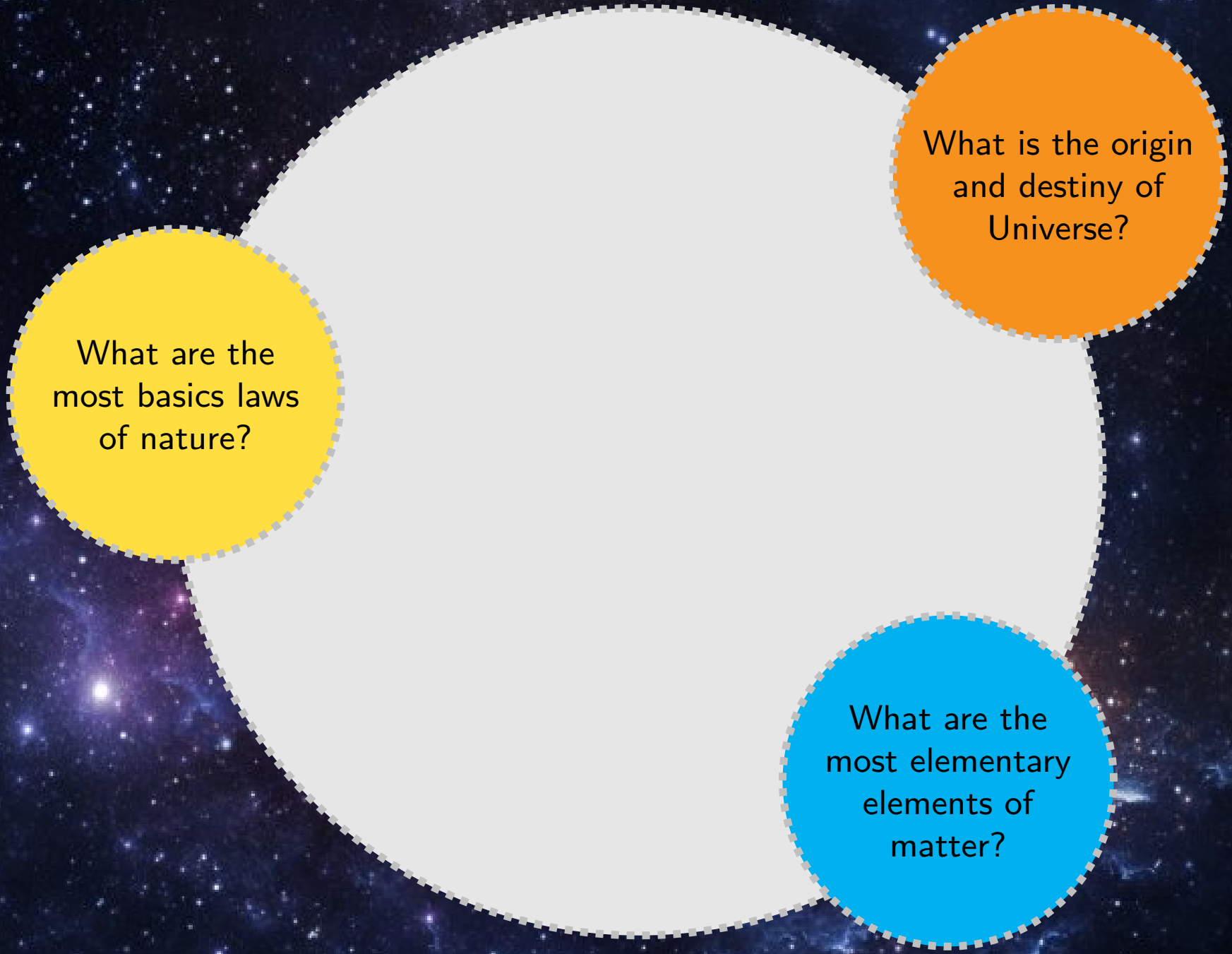

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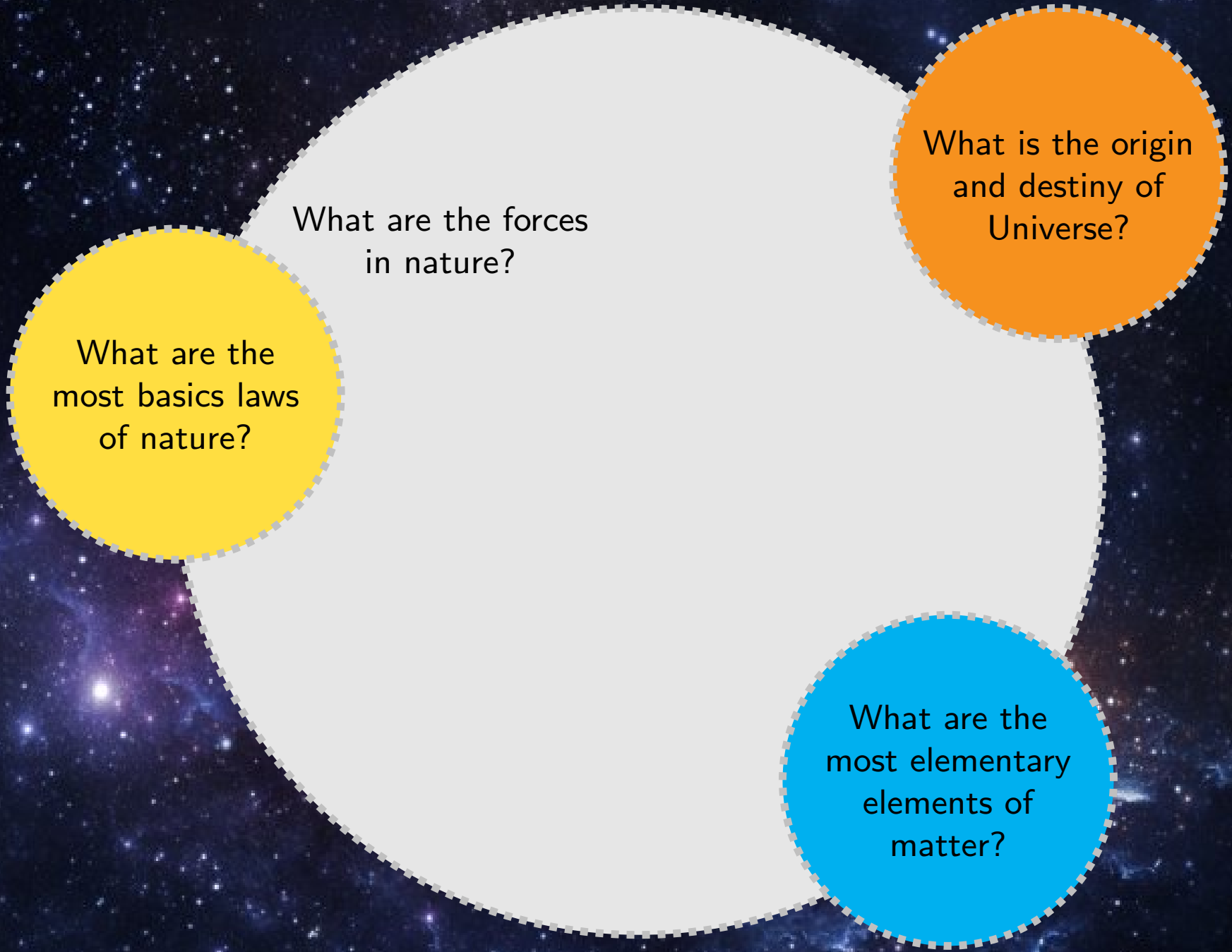

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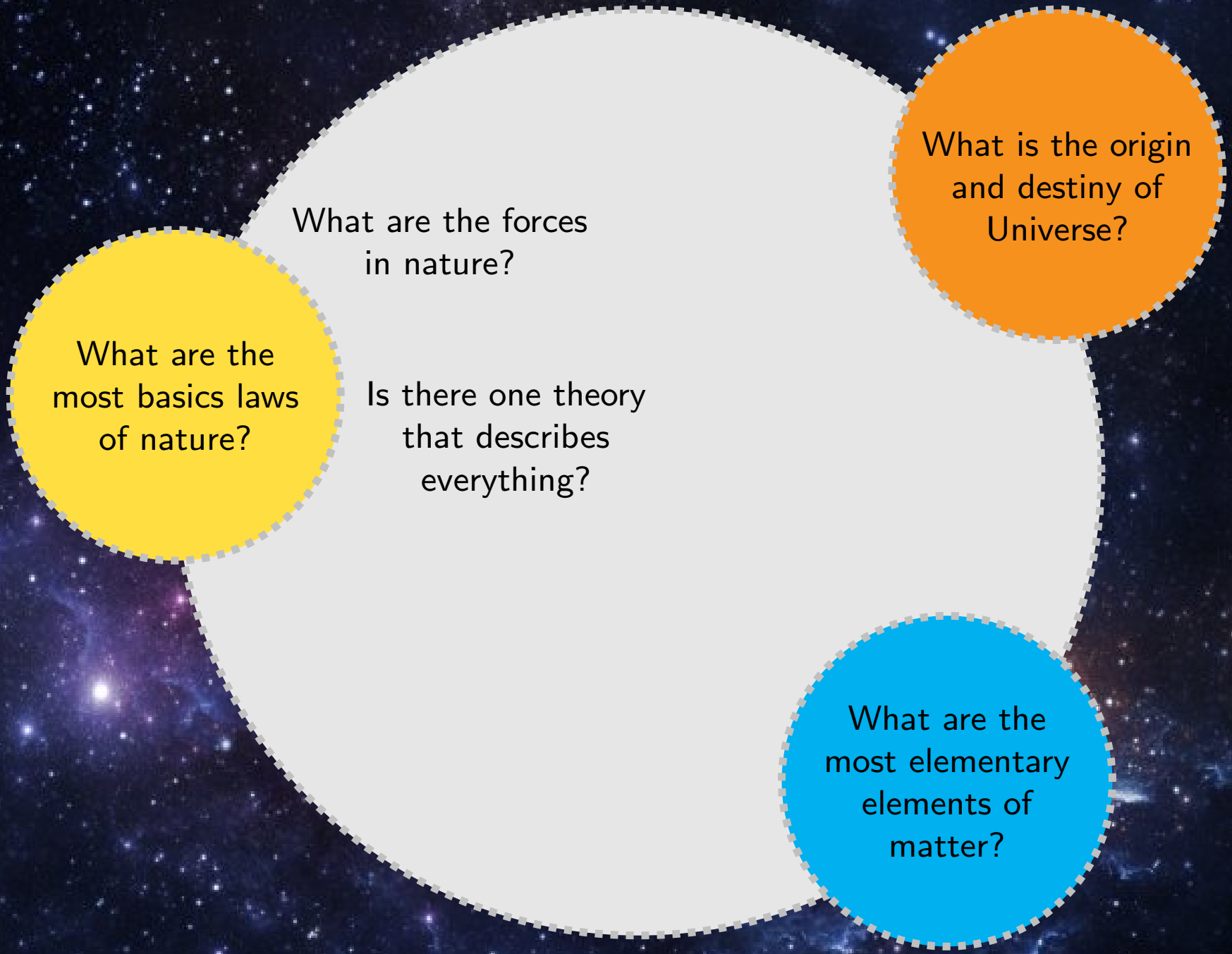

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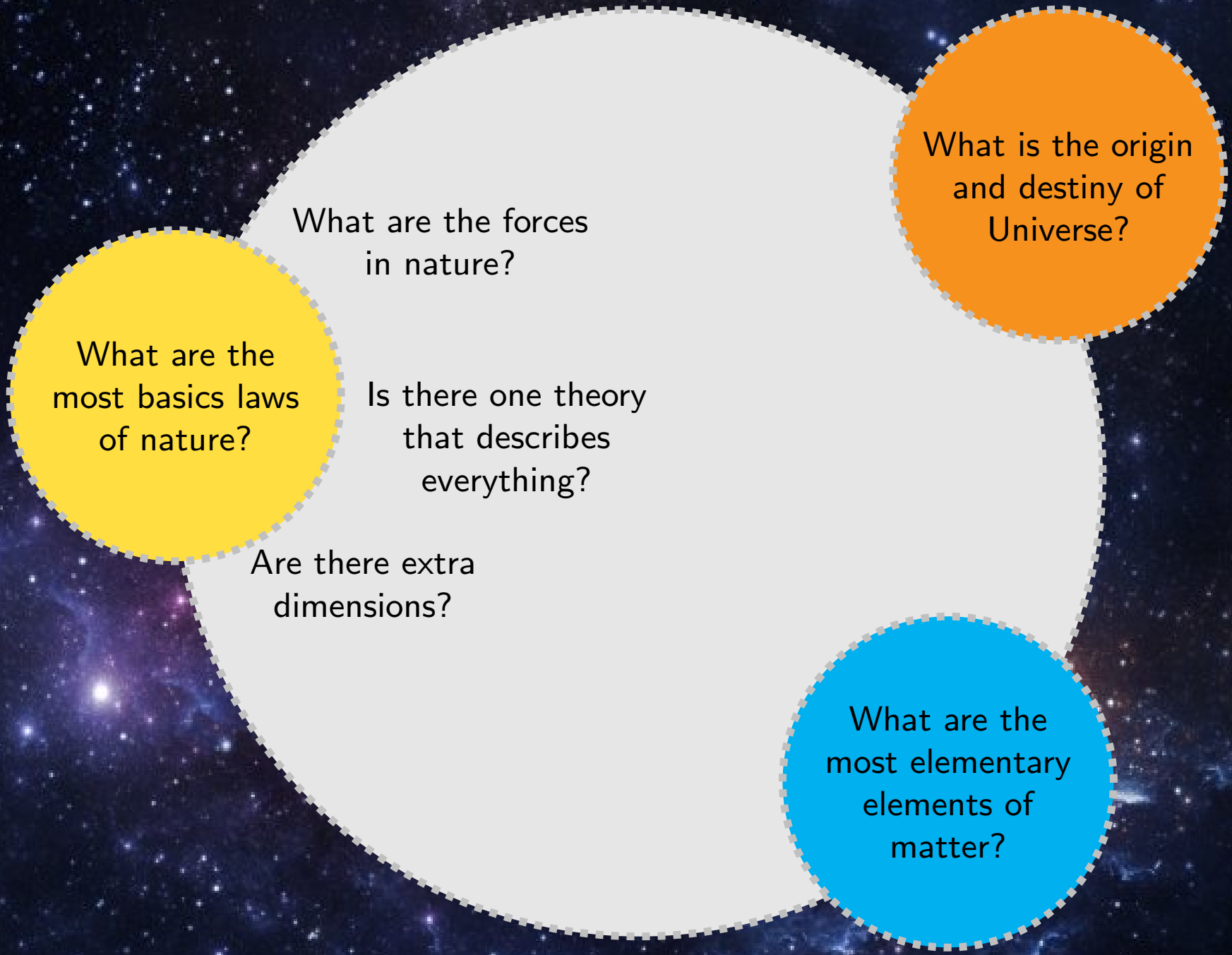

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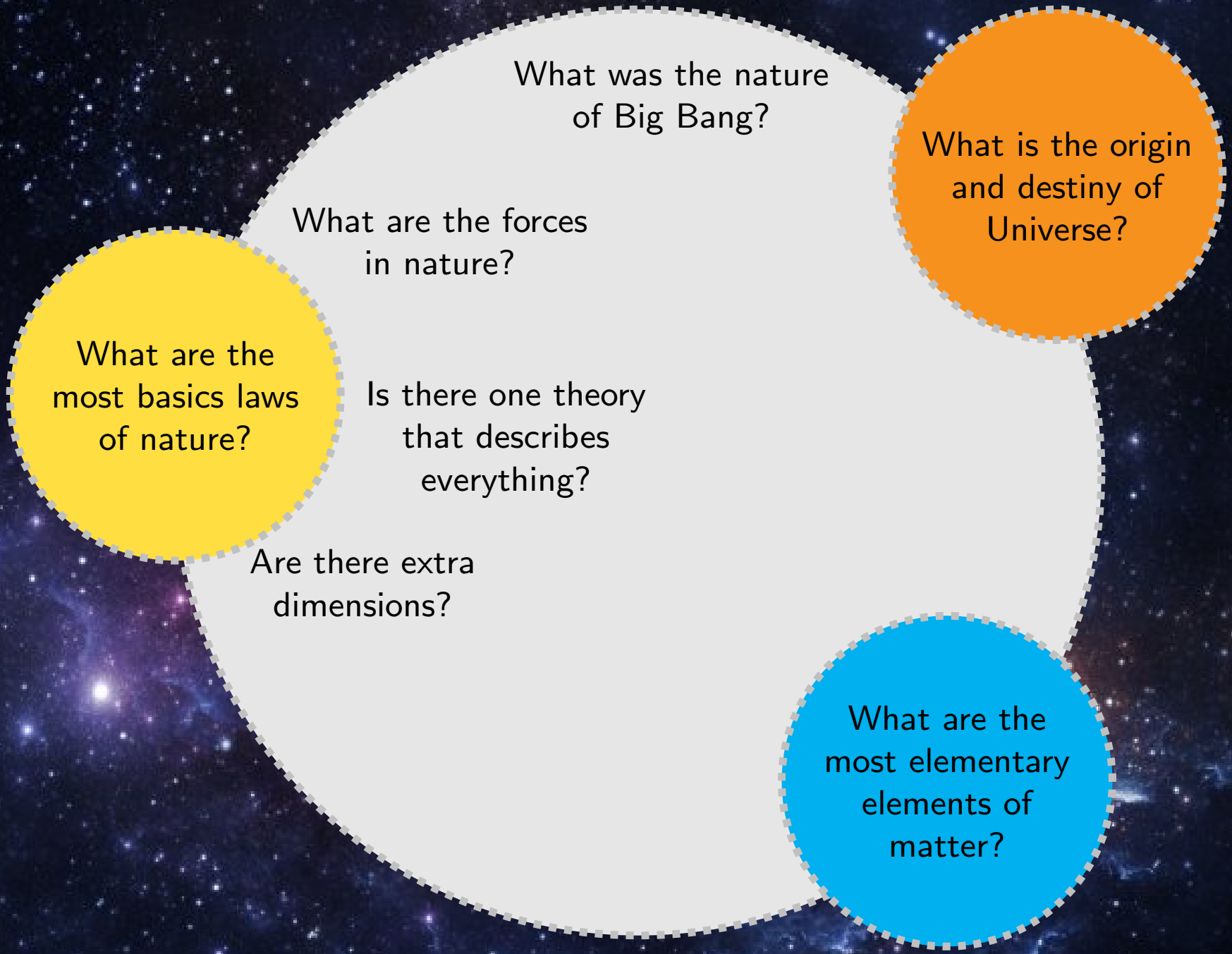

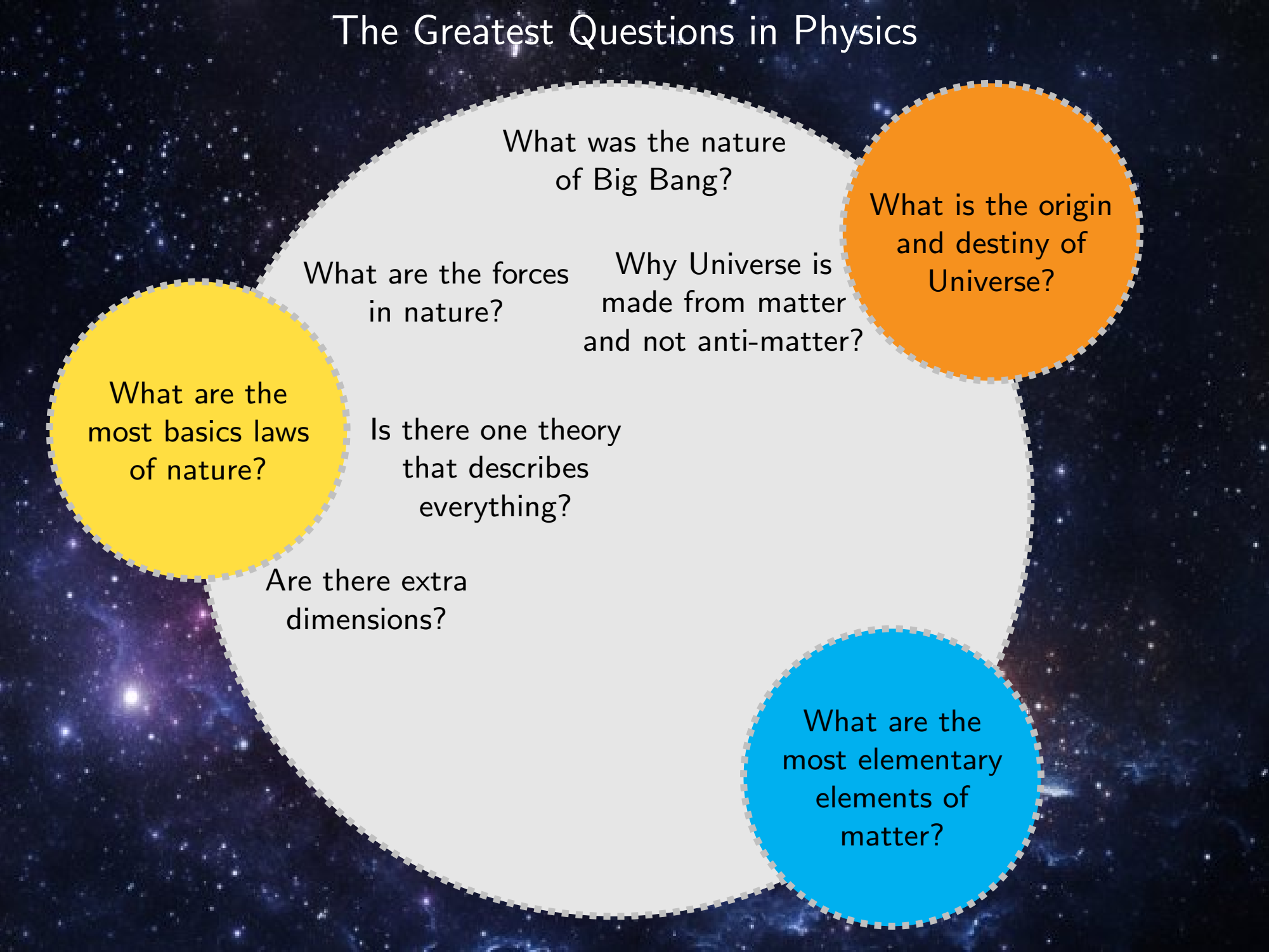
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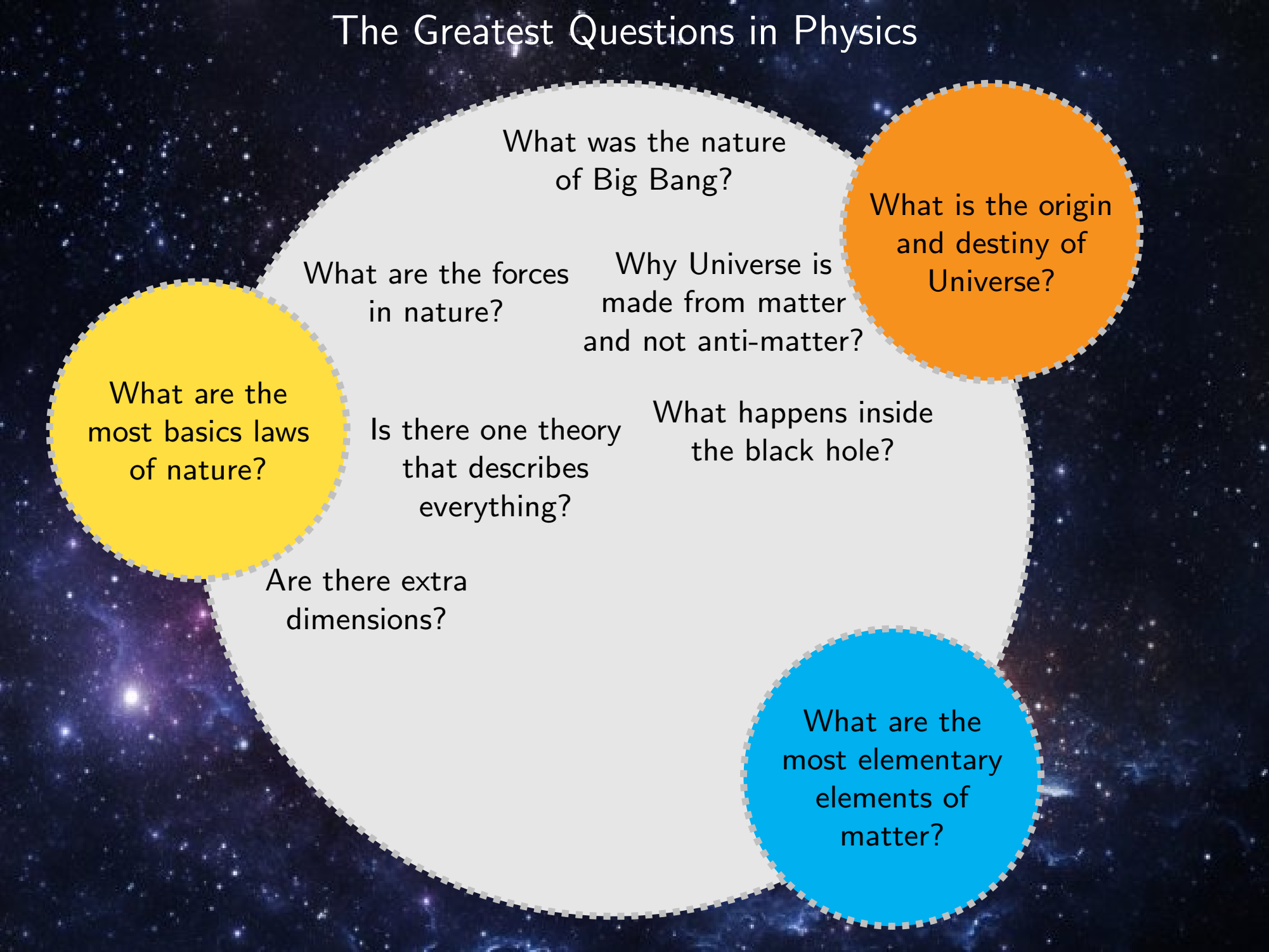
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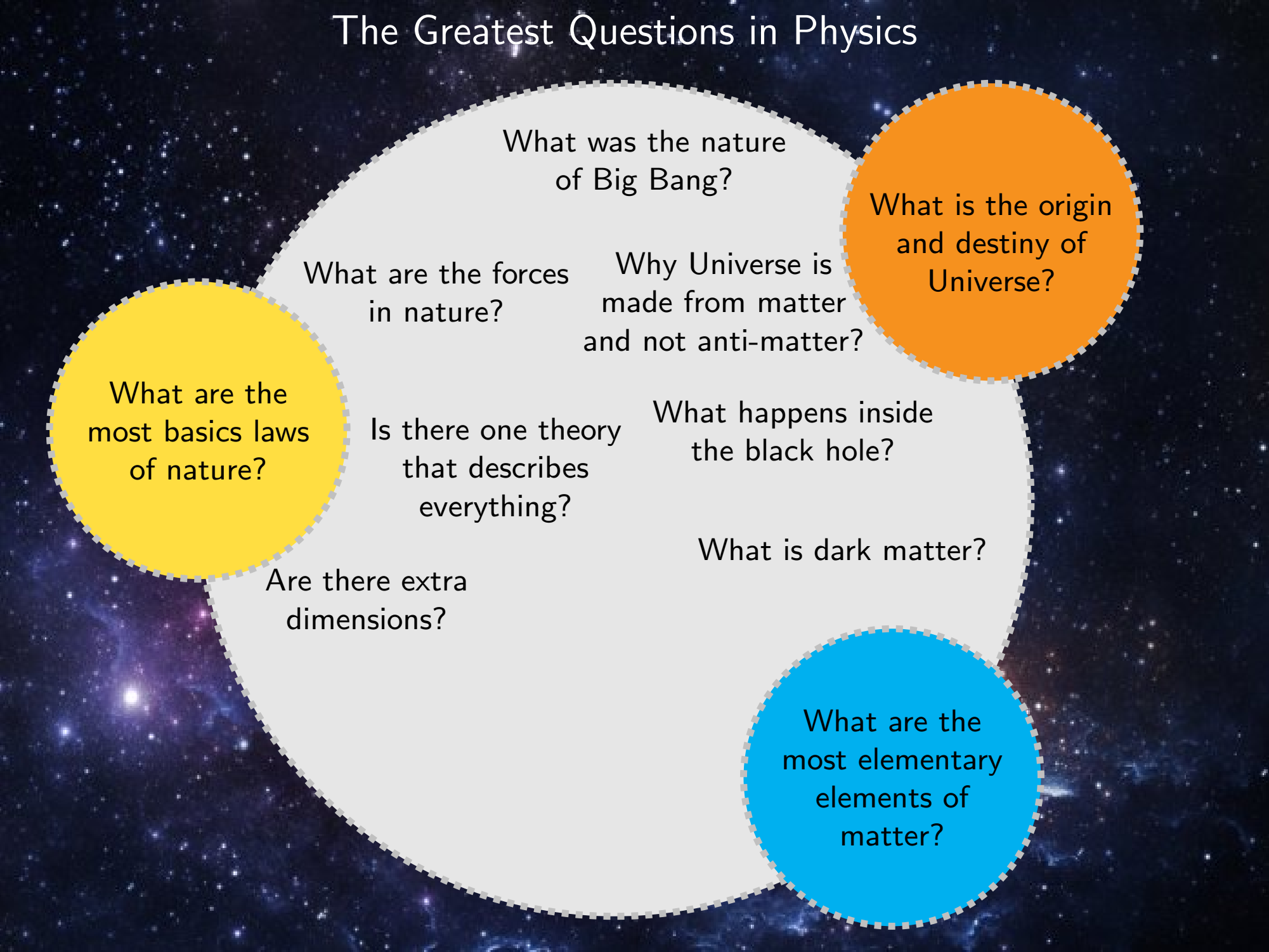
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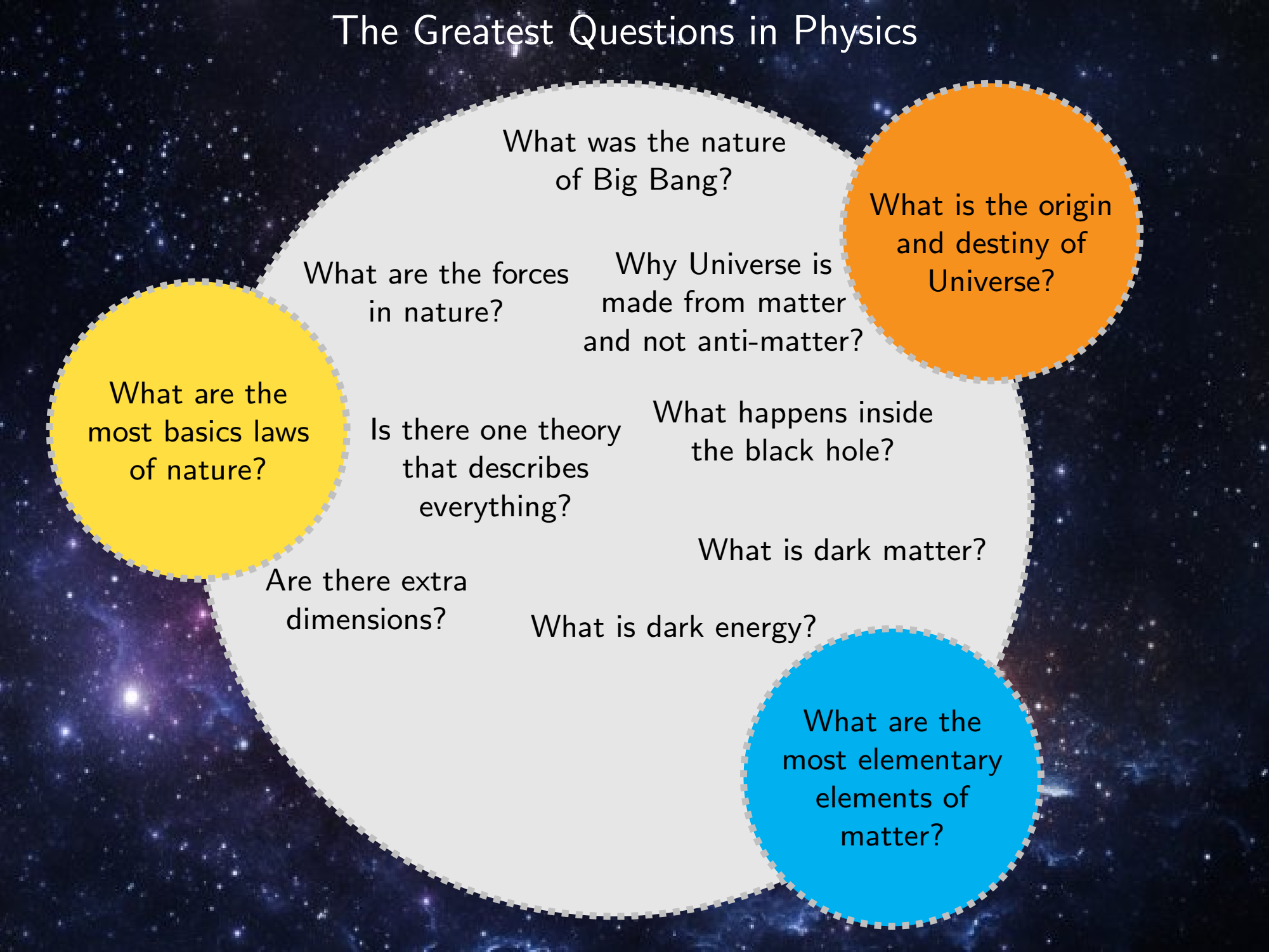
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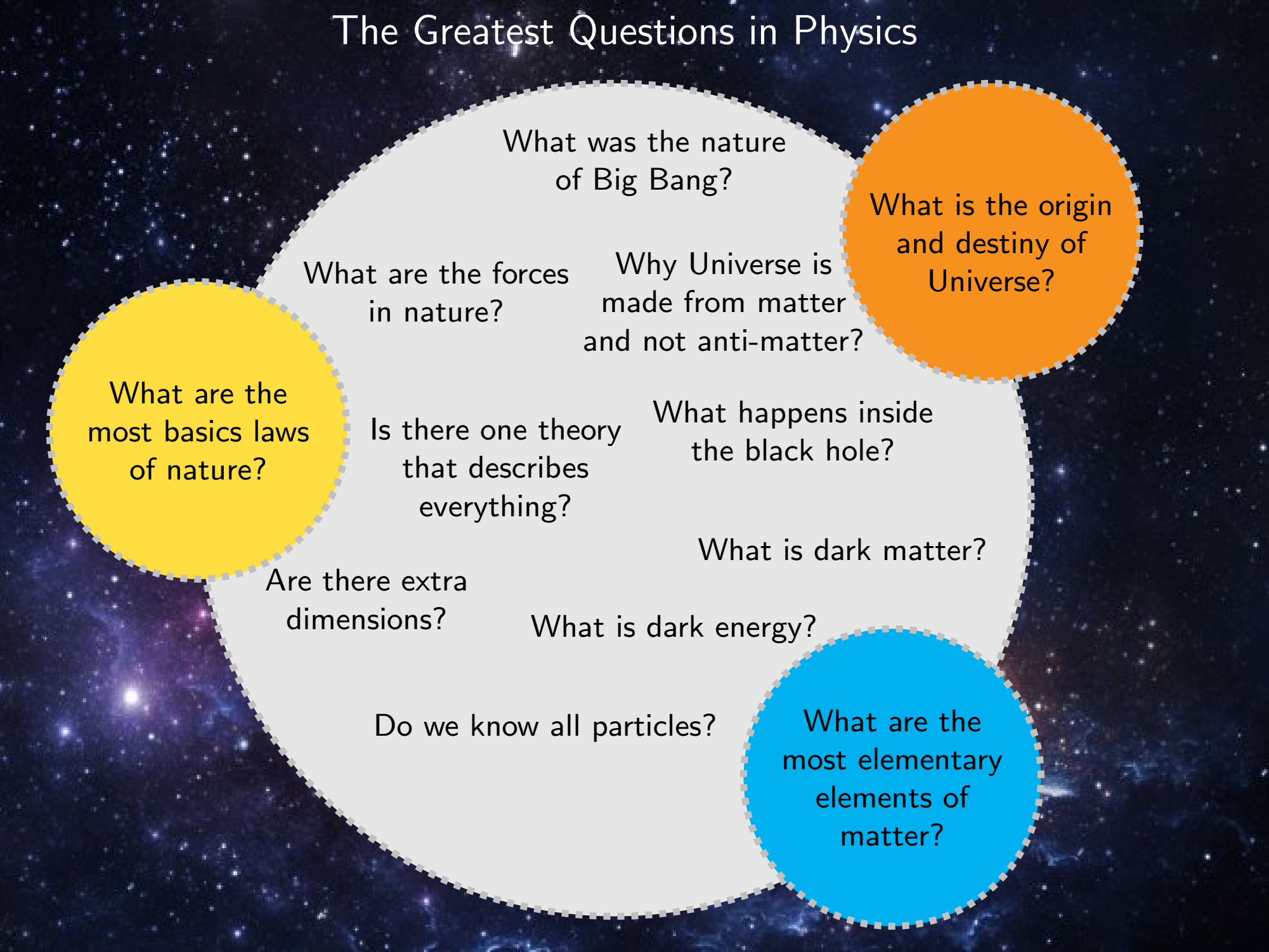
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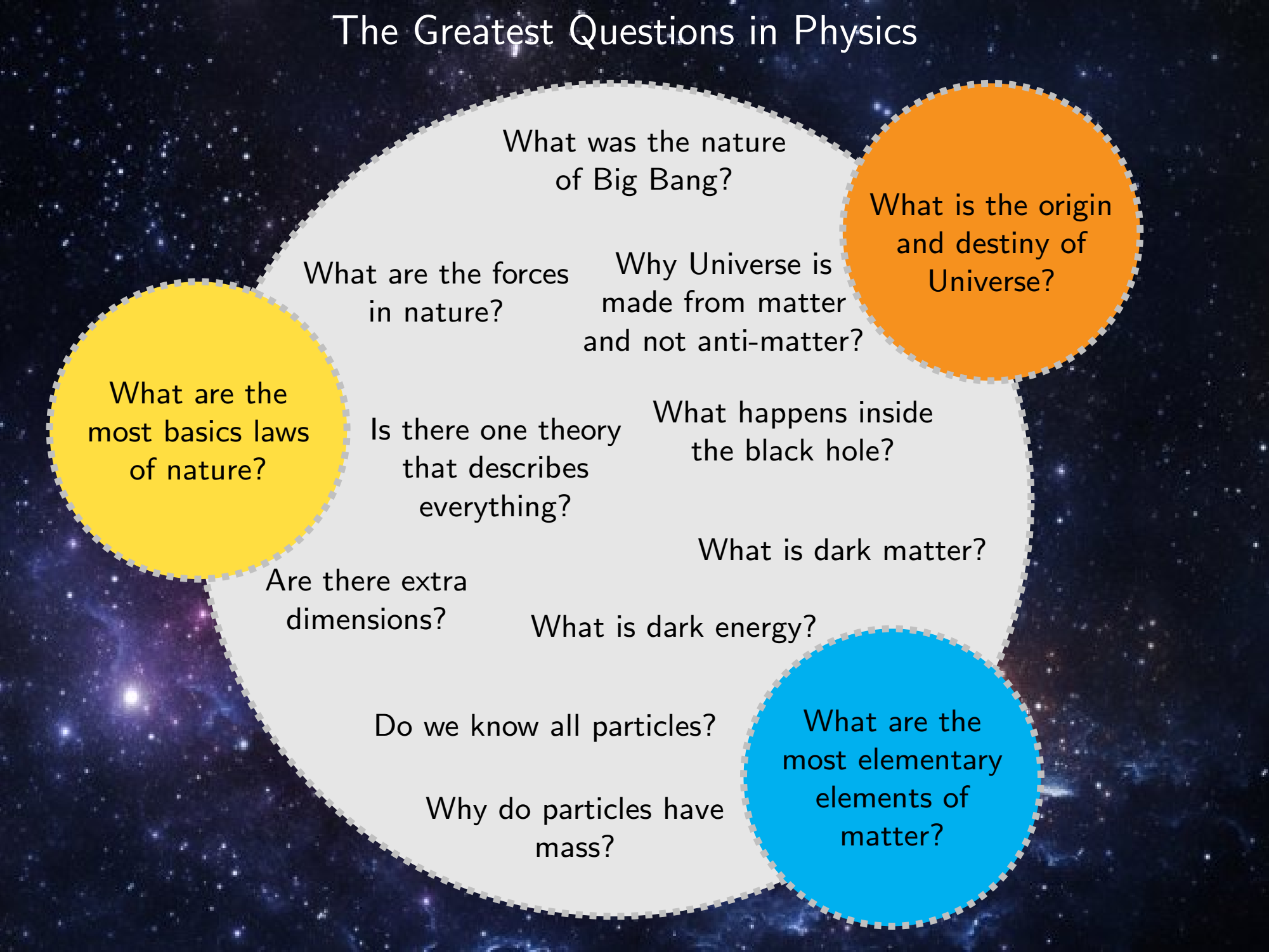
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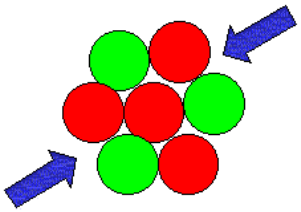
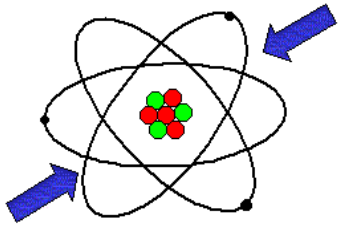
Forces in Nature

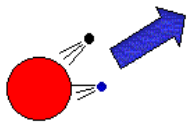
Four fundamental forces?



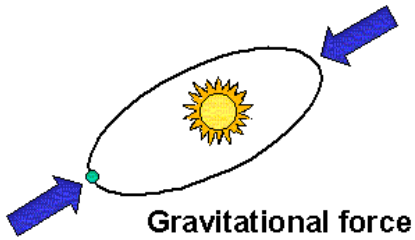
Strong force
binds the nucleus



Electromagnetic
force binds atoms

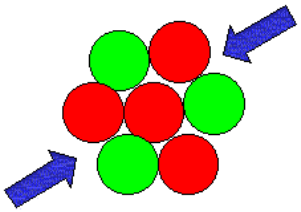


Weak force in
radioactive decay



Gravitational force
binds the solar system

Four fundamental forces?



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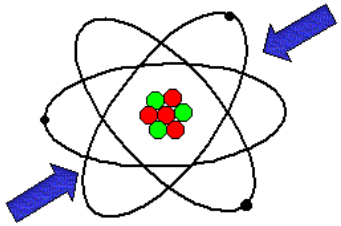

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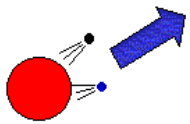

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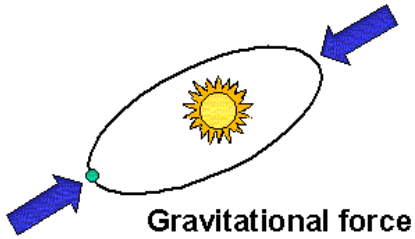
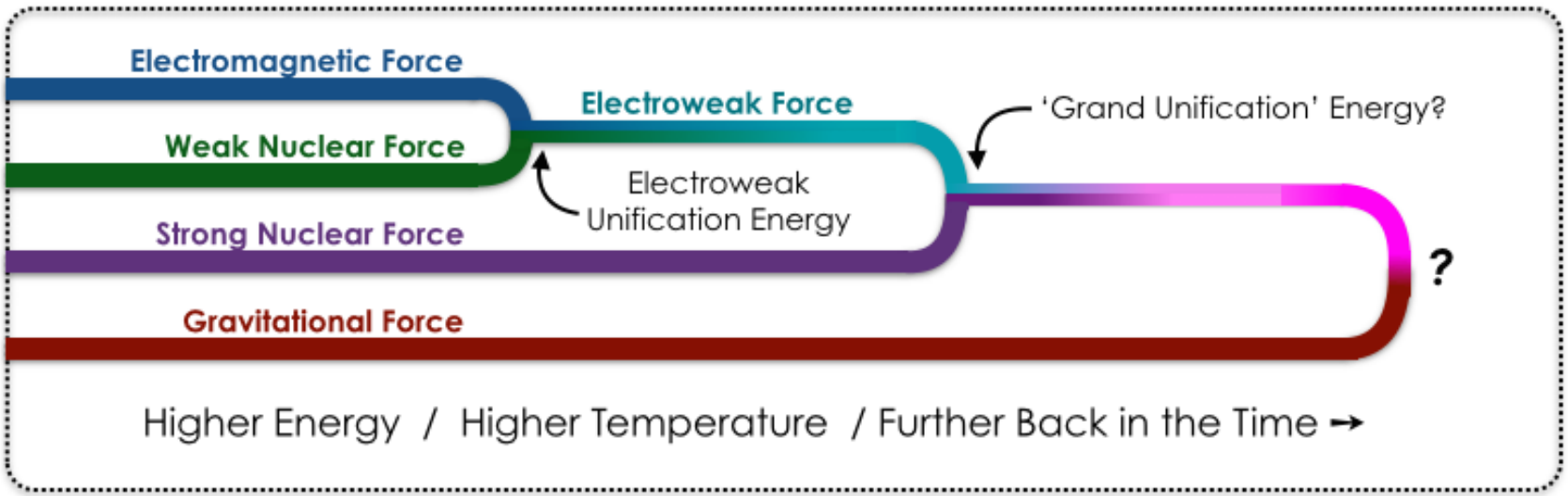


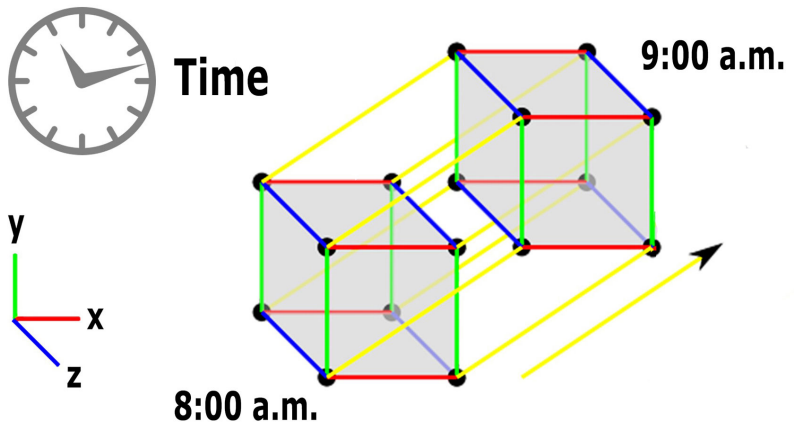
Gravitational force
binds the solar system

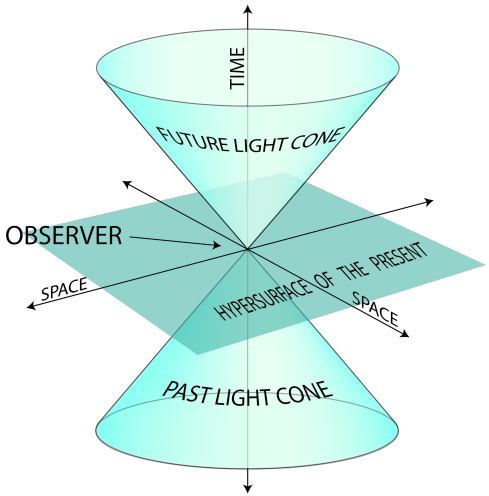
Or just one 'superforce'?



Dimensions

3 space and 1 time?





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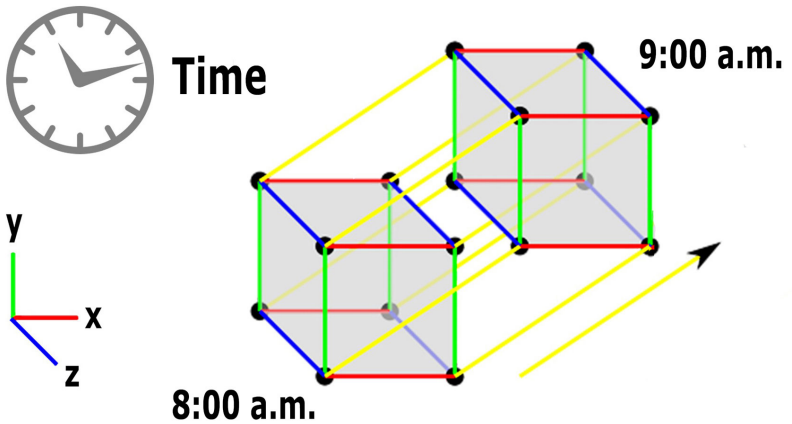
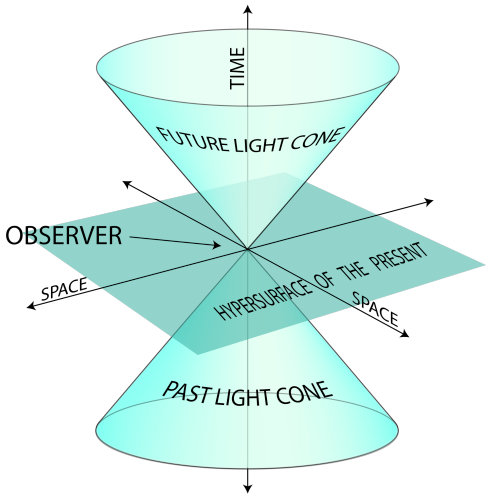
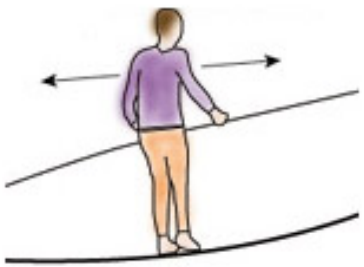
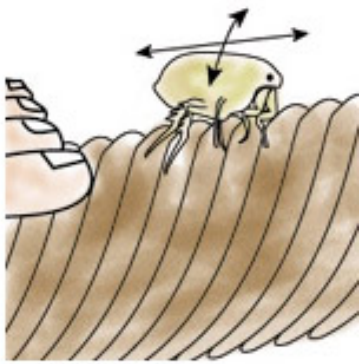




Or more?

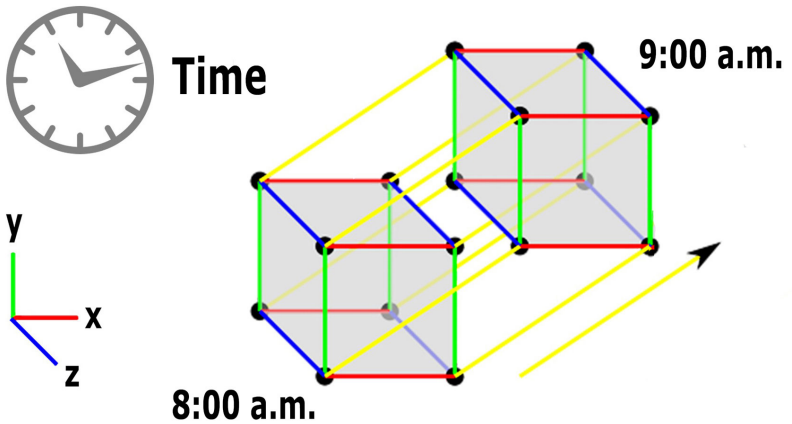


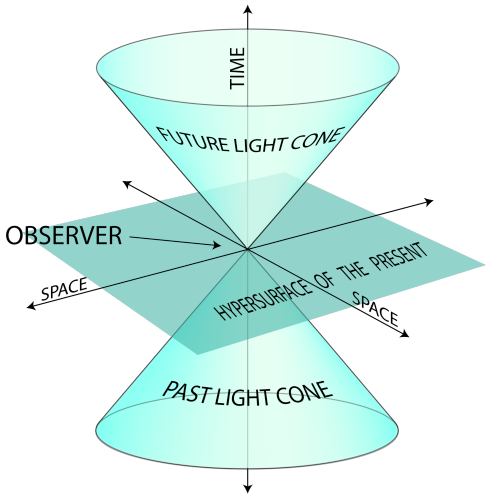
An acrobat can only move in one dimension along a rope..



...but a flea can move in two dimensions.

3 space and 1 time?





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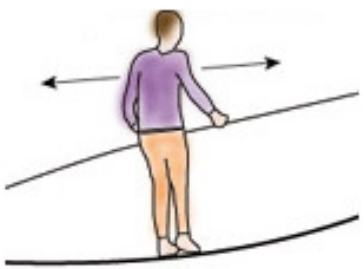

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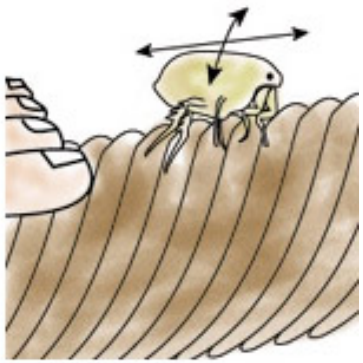

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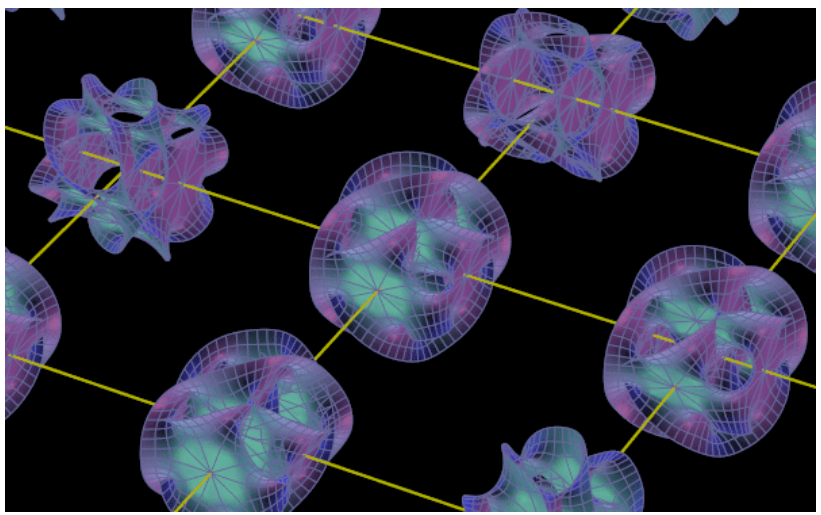
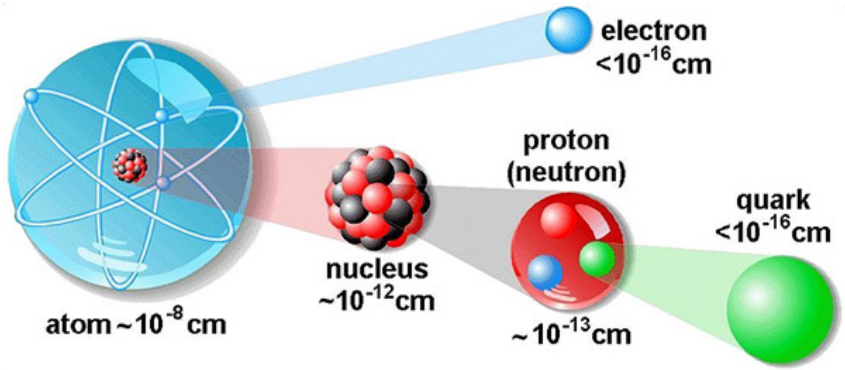
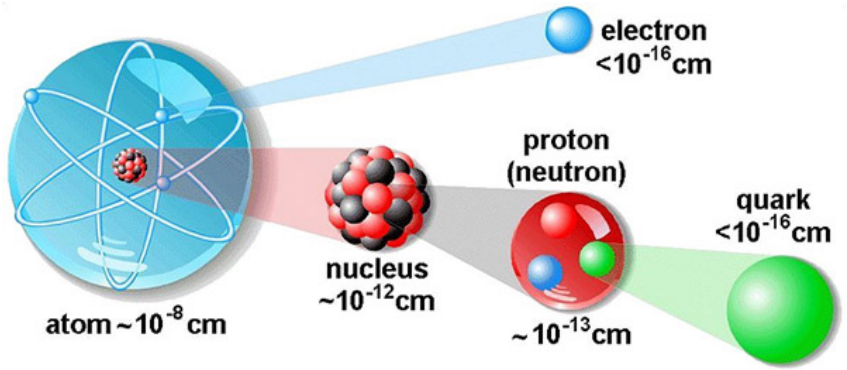
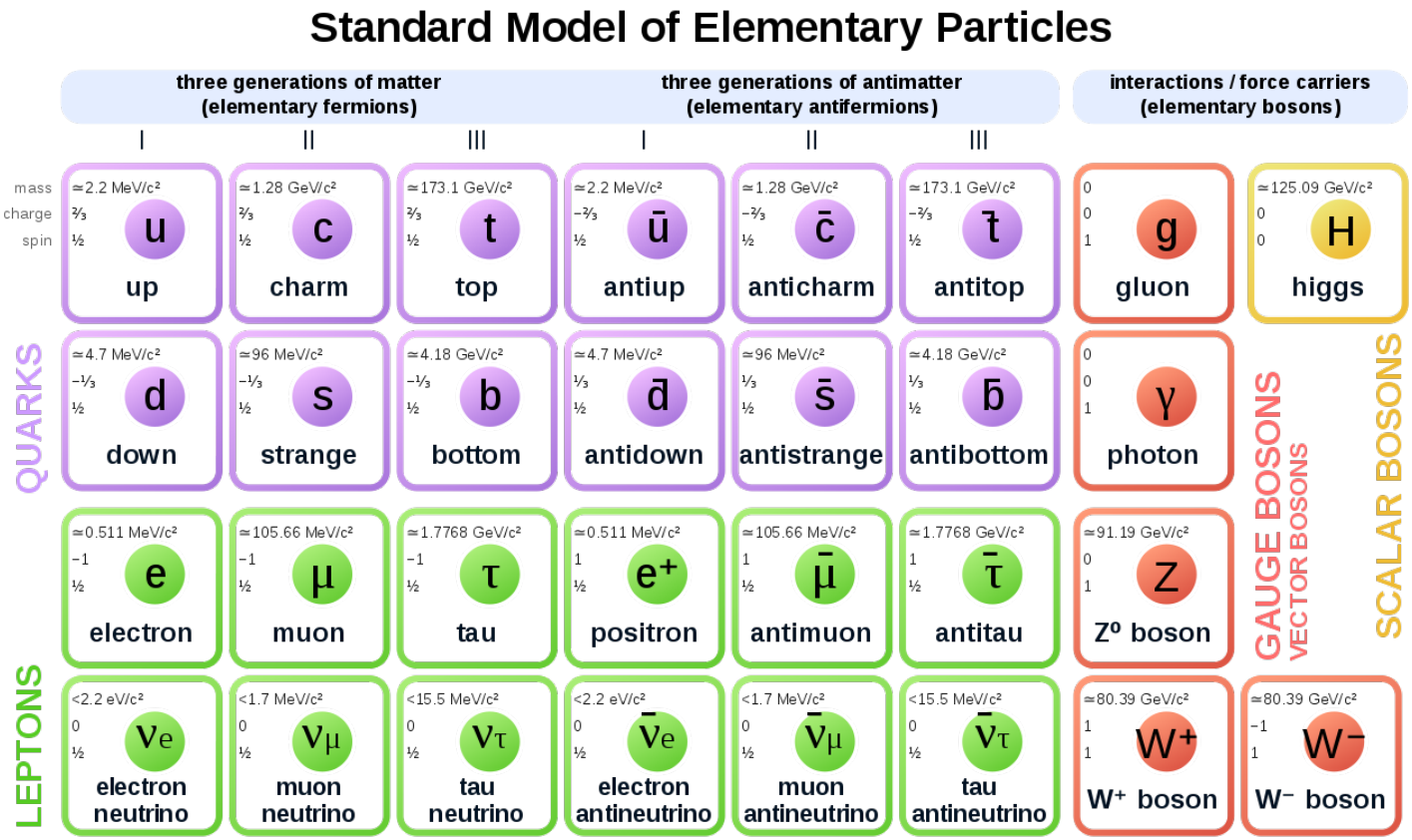


Components of Matter

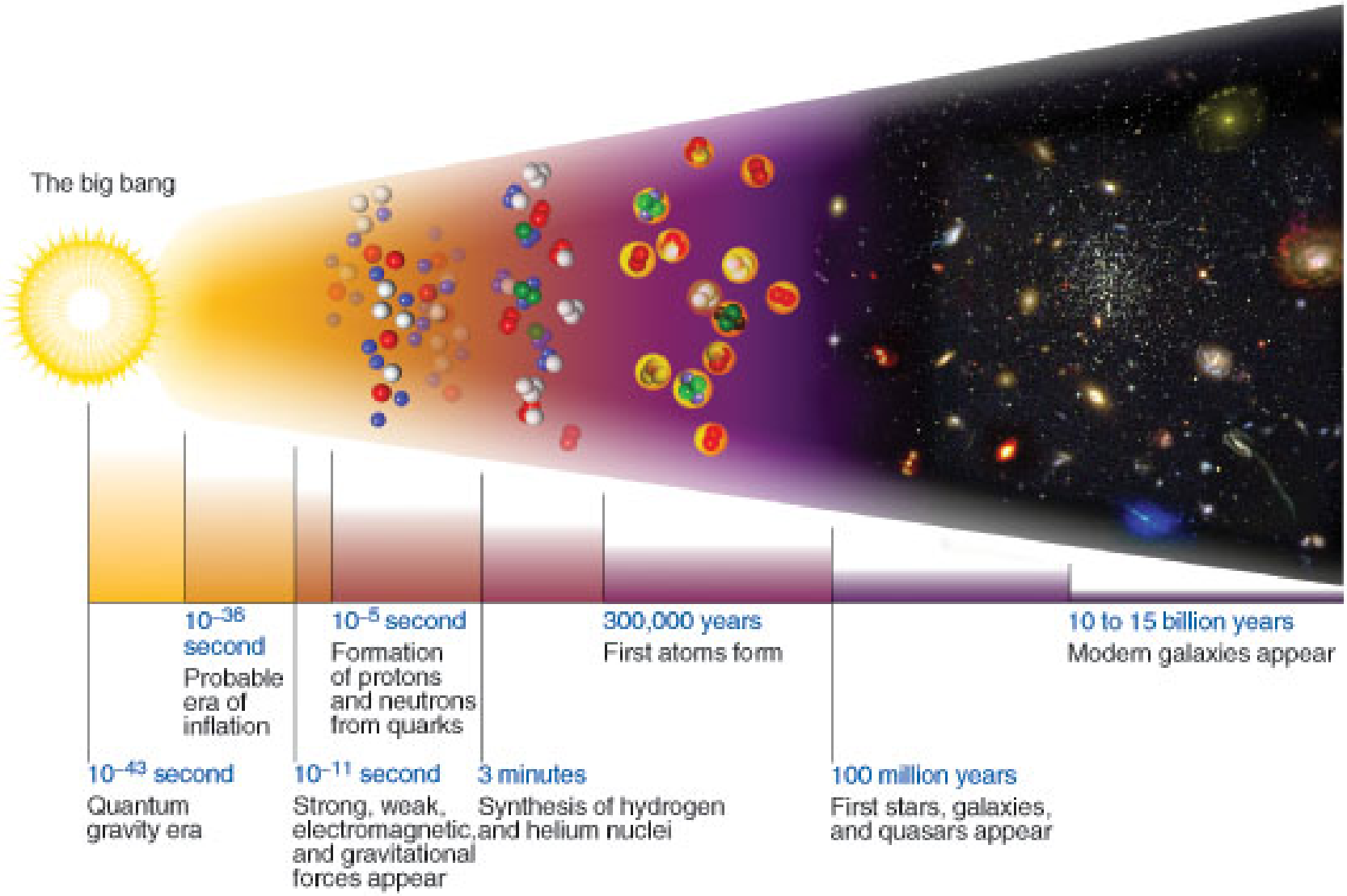




Our current best understanding of matter components:



Big Bang and Evolution of Universe



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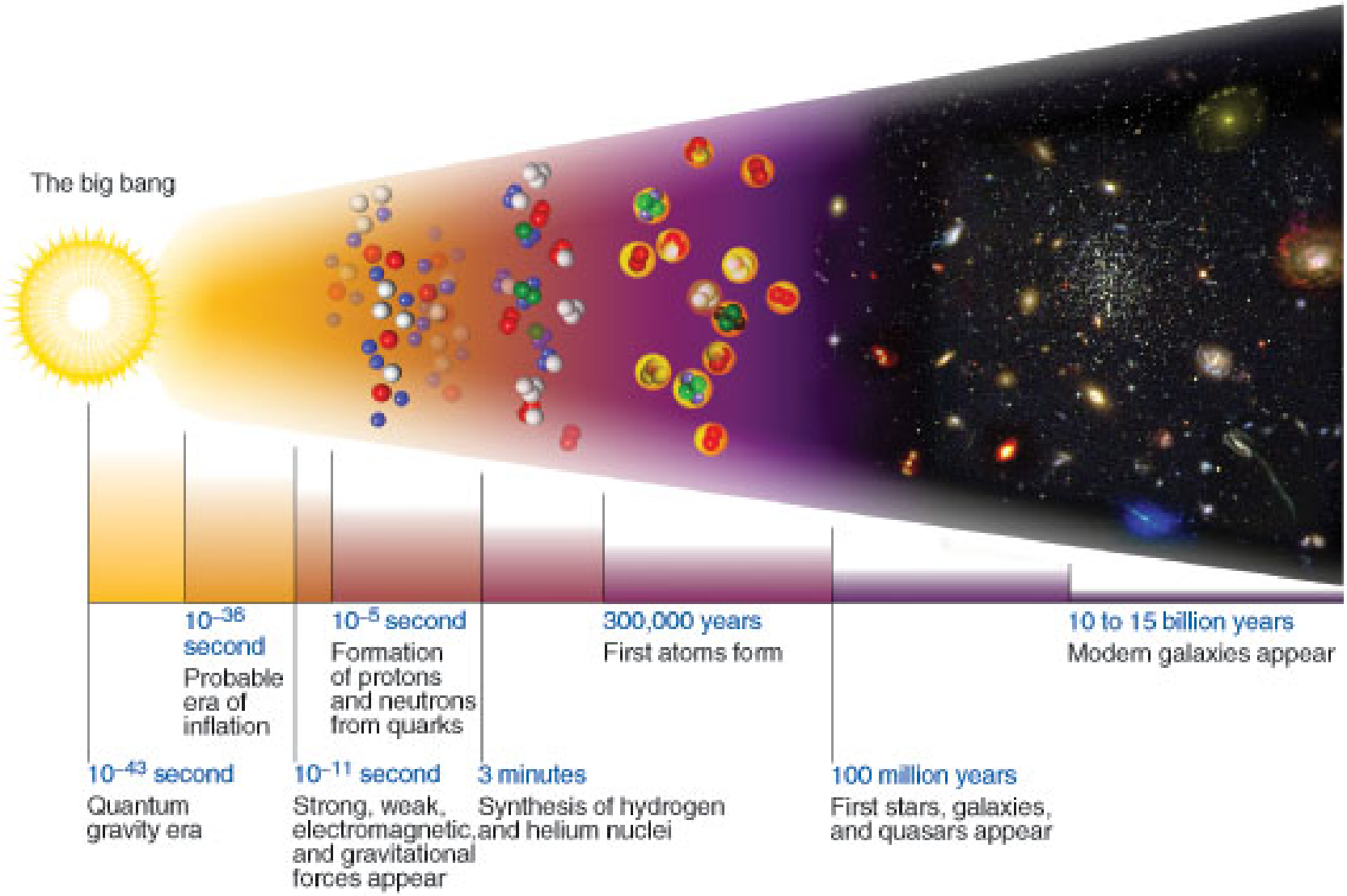
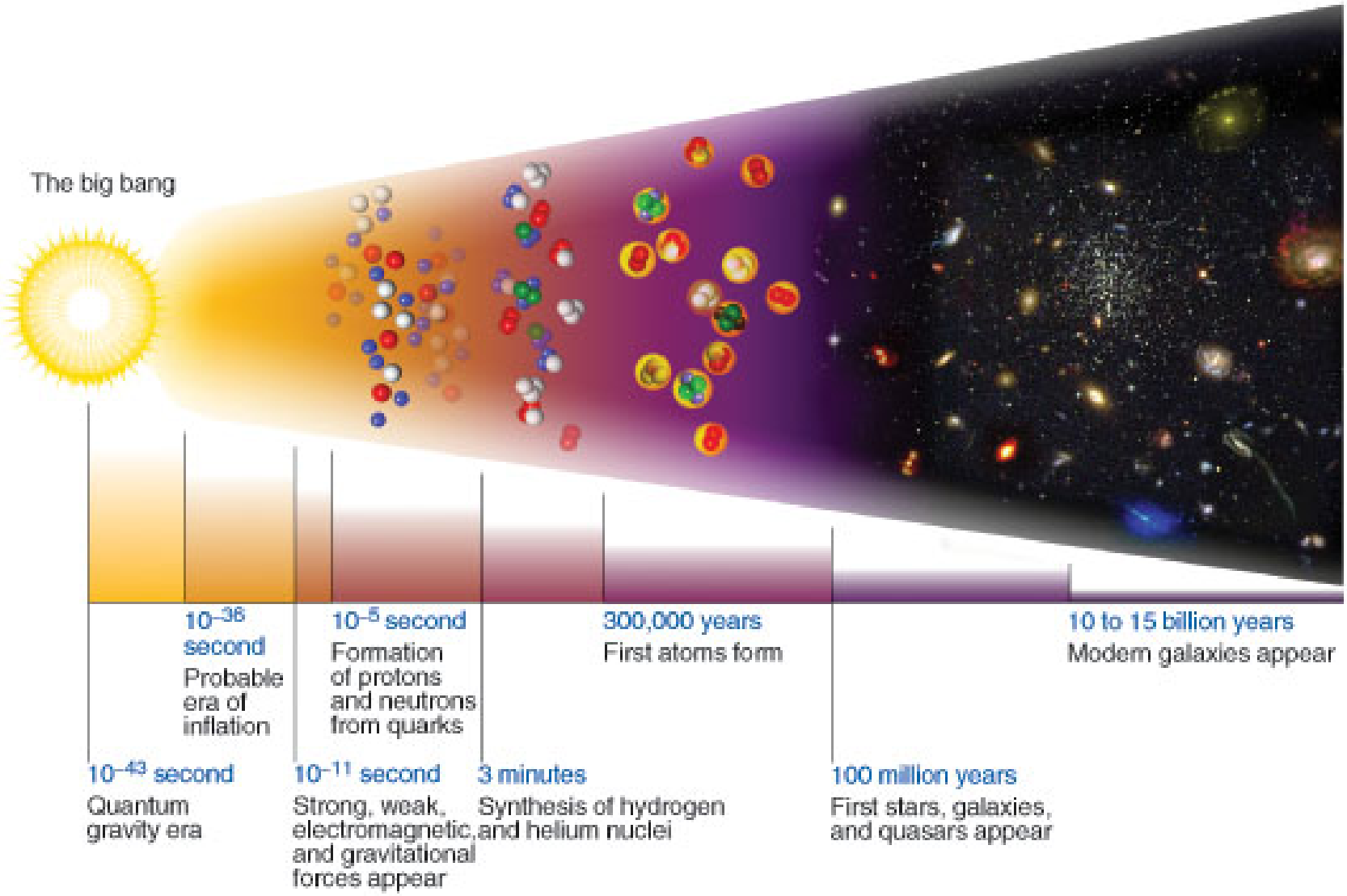


Quark-gluon plasma.

Big Bang and Evolution of Universe



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Matter-antimatter asymmetry riddle.

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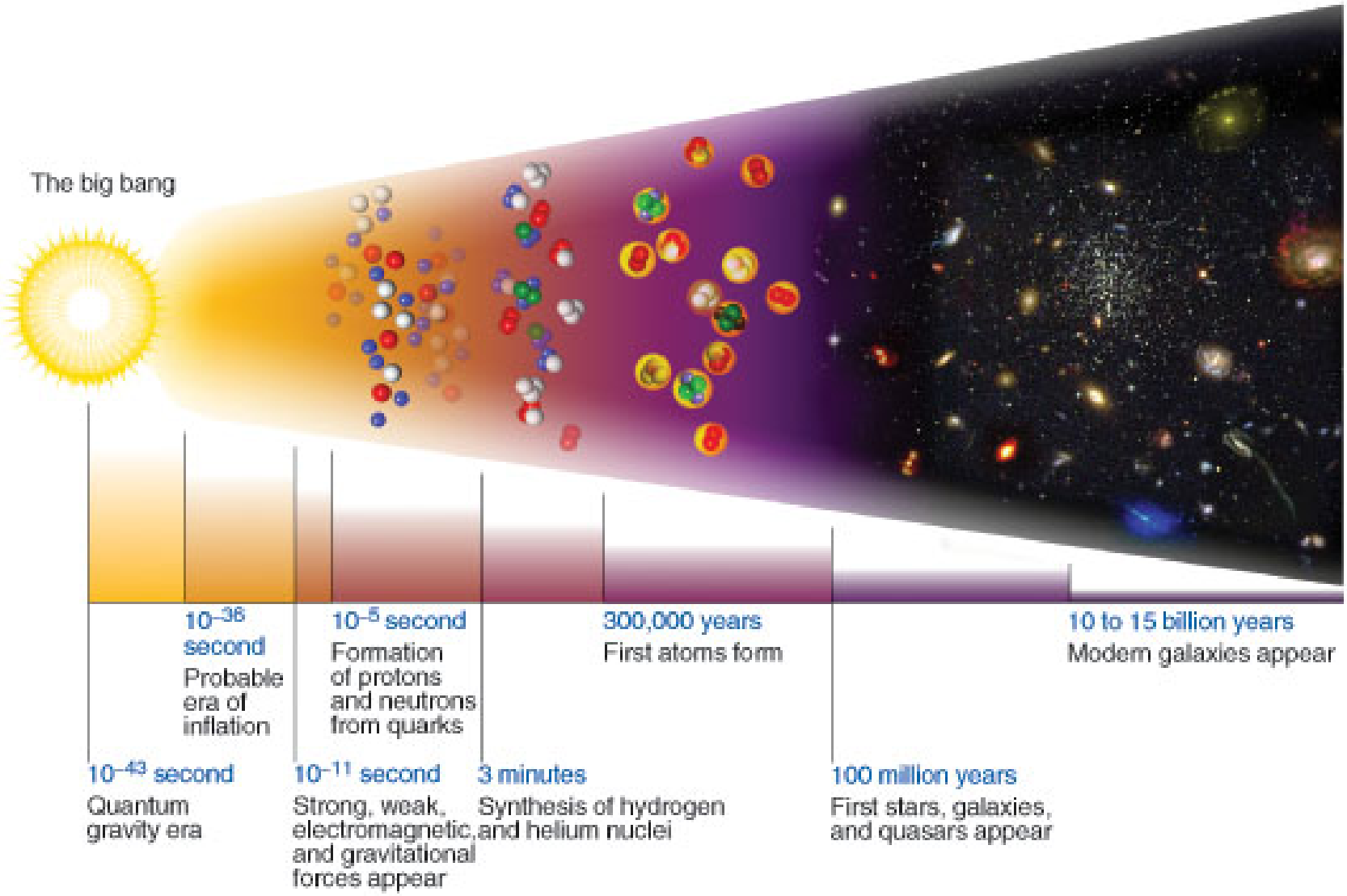

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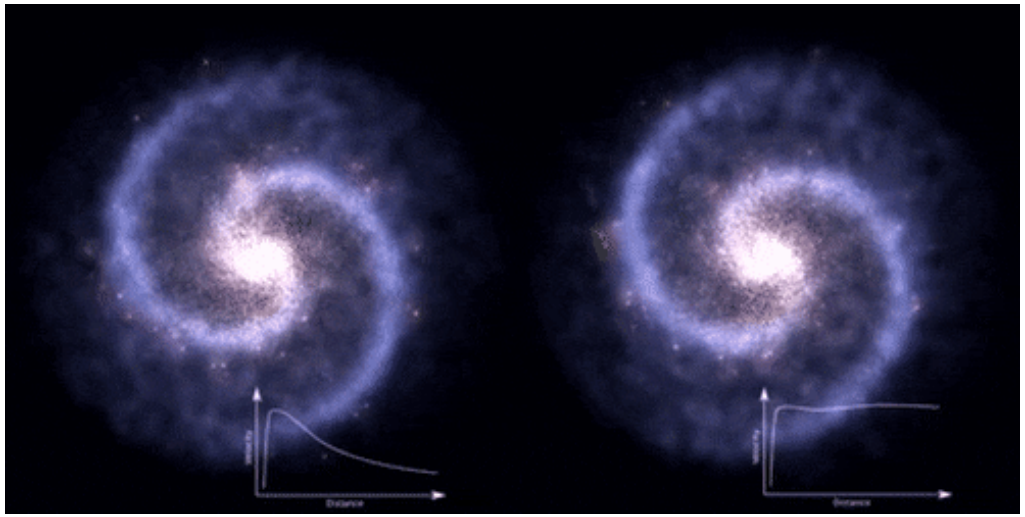
Open questions: inflation? origin and cause of Big Bang? era before Big Bang?

Components of Universe

Galaxies rotation – dark matter?



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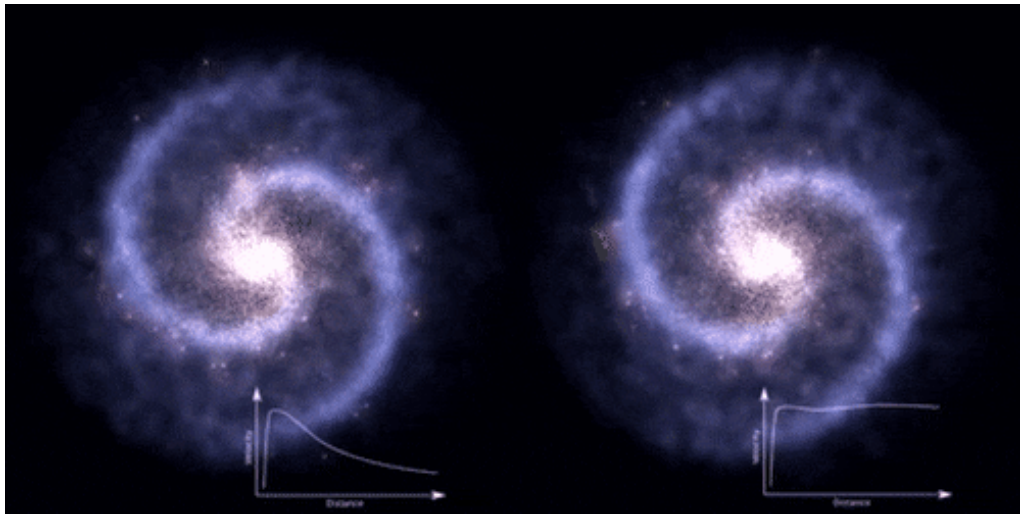
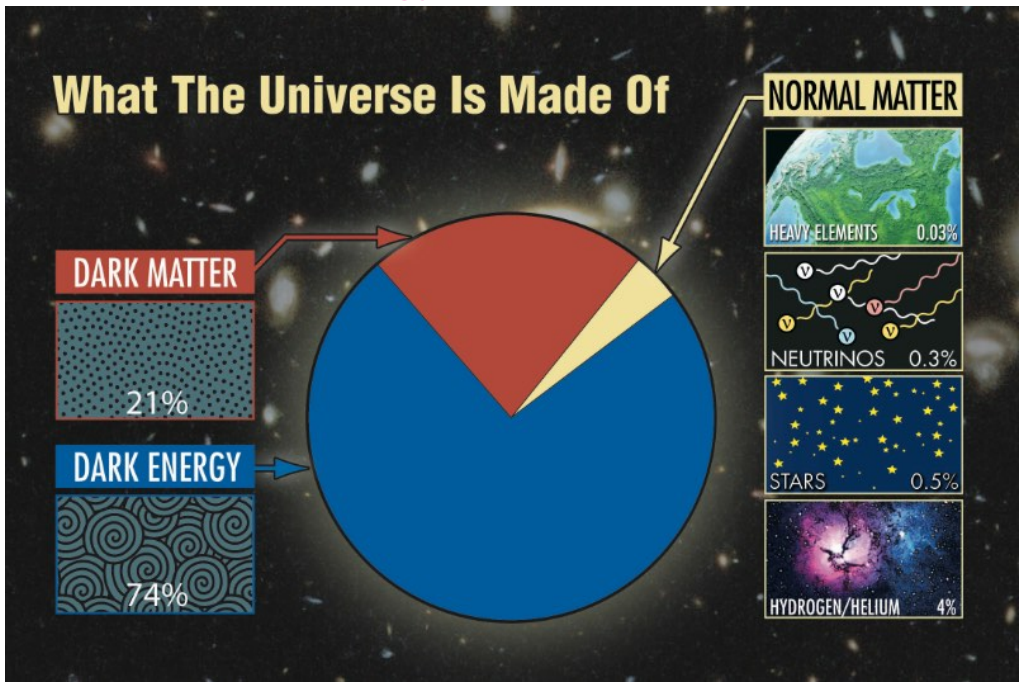


Expansion of Universe – dark energy?



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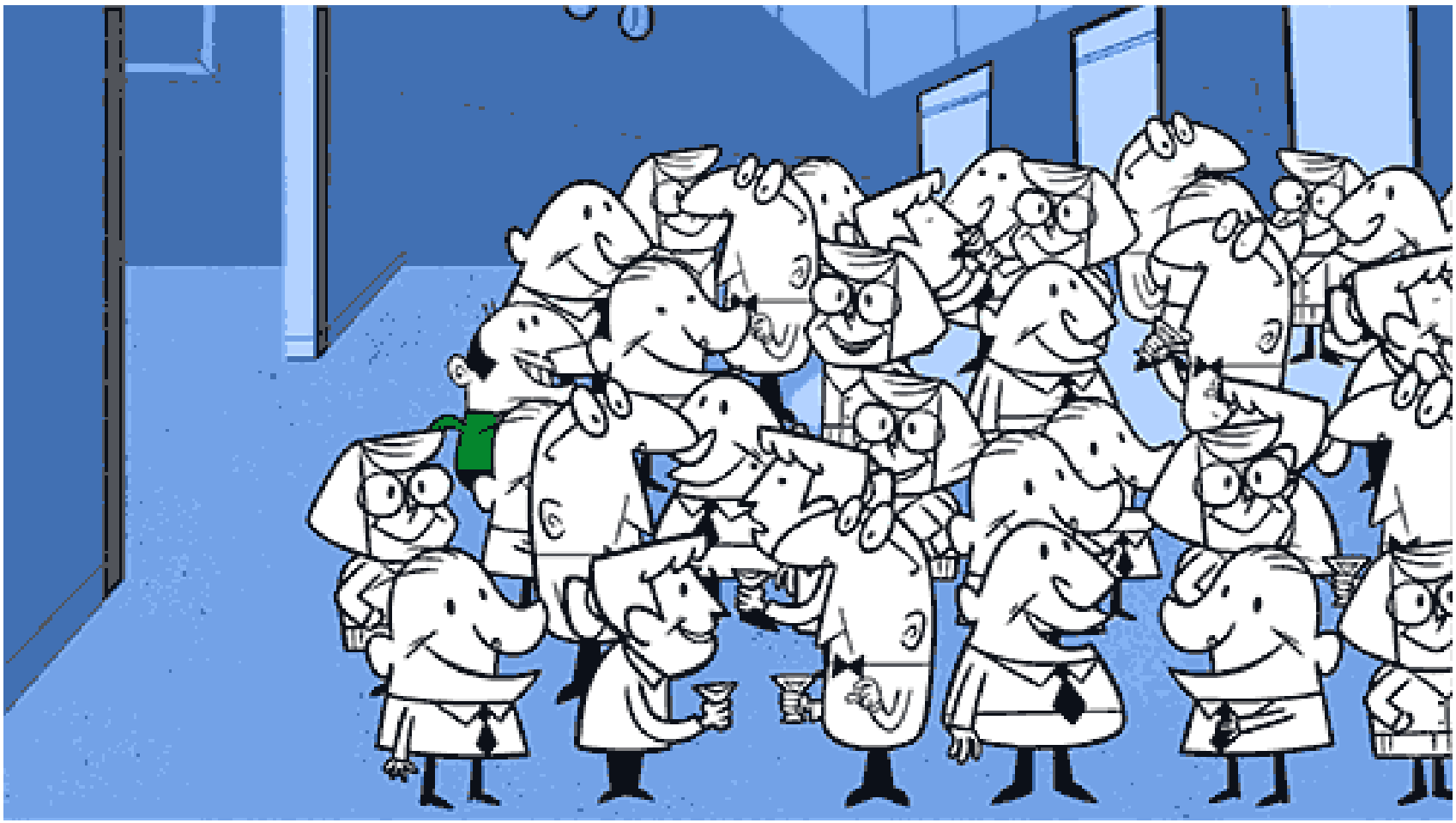

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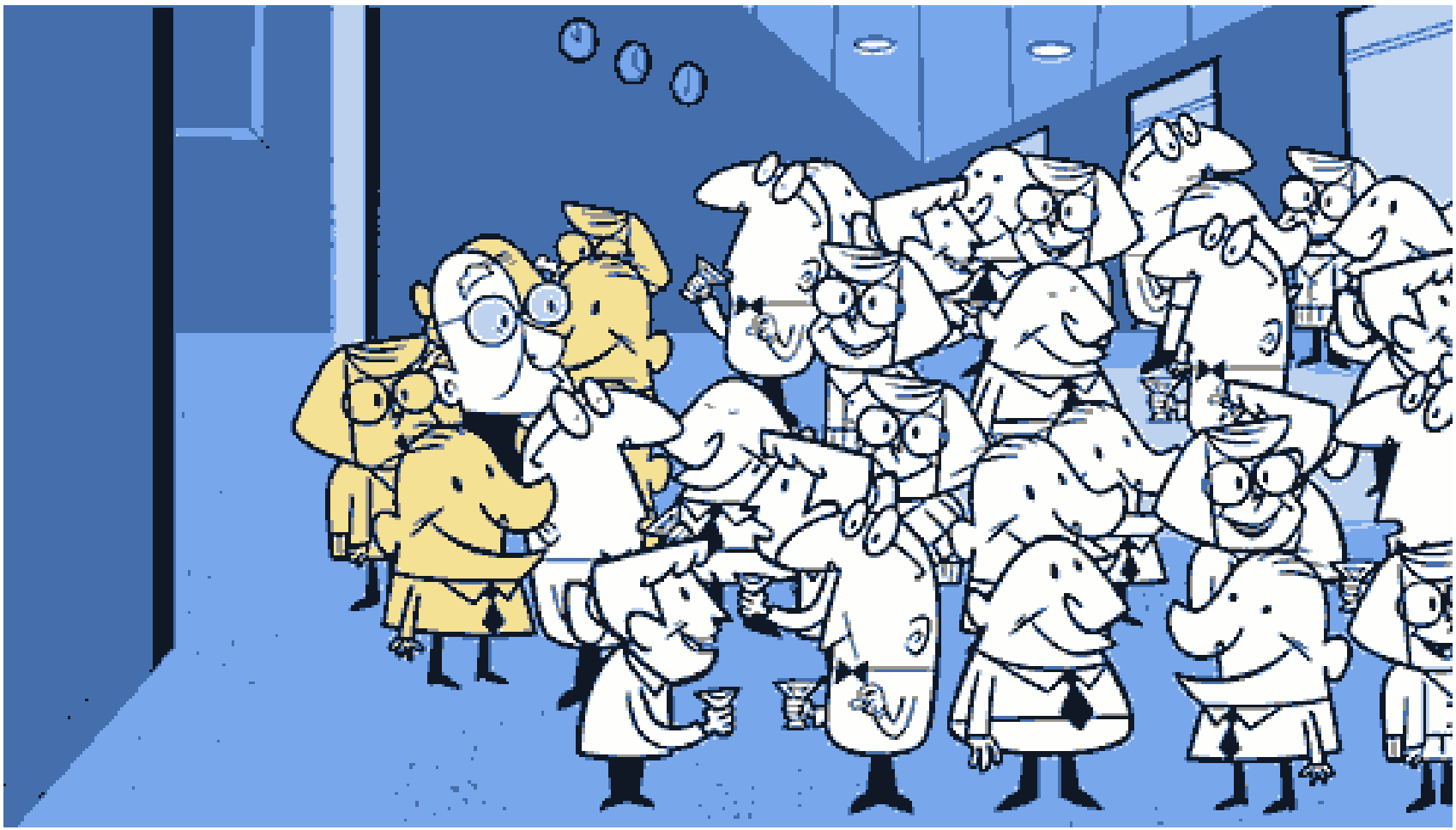

Analogy: the Higgs field $\rightarrow$ a room full of people

self interaction (fluctuation) of the Higgs field $\rightarrow$ the Higgs boson

CLASSICAL PHYSICS

ISAAC NEWTON

LAWS OF MOTION

LAW OF UNIVERSAL GRAVITATION

GRAVITY

ORBITS

CALCULUS

$\int x^2\,dx$ $\frac{dy}{dx}$

COSMOLOGY

ASTROPHYSICS

PRISM

OPTICS

REFLECTION
REFRACTION
DIFFRACTION

MICROSCOPE

TELESCOPE

CLASSICAL MECHANICS

WAVES

TRANSVERSE

LONGITUDINAL

ELECTRIC FIELDS

MAGNETIC FIELDS

JAMES CLERK MAXWELL

ELECTROMAGNETISM

FLUID MECHANICS

FLOW

LIFT

AERODYNAMICS

ELECTRICITY

LIGHT

THERMODYNAMICS

ENERGY

HEAT

TEMPERATURE

ENTROPY

CHAOS THEORY

RELATIVITY

CONSTANT SPEED OF LIGHT

ALBERT EINSTEIN

GENERAL THEORY OF RELATIVITY

SPECIAL THEORY OF RELATIVITY

$E=mc^2$

TIME

SPACE

SPACETIME

PHILOSOPHY

PHILOSOPHY OF SCIENCE

FREE WILL

HOW COME?

NATURE OF REALITY

JUST... WHY?

THE CHASM OF IGNORANCE

THE FUTURE

QUANTUM GRAVITY

STRING THEORY

LOOP QUANTUM GRAVITY

DARK ENERGY

DARK MATTER

AND MANY MORE...

QUANTUM PHYSICS

QUANTUM FIELD THEORY

QUANTUM ELECTRO DYNAMICS

THE STANDARD MODEL

ATOMIC THEORY

NUCLEAR PHYSICS

FISSION

FUSION

CONDENSED MATTER PHYSICS

QUANTUM INFORMATION

COMPUTERS

LASERS

PARTICLE PHYSICS

YOUTUBE.COM/USER/DOMINICWALLIMAN @DOMINICWALLIMAN

Fundamental problems:

- When?
- Why?
- How?
- Components?
- Principles?

High Energy Physics addresses these questions by studying the behaviour of the Nature at the smallest possible distances, where its elementary ingredients interact.

- Structure of matter?
- Mass hierarchy?
- Particle interactions?

'Tools' in Our Workshop

Source of data:

- cosmic rays,
- particle accelerators and decelerators,
- neutrino beams.

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Other important 'side' systems:

- trigger,
- slow control,
- data acquisition,
- ...

Particle Production at the Interaction Point

How one can produce all these new particles?

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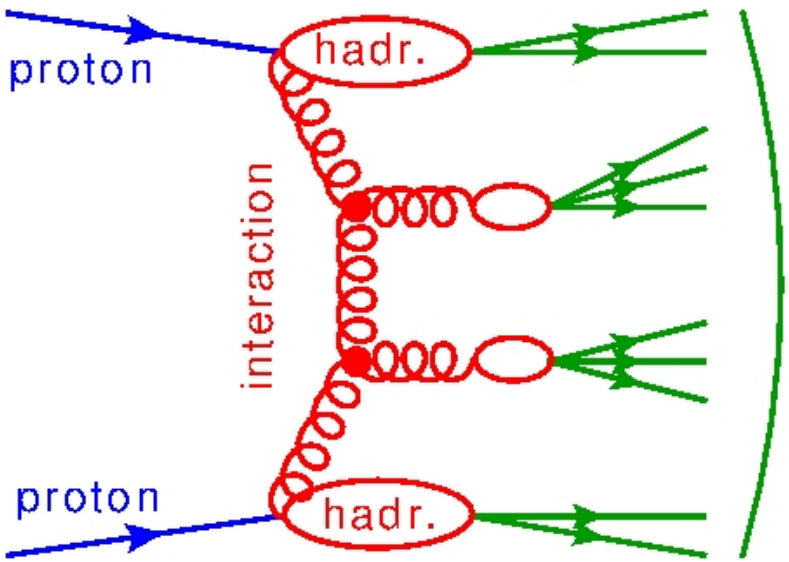

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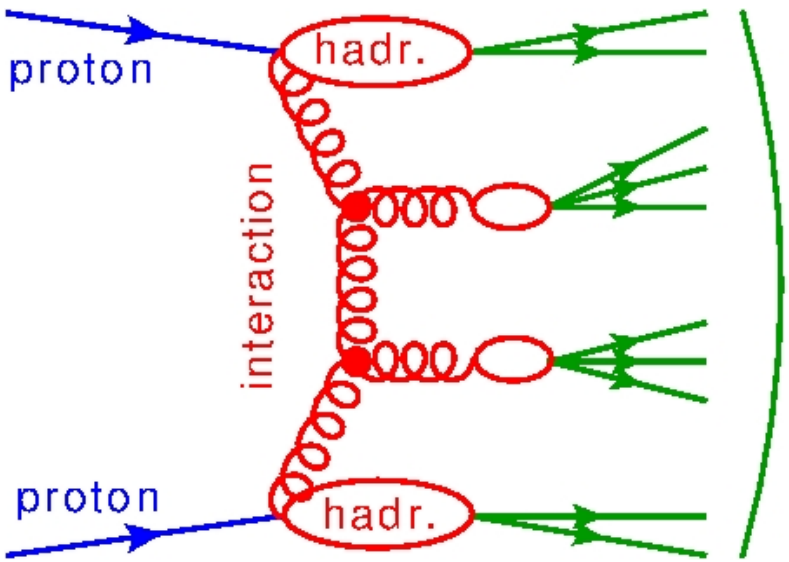

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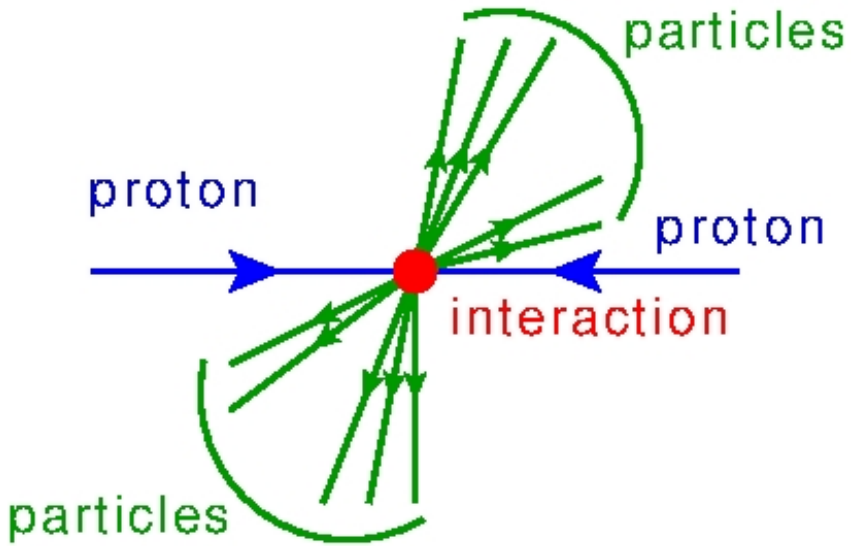

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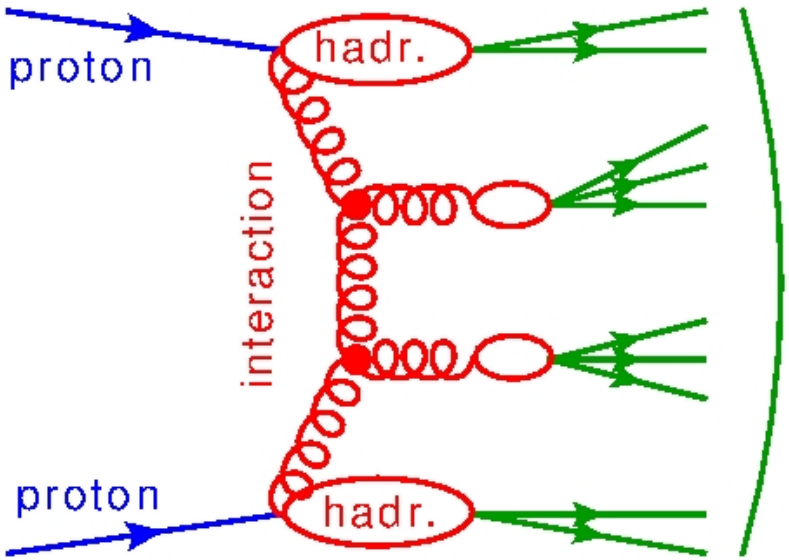

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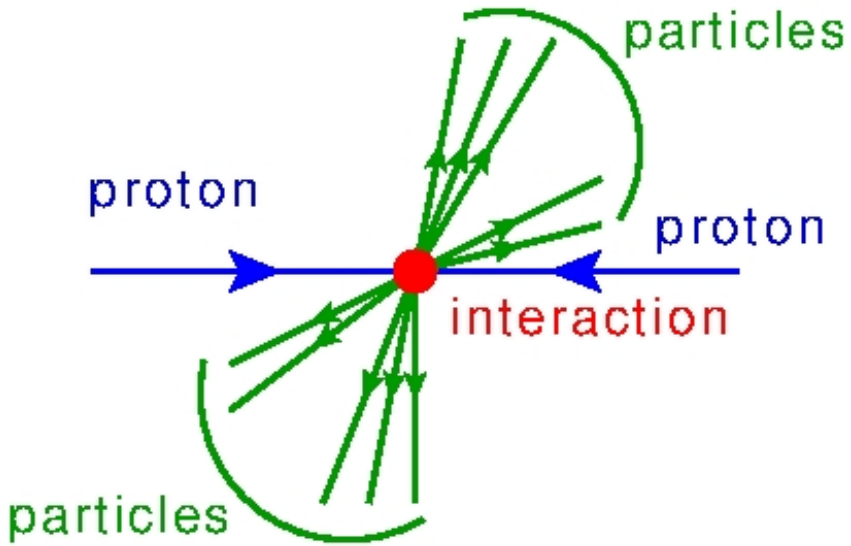

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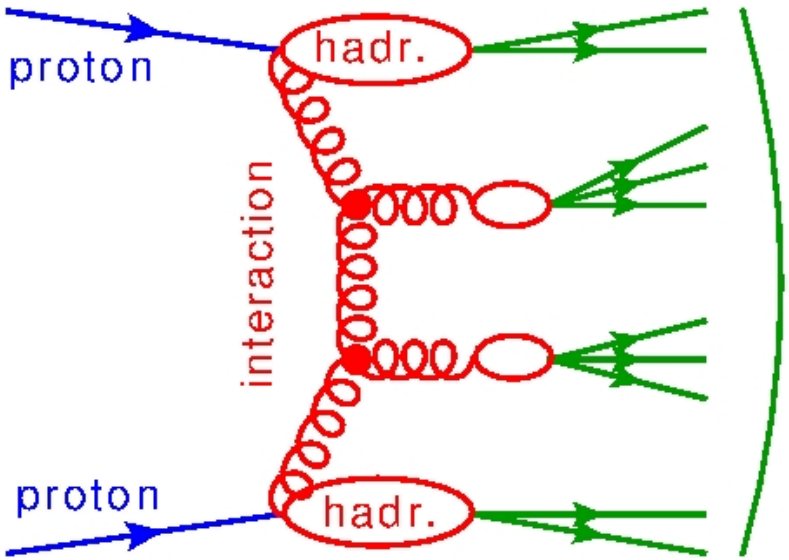

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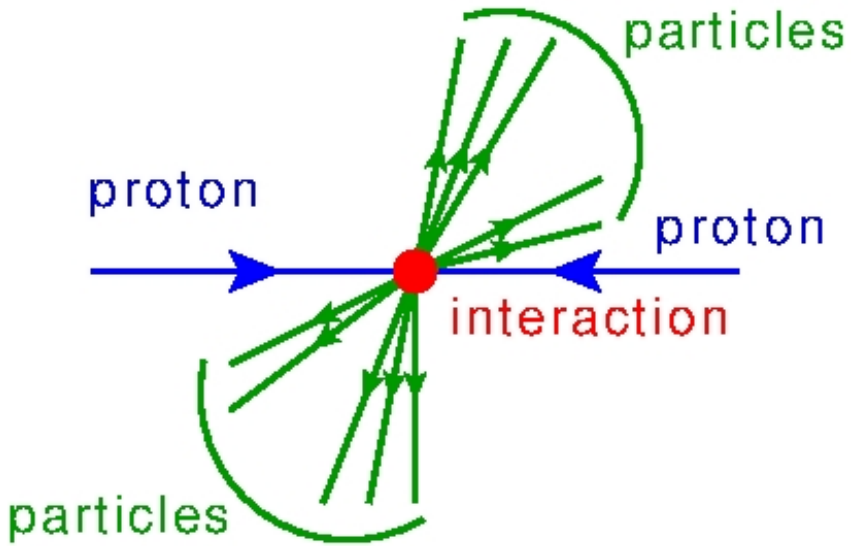

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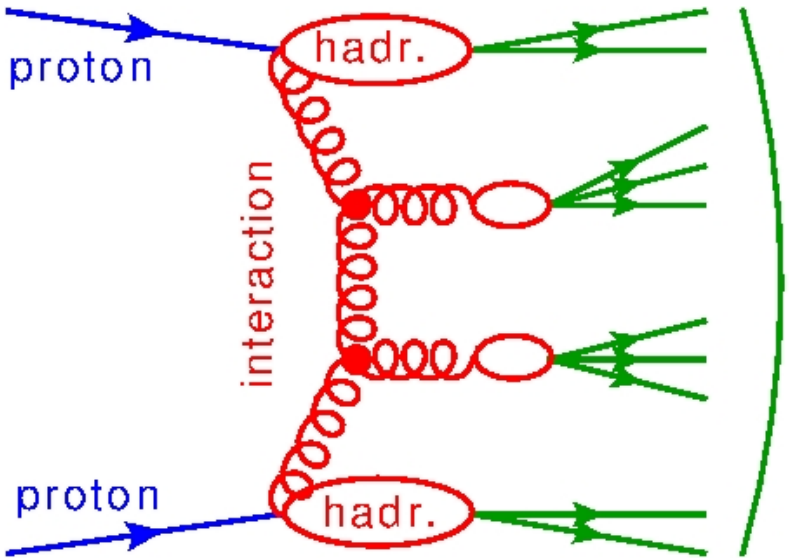

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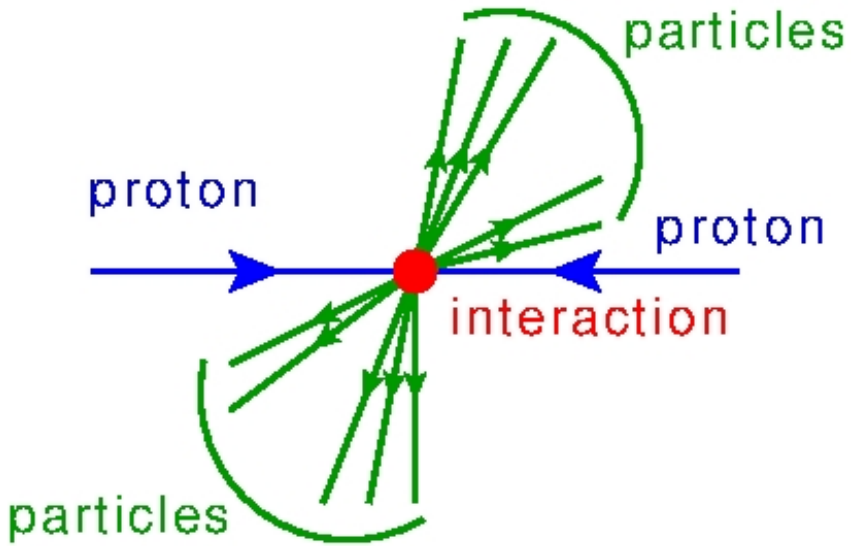


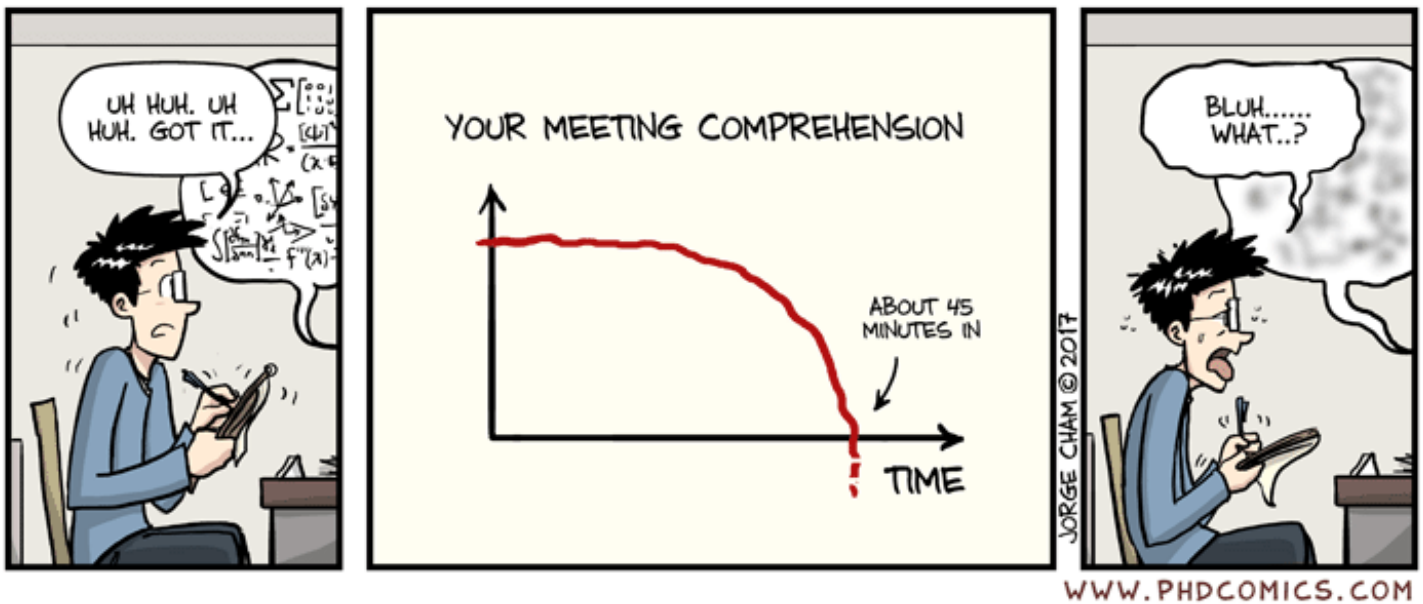
We cannot directly see what happened in the interaction point

BUT

by studying behaviour and properties of products we can make conclusions.

Intermezzo

do not take this part (too) seriously :)



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End of Intermezzo

lets focus again :)

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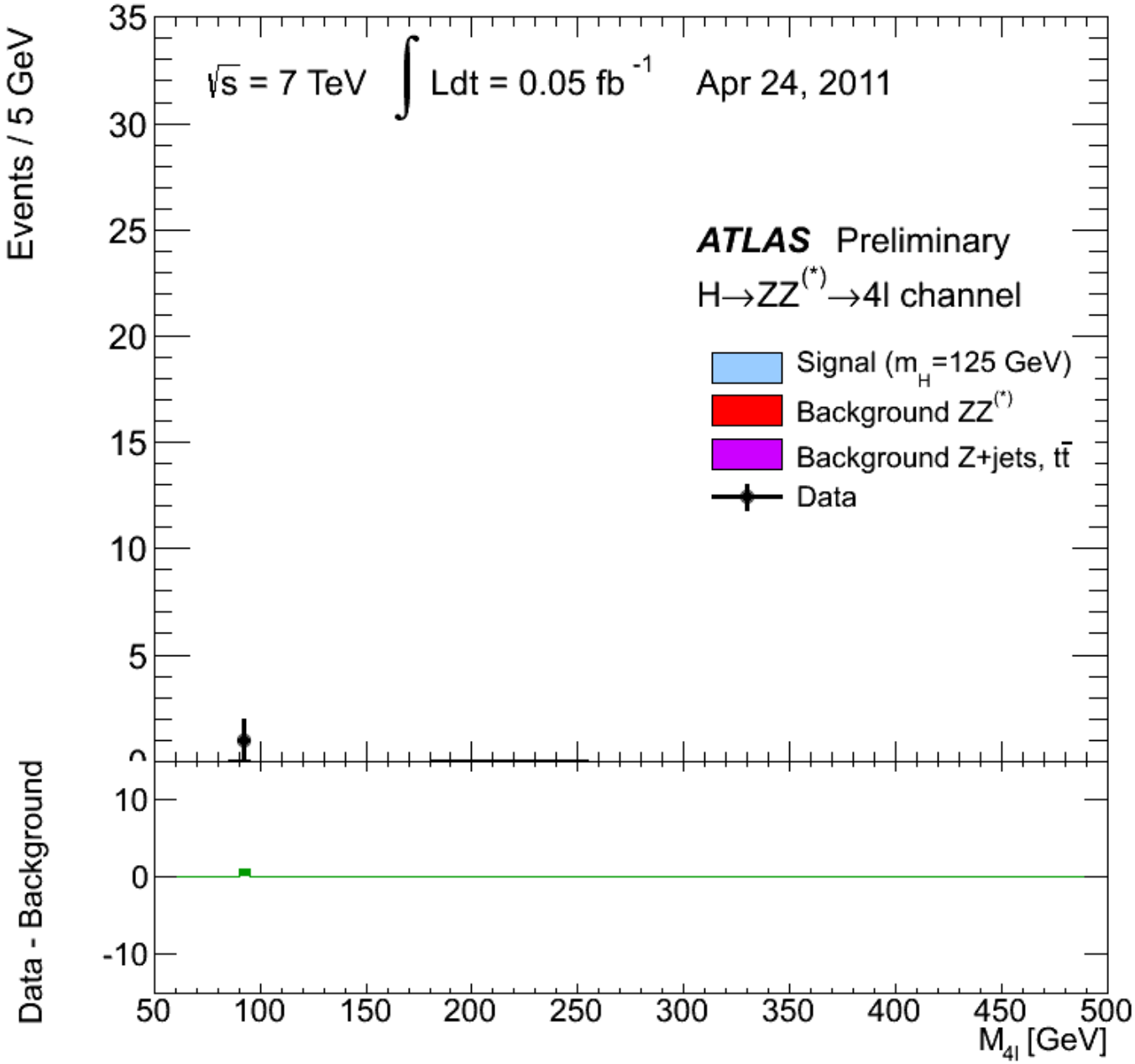
Now it is more like two years!

Finally – The Dreamed Result



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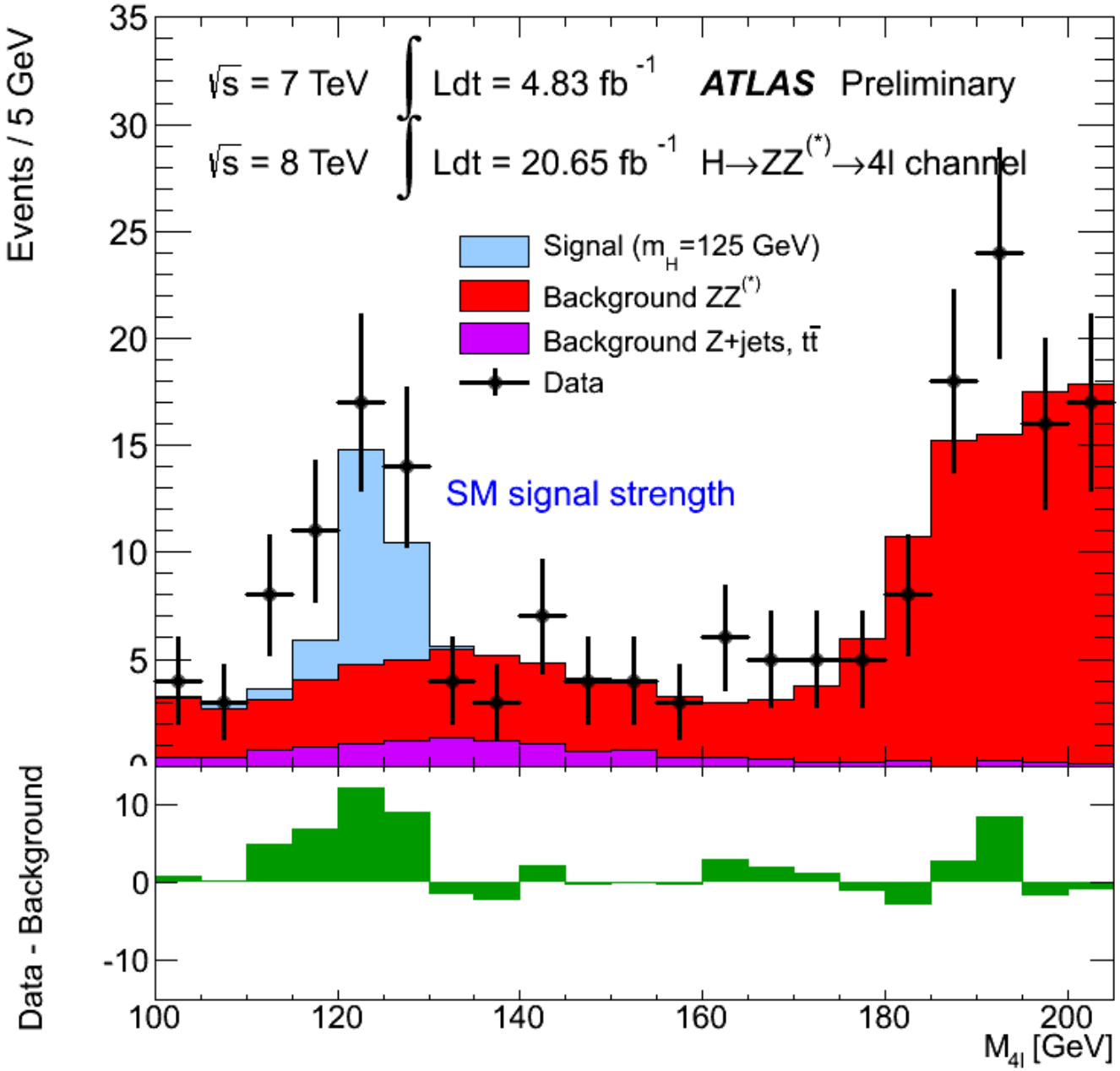

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Michael Faraday

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I have steadily endeavoured to keep my mind free so as to give up any hypothesis, however much beloved (and I cannot resist forming one on every subject) as soon as facts are shown to be opposed to it... I cannot remember a single first formed hypothesis which had not after a time to be given up or be greatly modified.

Charles Darwin

Straight Way to Make a Discovery?

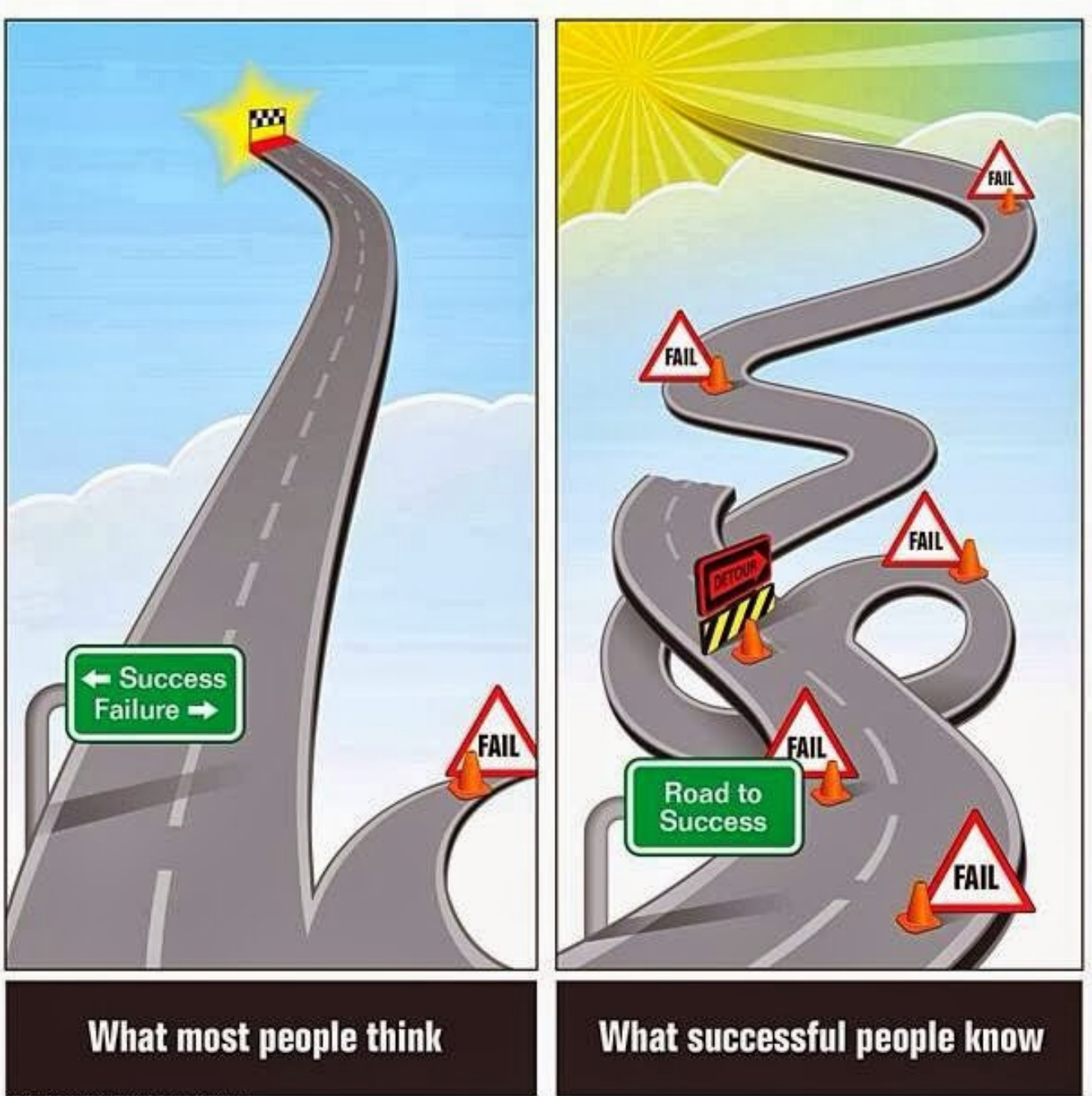
In 1891 I have been able to solve a few problems in mathematics and physics including some that the great mathematicians had puzzled over in vain from Euler onwards... But any pride I might have felt in my conclusions was perceptibly lessened by the fact I knew that the solution of these problems had almost always come to me as a gradual generalisation of favourable examples, by a series of fortunate conjectures, after many errors.

I am fain to compare myself with a wanderer on the mountains who, not knowing the path, climbs slowly and painfully upwards and often has to retrace his steps because he can go no further – then, whether by taking thought or from luck, discovers a new track that leads him on a little till at length when he reaches the summit he finds to his shame that there is a royal road, by which he might have ascended, had he only had the wits to find the right approach to it.

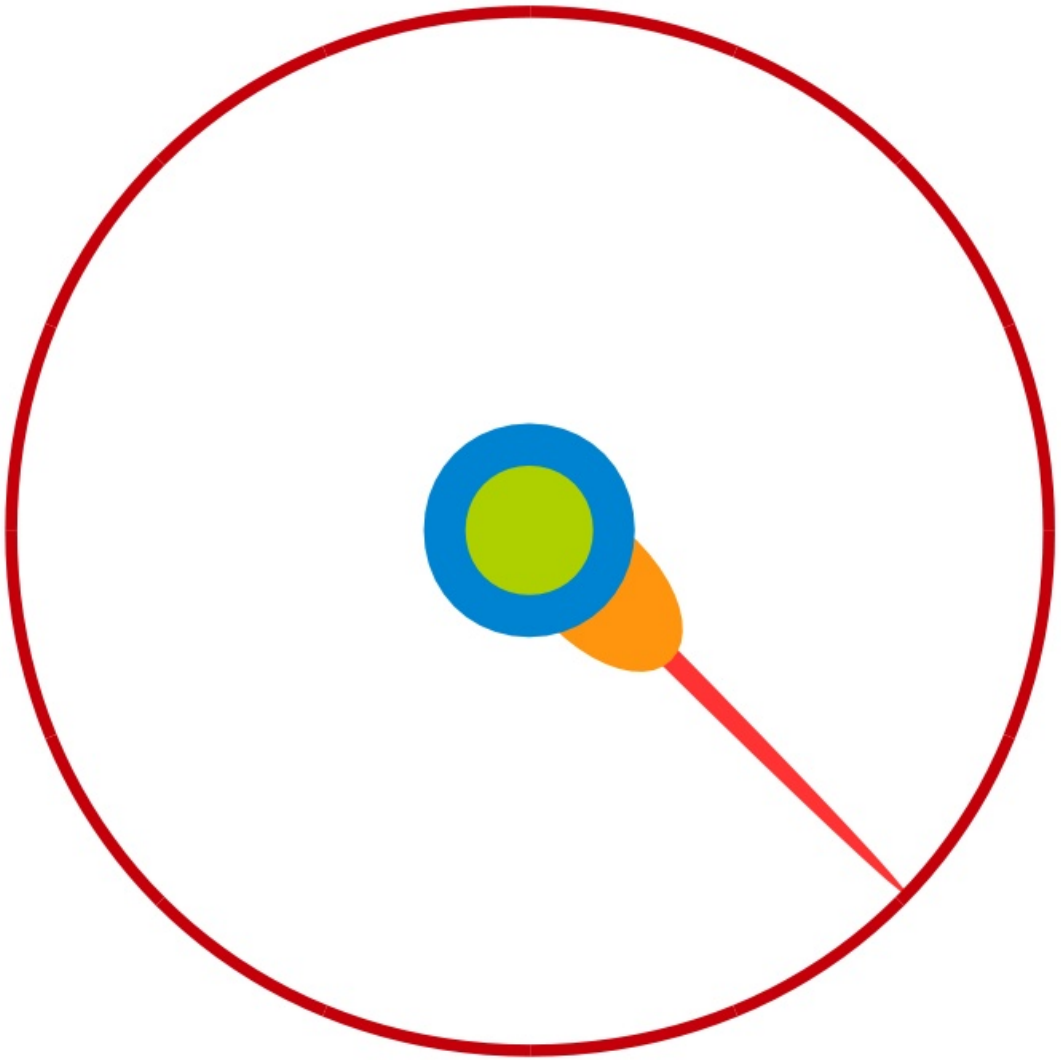
In my works, I naturally said nothing about my mistake to the reader, but only described the made track by which he may now reach the same heights without difficulty.

Hermann Helmholtz

Straight Way to Make a Discovery?



Big Goal: Broaden Our Knowledge!



Everything humanity knows

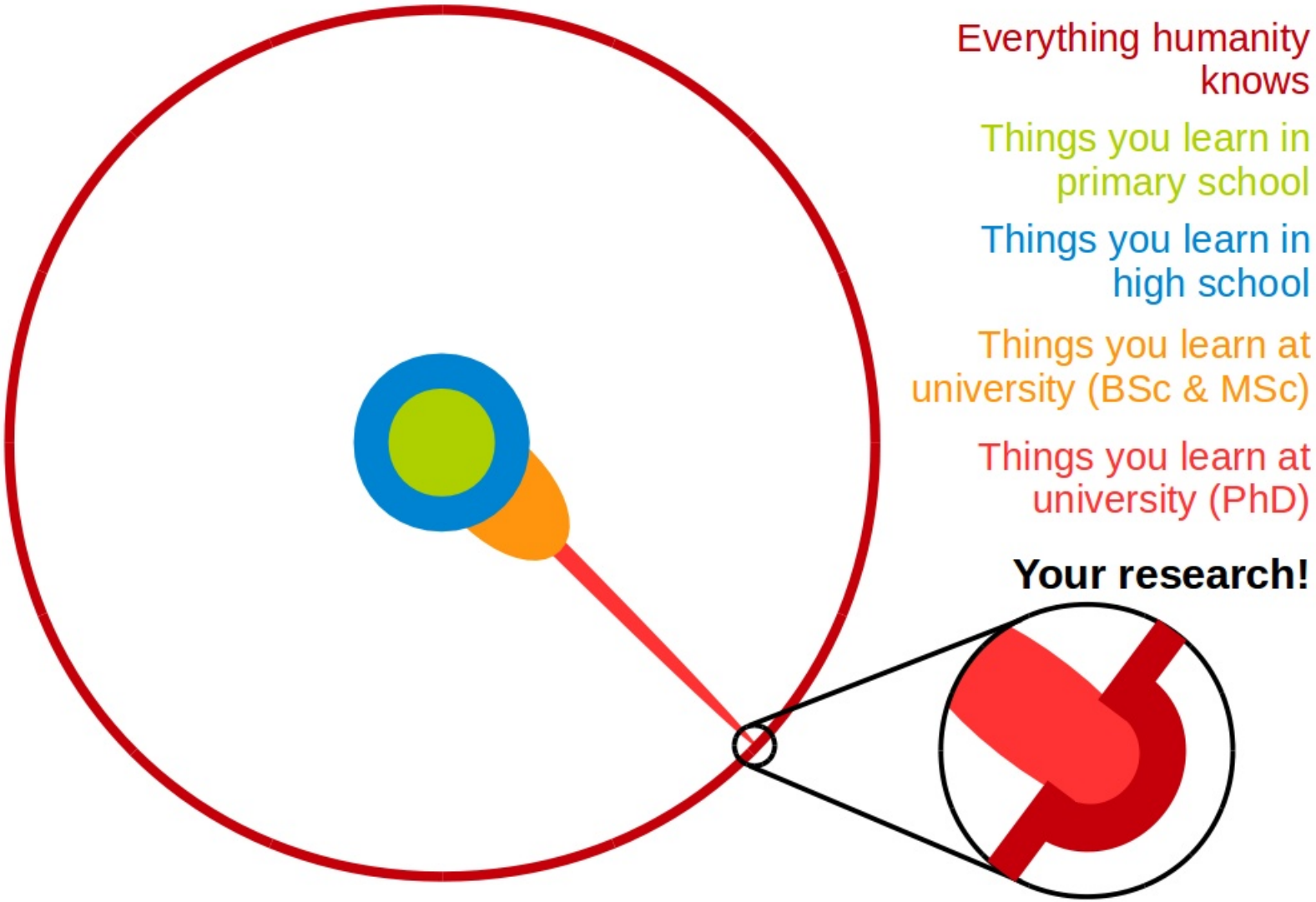
Things you learn in primary school

Things you learn in high school

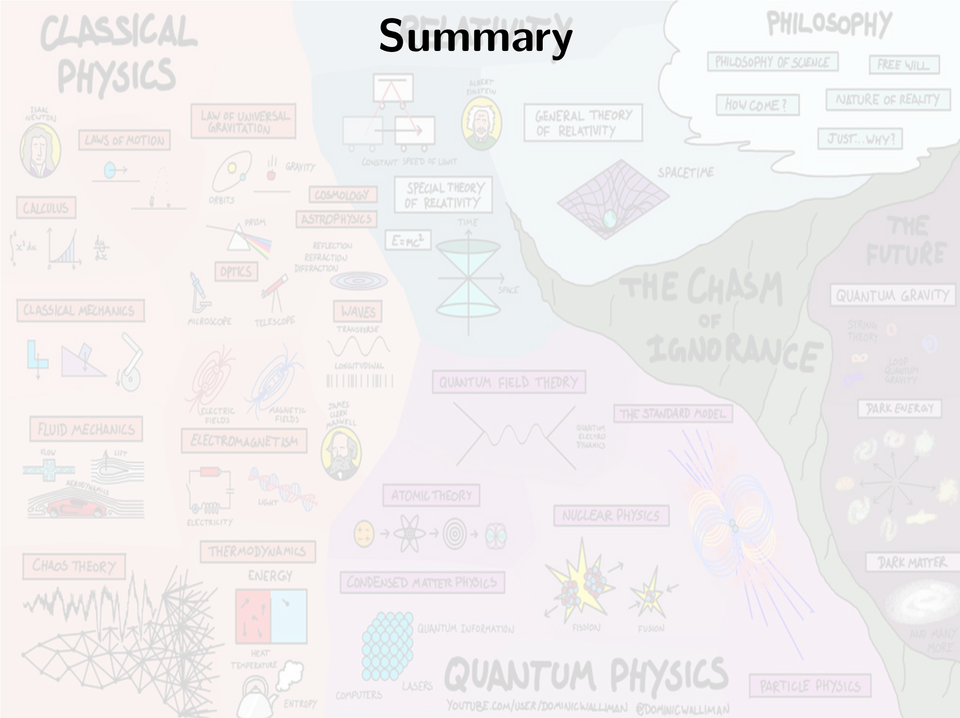
Things you learn at university (BSc & MSc)

Things you learn at university (PhD)

Big Goal: Broaden Our Knowledge!



Summary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$\frac{dy}{dx}$
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PARTICLE PHYSICS
YOUTUBE.COM/USER/DOMINICWALLIMAN @DOMINICWALLIMAN

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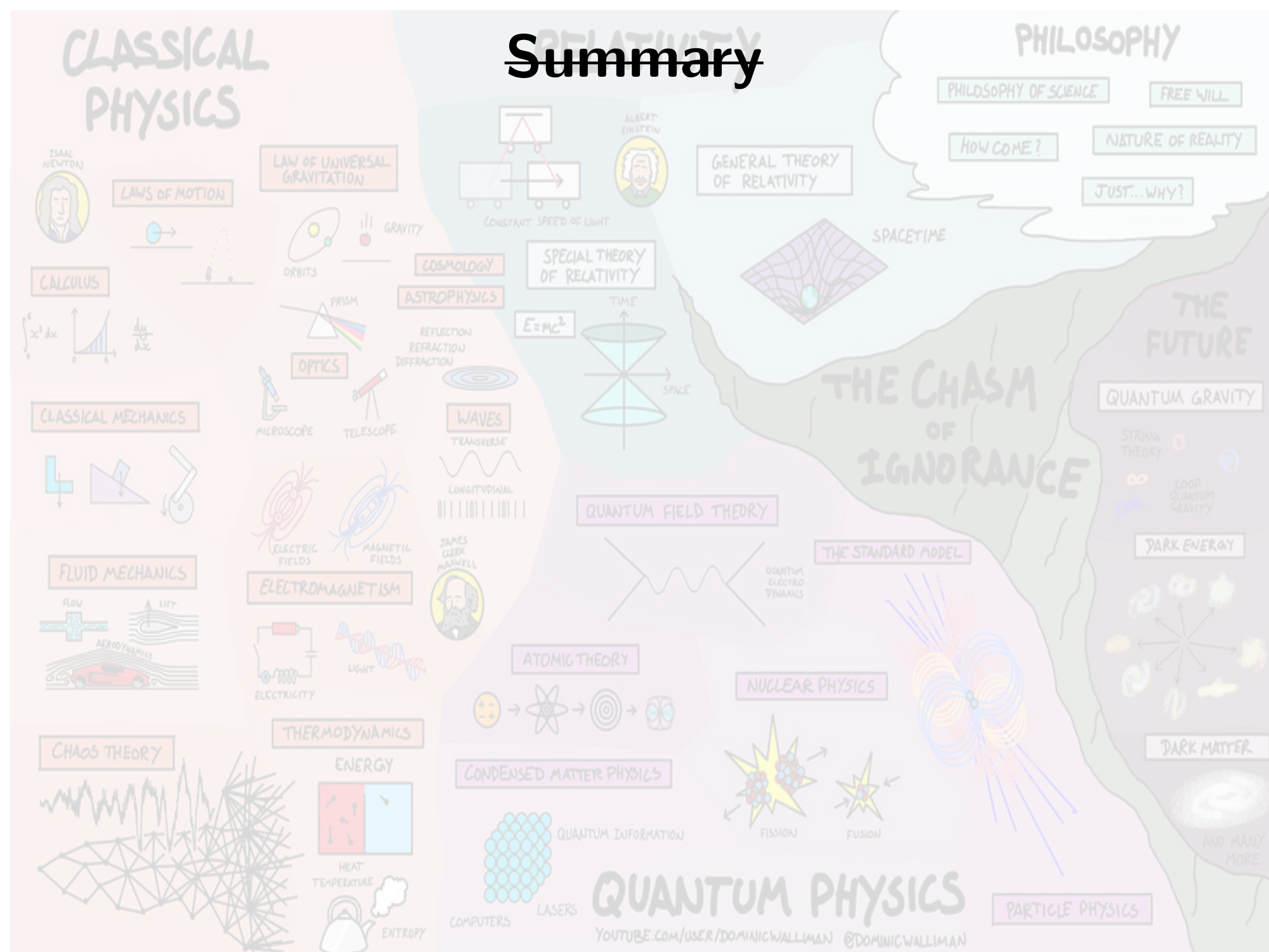
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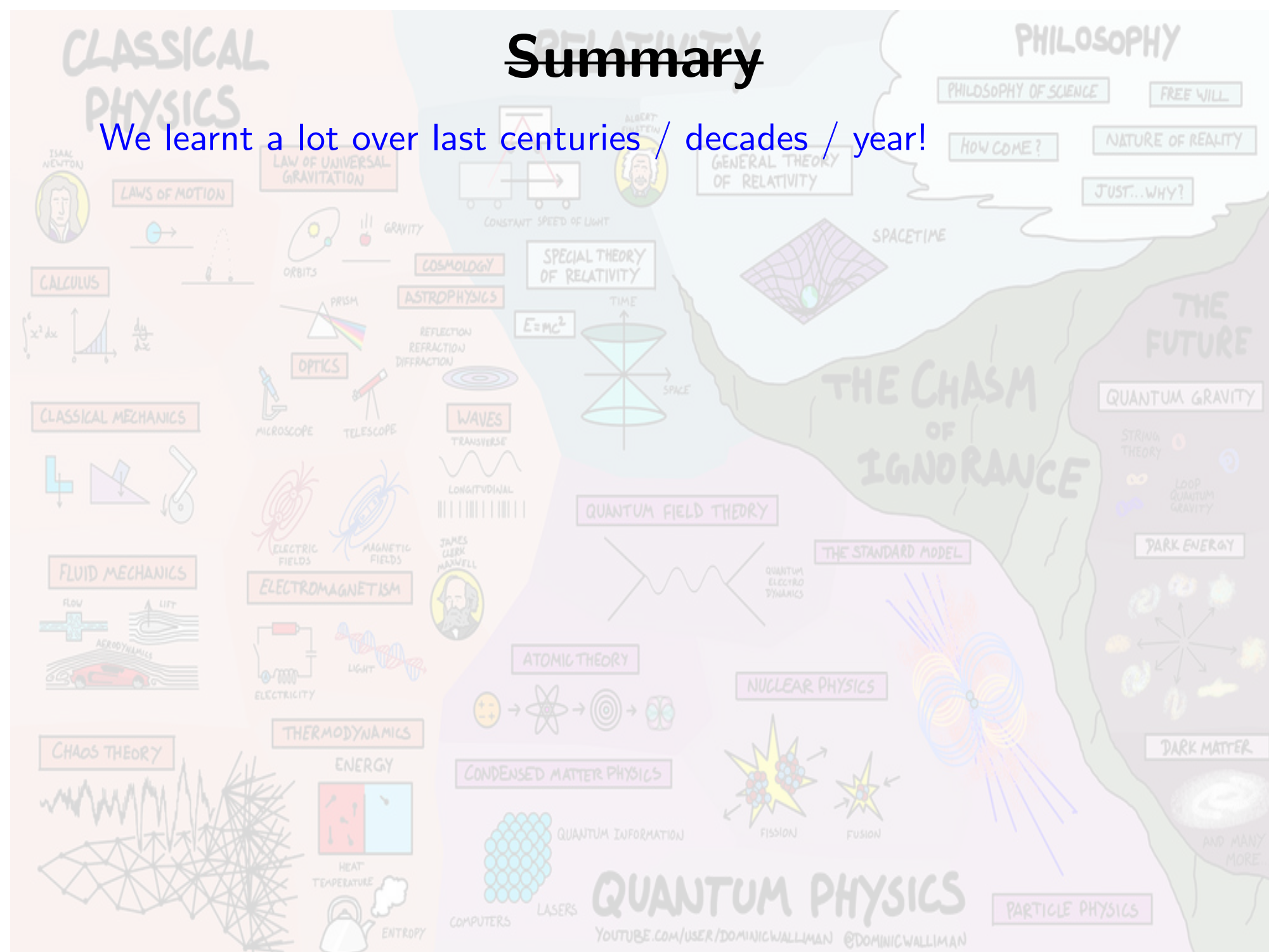
We learnt a lot over last centuries / decades / year!



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However, it seems that the more we learn the more questions appear!

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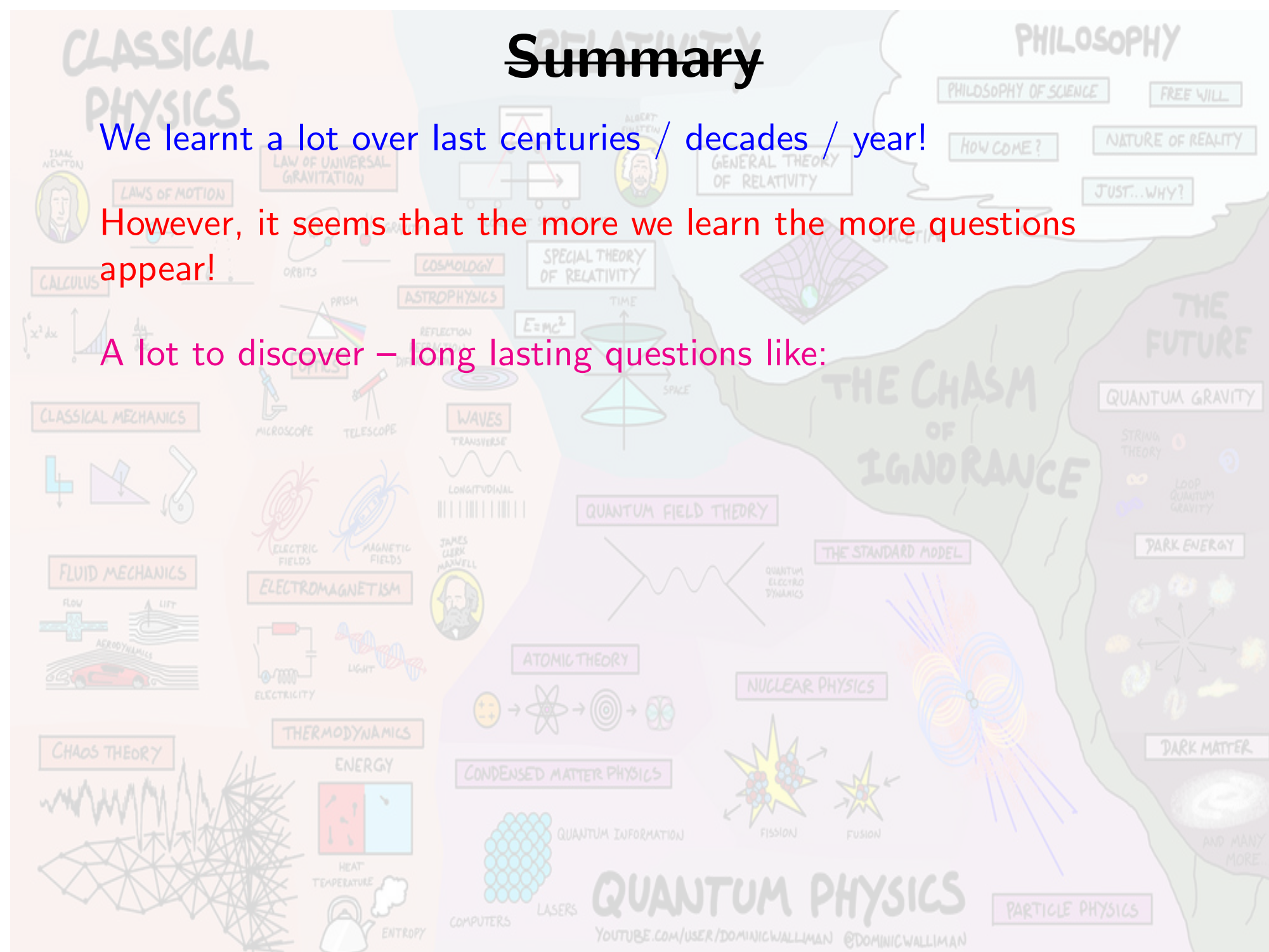

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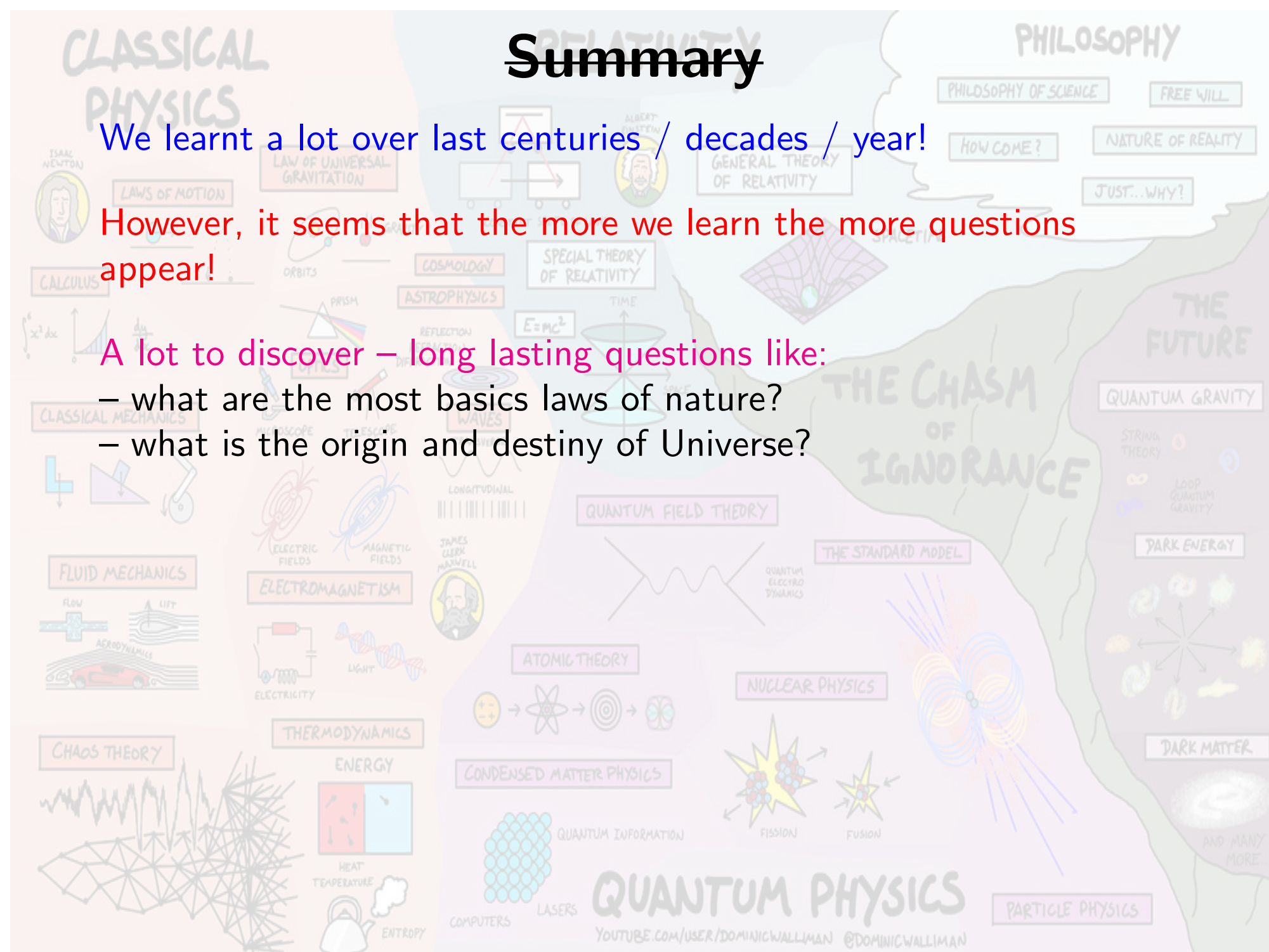

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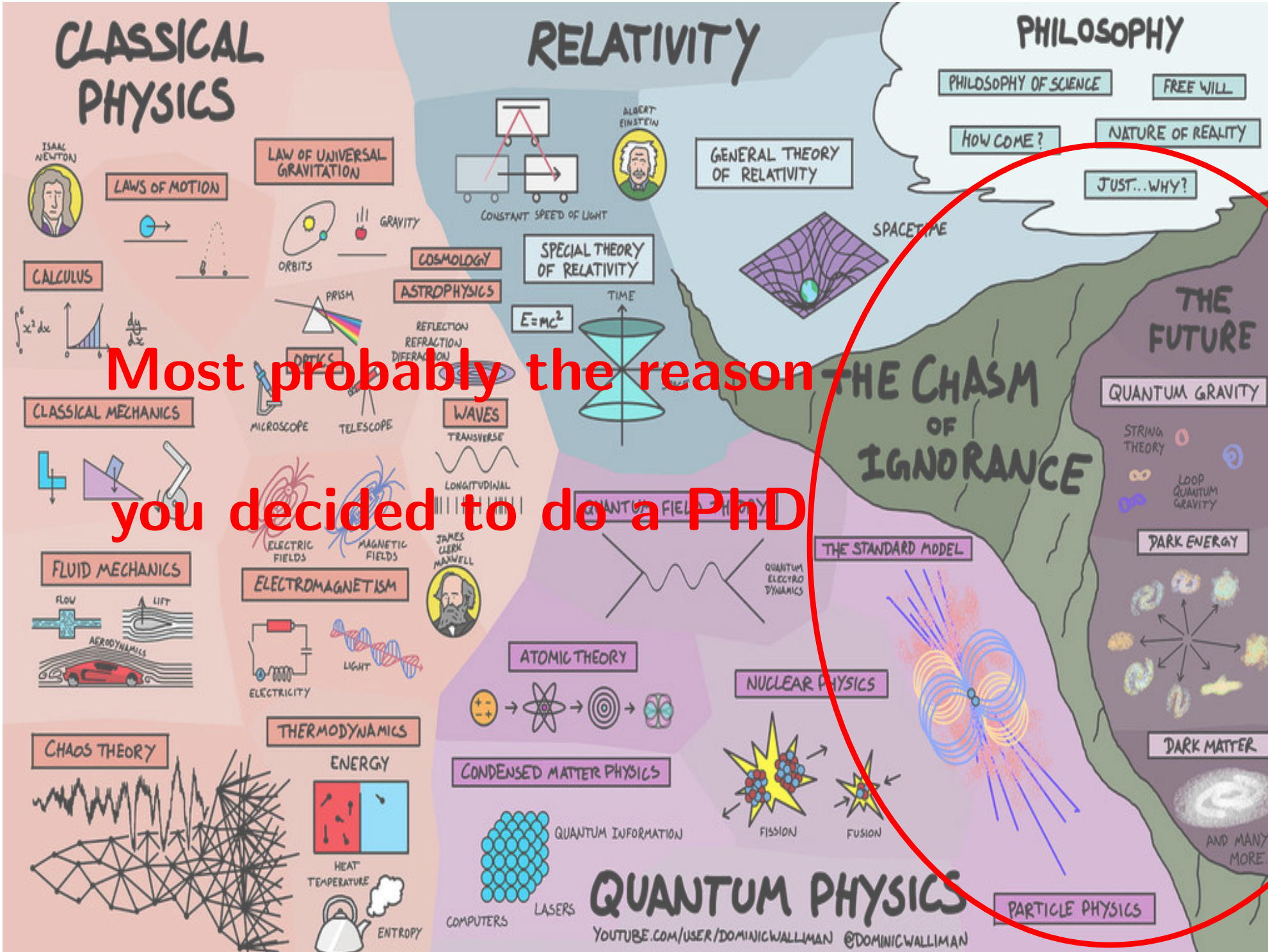
Tools: particle accelerators and detectors.

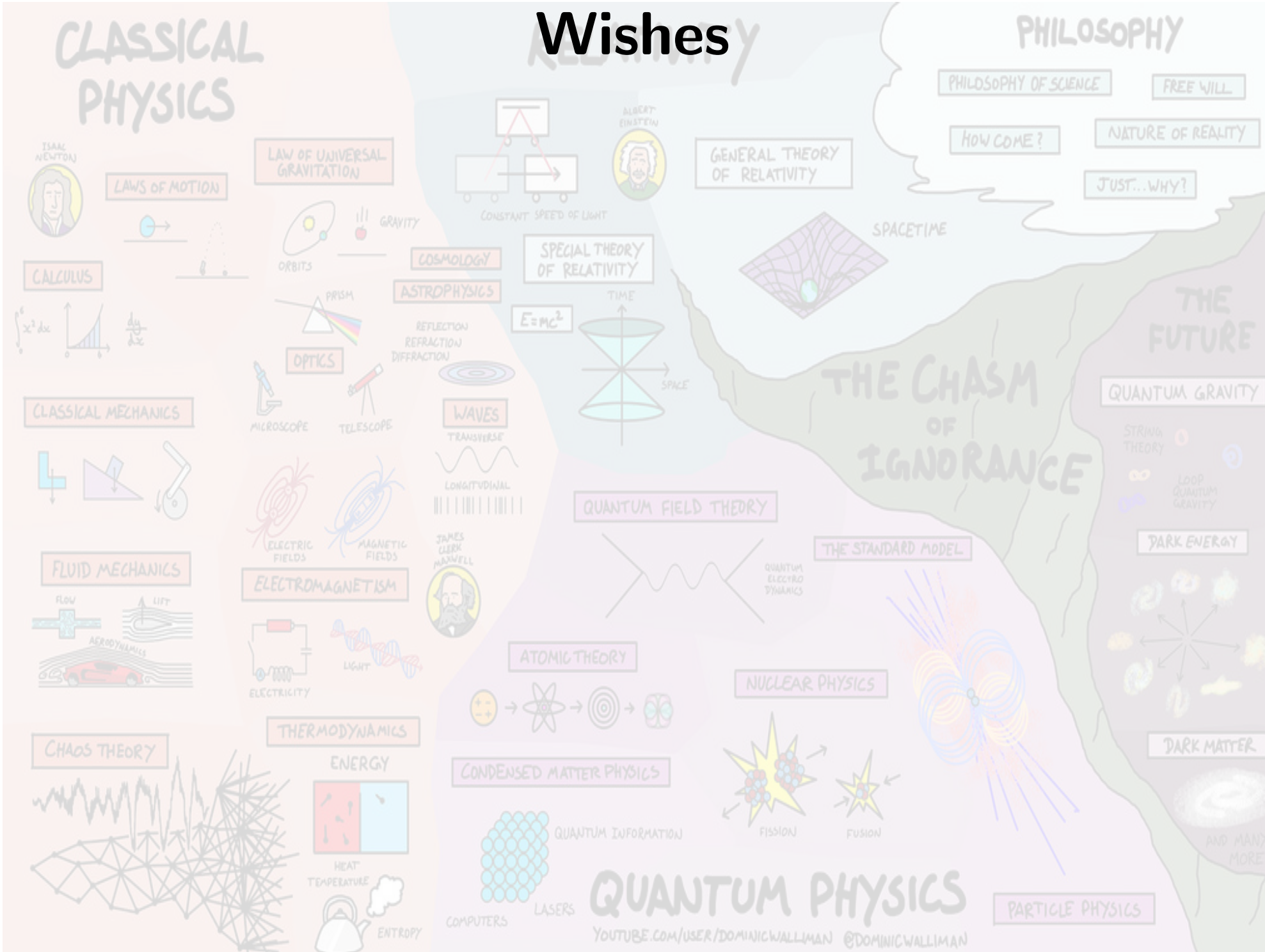
It seems that very interesting times are coming!



Most probably the reason

you decided to do a PhD

Wishes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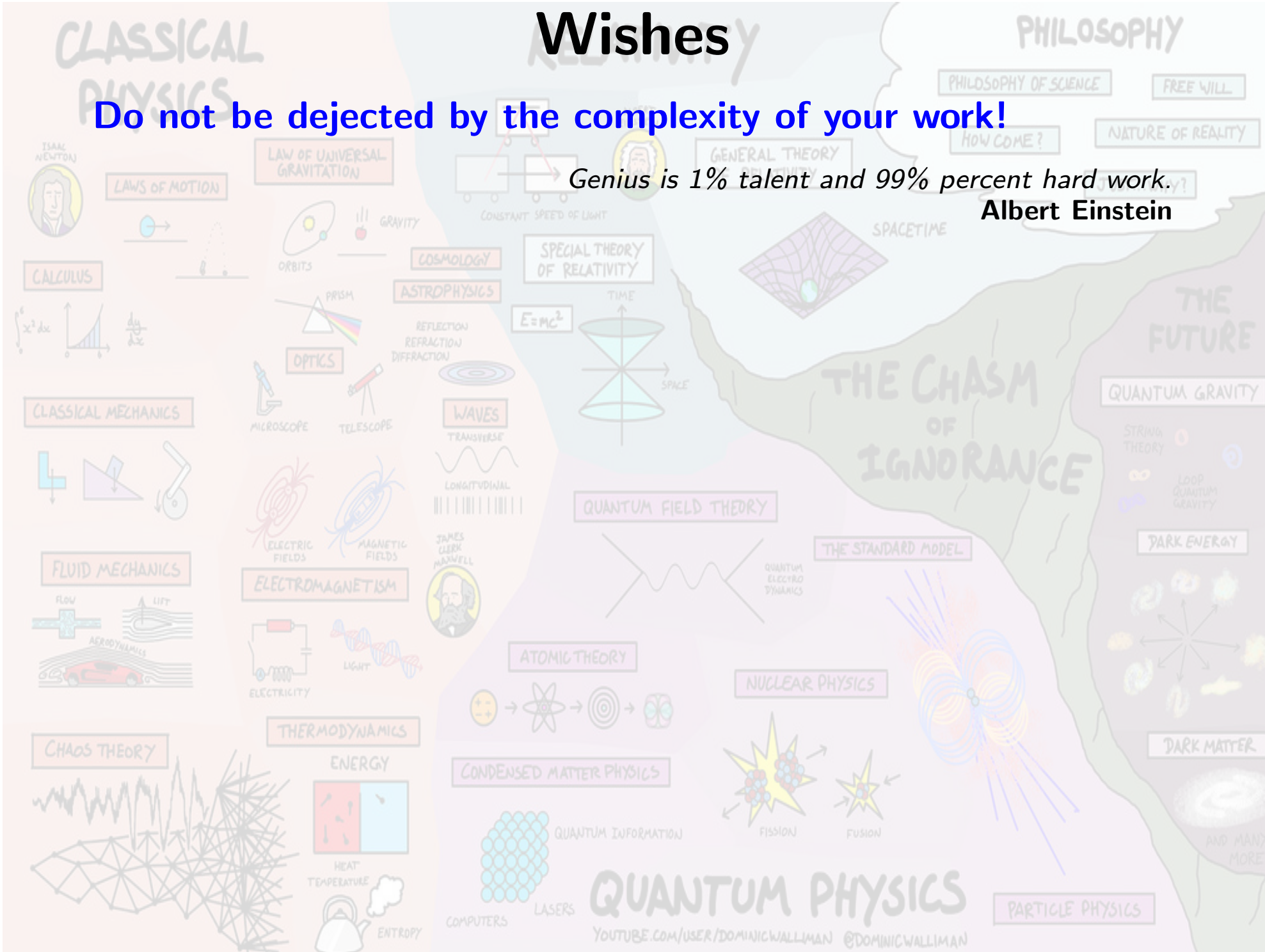

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Enjoy what you are doing!

Science is fun. Science is curiosity. We all have natural curiosity. Science is a process of investigating. It's posing questions and coming up with a method. It's delving in.
Sally Ride

Acknowledgments

What you write:	What you actually want to say:
"Thanks to the editor and the referees for their exceptionally helpful comments during the review process."	"Thank you for your endless requests and revisions that sucked the life out of a poor Ph.D. student."
"Thanks to the person in our research group with whom we had long conversations regarding the subject of this paper."	"Thank you for helping us come up with the critical idea that helped solve our problem but you don't get authorship credit."
"Thanks to the Grant Funding Agency for supporting this work. This work was supported under grant N00014-98-7994."	"None of the money was actually used for this paper but we needed to say this in order to get more $$ from them."
"Thanks to certain Professors in other Institutions for their insight and helpful feedback provided at Conference discussions."	"Your comments were not helpful, but I'm writing this in case any of you happen to be reviewing this paper."
"Thanks to our collaborators who provided the data used in this work."	"Actually, we really do want to thank them. They saved us a TON of work! (But they still don't get authorship credit)."