Process Theology as a Lens for Bringing Quantum Physics into Focus

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Lecture 7: Bound States: The Hydrogen Atom and Stable Matter → Enduring Relations (Societies with inherited order)

Can the Quantum State Machine Build an Atom?

From Stable Hadrons to Hydrogen

- In our last lecture, we used the Quantum State Machine to build hadrons.
- Today we take the next step.
- Can the same machinery build atoms?

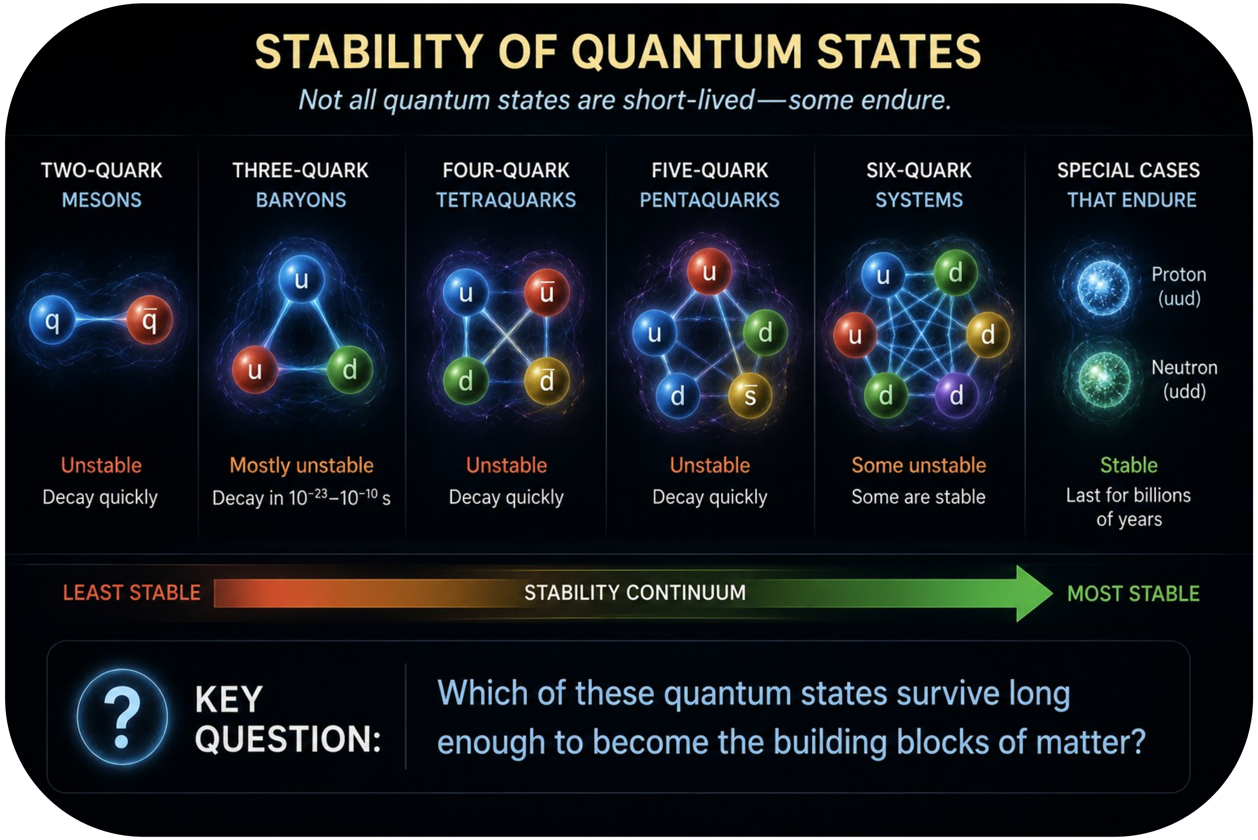
Review: What Did We Build?

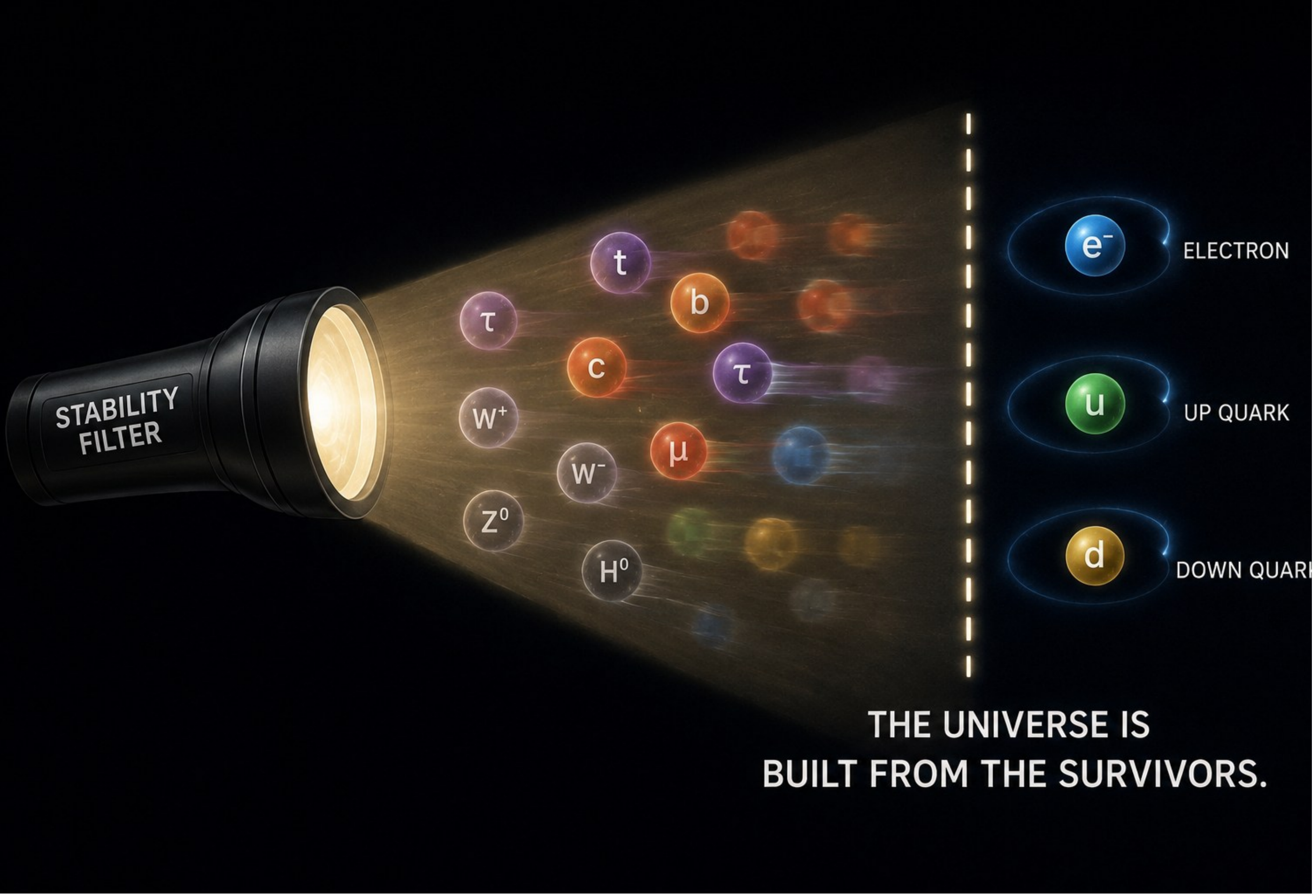
Back in Lecture 5 we used the Quantum State Machine to build:

- Two-quark mesons
- Three-quark baryons
- Four-quark tetraquarks
- Five-quark pentaquarks
- Six-quark systems

Key Question

- Which of these quantum states survive long enough to become the building blocks of matter?





Of the eighteen elementary particles in the Standard Model:

- Most decay rapidly
- Heavy quarks decay
- Muons and taus decay
- W, Z, and Higgs bosons decay

Among the particles that make ordinary matter:

- Electron is stable
- Up quark is stable
- Down quark is stable

The universe is built from the survivors.

Stability Matters

Particle Detections and Actual Occasions

Every Particle Detection is an Actual Occasion

- Every detected particle is a momentary event.
- It exists only in the present.
- It is immediately succeeded by the next actual occasion.
- Even particles that appear "persistent" are experienced as a succession of new actual occasions.
- Reality unfolds as an ongoing sequence of events rather than enduring objects.

The Consequent and Primordial Nature of God

Through the Process Lens

- Consequent Nature
    - Every particle detection becomes an actual occasion.
    - Each actual occasion is immediately received into God's consequent nature.
    - Reality unfolds one event at a time.
- Primordial Nature
    - Provides the mathematical possibilities expressed as the laws of physics.
    - The Quantum State Machine embodies those laws.
    - Those laws determine which particles remain stable and which decay.

Why Ordinary Matter Exists

Most Particles Are Temporary

- Heavy quarks rapidly decay into lighter particles.
- Muons and tau particles are unstable.
- Most hadrons exist for only tiny fractions of a second.

Only a small family of particles remains stable long enough to build the ordinary universe:

- electrons
- up quarks
- down quarks
- protons
- neutrons

These enduring particles become the building blocks of atoms and ordinary matter.

The Superjective Nature: The Lure Toward Enduring Patterns

Through the Process Lens

Superjective Nature

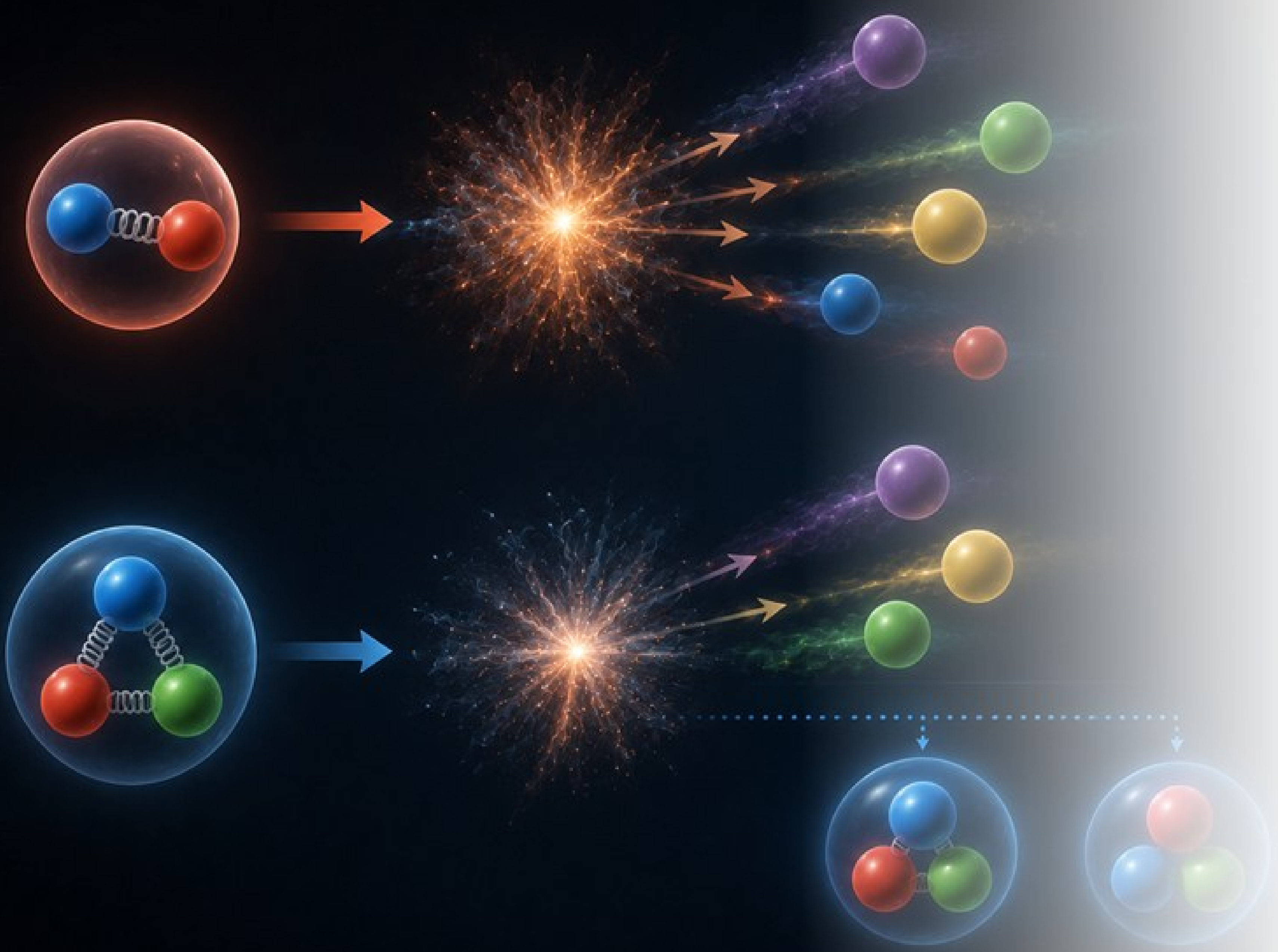
- God lures creation toward enduring patterns of order and complexity.
- This lure never overrides the laws of physics.

Instead, stable structures emerge because the laws of physics make them possible.

- Enduring particles become atoms.
- Atoms become chemistry.
- Chemistry becomes stars, planets, and eventually life.

The Quantum State Machine describes how these stable patterns emerge.

- The Process Lens offers one way of understanding why enduring patterns have such profound significance in the unfolding of reality.



The Fate of the Hadrons

Mesons (2 quarks)

- All mesons eventually decay
- None are permanent building blocks of matter

Baryons (3 quarks)

- Most baryons decay.

Two are special:

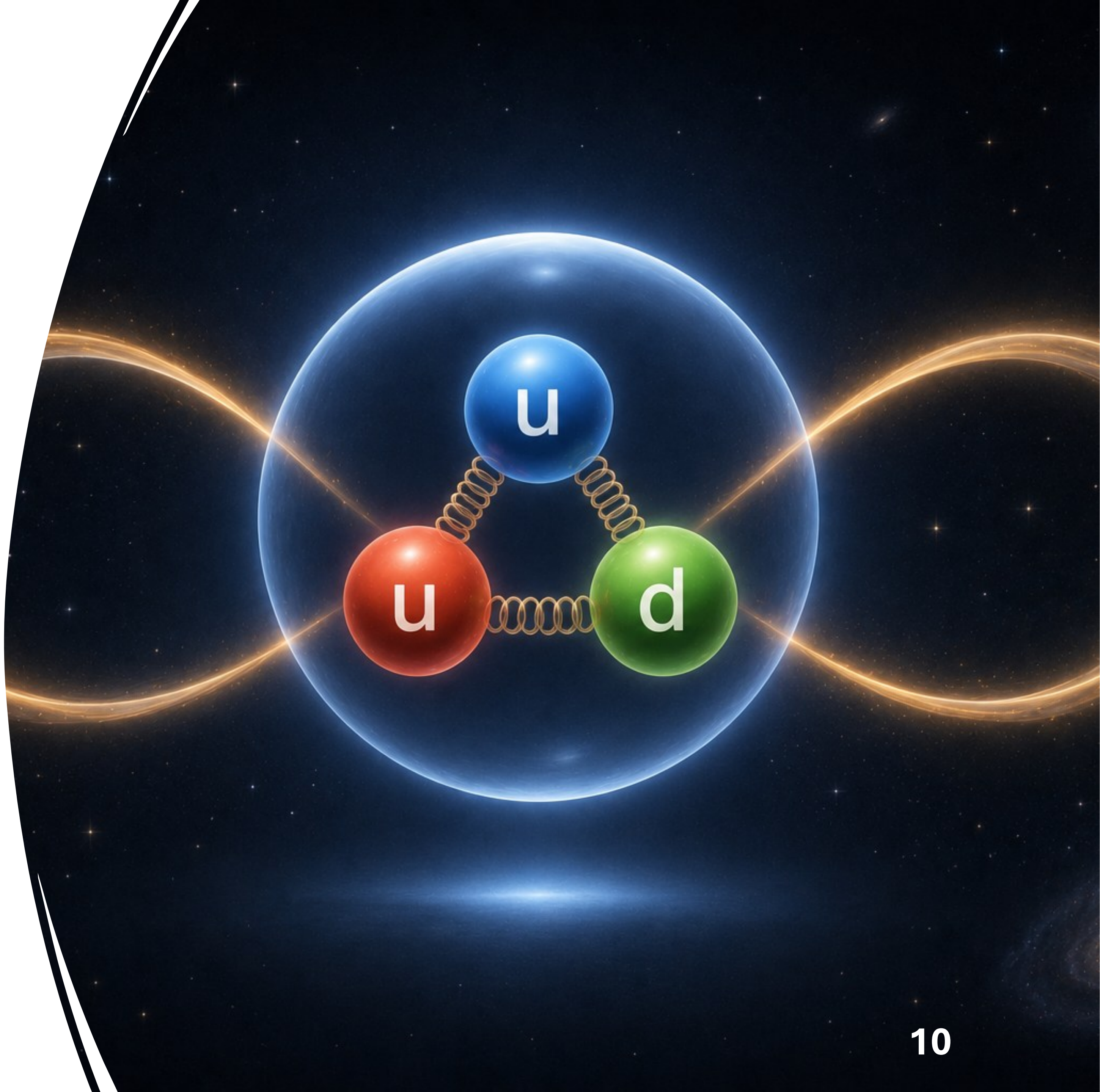
- Proton
- Neutron

These become the foundation of everything around us.

The Champion of Stability

Proton (uud)

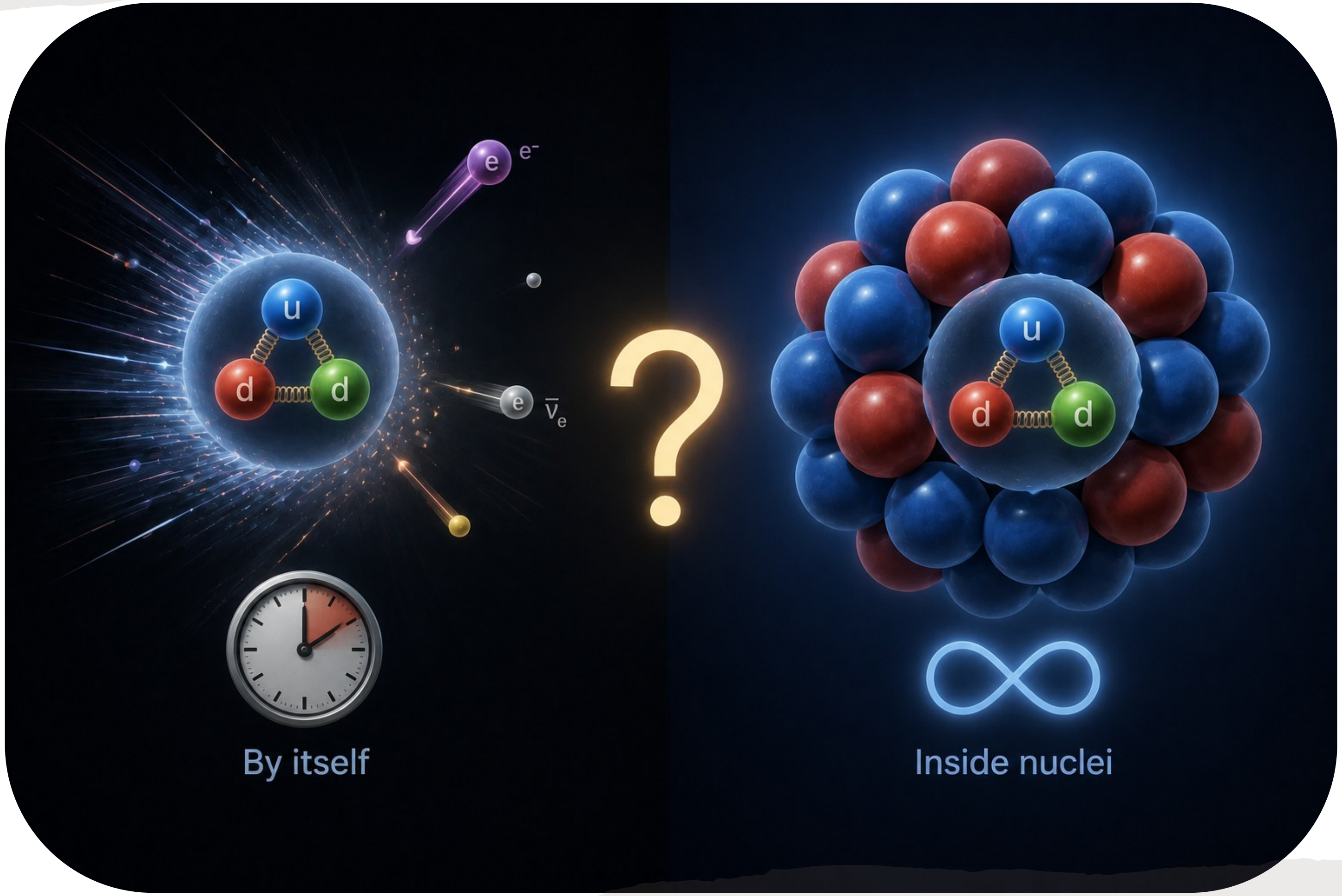
- No proton decay has ever been observed
- Experimental limits exceed 10^{34} years
- The proton may be the most stable massive particle in the universe.
- Every atom depends on its stability.



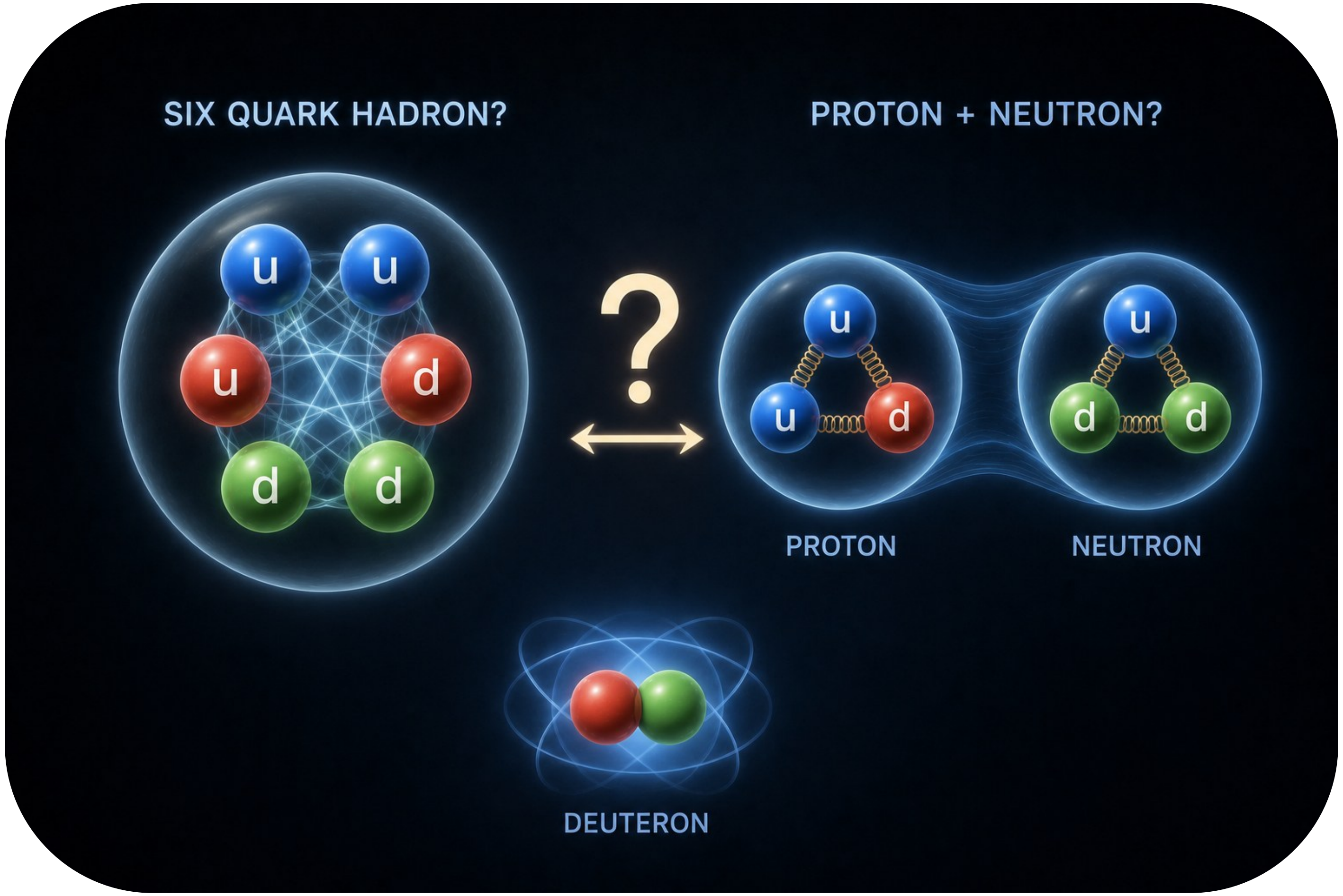
The Curious Case of the Neutron

Neutron (udd)

- By itself:
  - Half-life ≈ 15 minutes
- Inside many nuclei:
  - Stable for billions of years
- Question: What changed?
  - The neutron did not change.
  - The quantum state changed.



Remember the Six-Quark Hadron



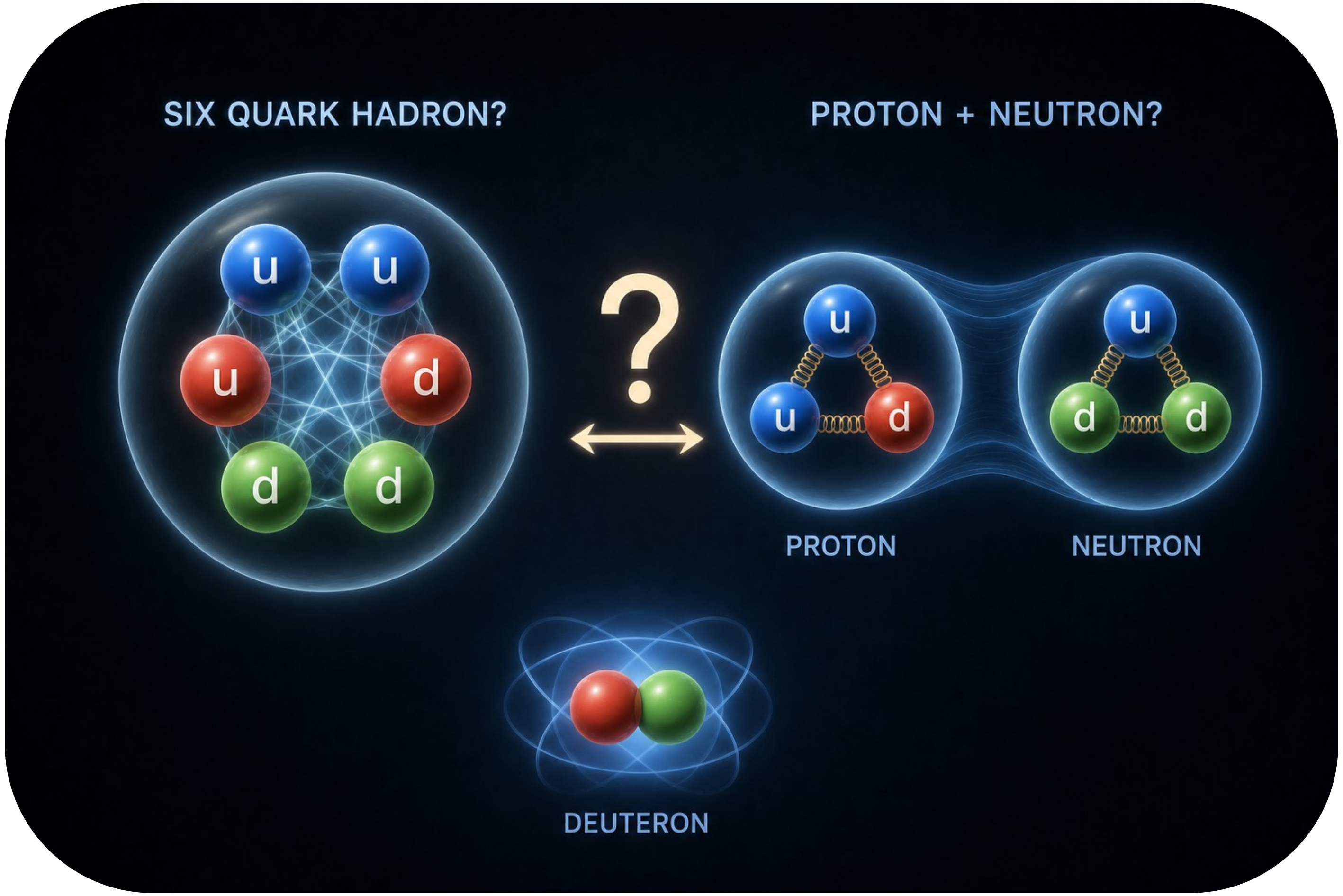
Combine:

- One proton (uud)
- One neutron (udd)

Total: Six quarks

- This combination forms the deuteron.
- The simplest stable nucleus containing a neutron.

Remember the Six-Quark Hadron



What Did We Actually Build?

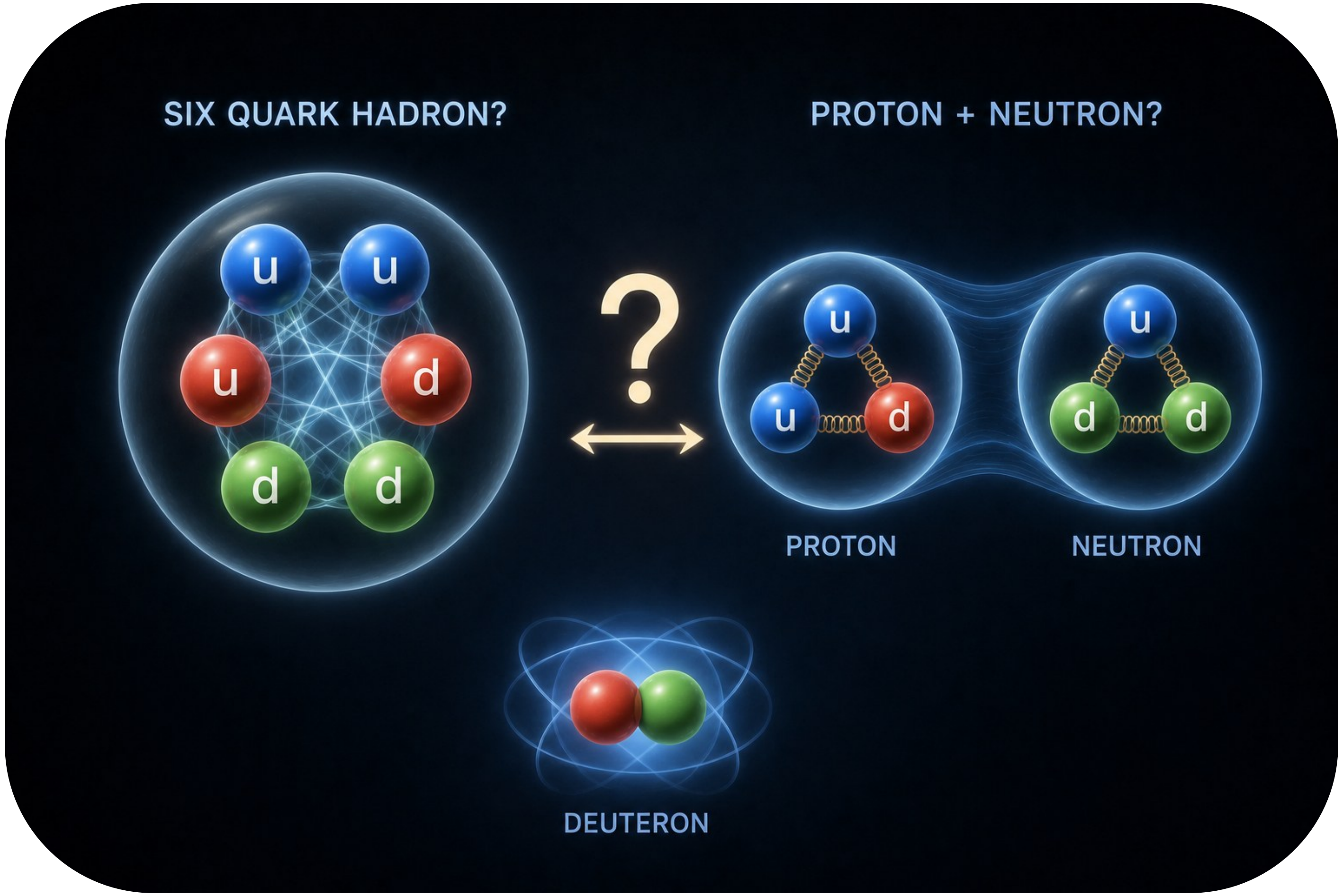
Did we build:

- A six-quark hadron?

or

- A proton and neutron bound together?

Remember the Six-Quark Hadron



The Answer Is Both

At the quark level:

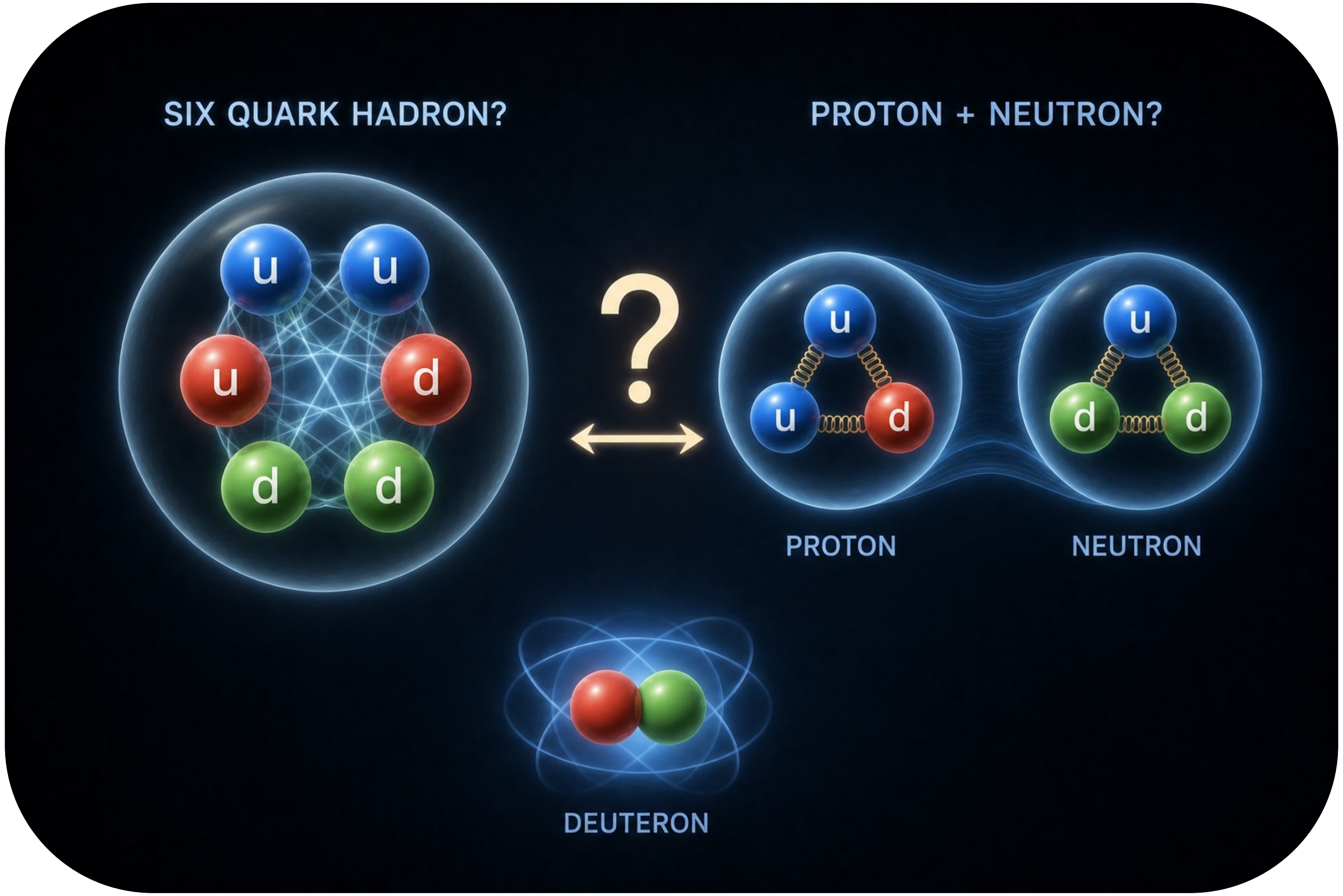
- **The deuteron contains six interacting quarks.**

At the nuclear level:

- **It behaves like a proton and a neutron bound together.**

These are two different descriptions of the same quantum system

Remember the Six-Quark Hadron



What Holds the Deuteron Together?

- Not the strong force that confines quarks inside a proton.
- Not the strong force that confines quarks inside a neutron

Instead...

- There is a residual strong interaction that acts between the proton and neutron.
- This residual force binds them into a stable nucleus

That is why physicists don't usually call the deuteron a six-quark hadron.

Hydrogen Is More Than One Nucleus

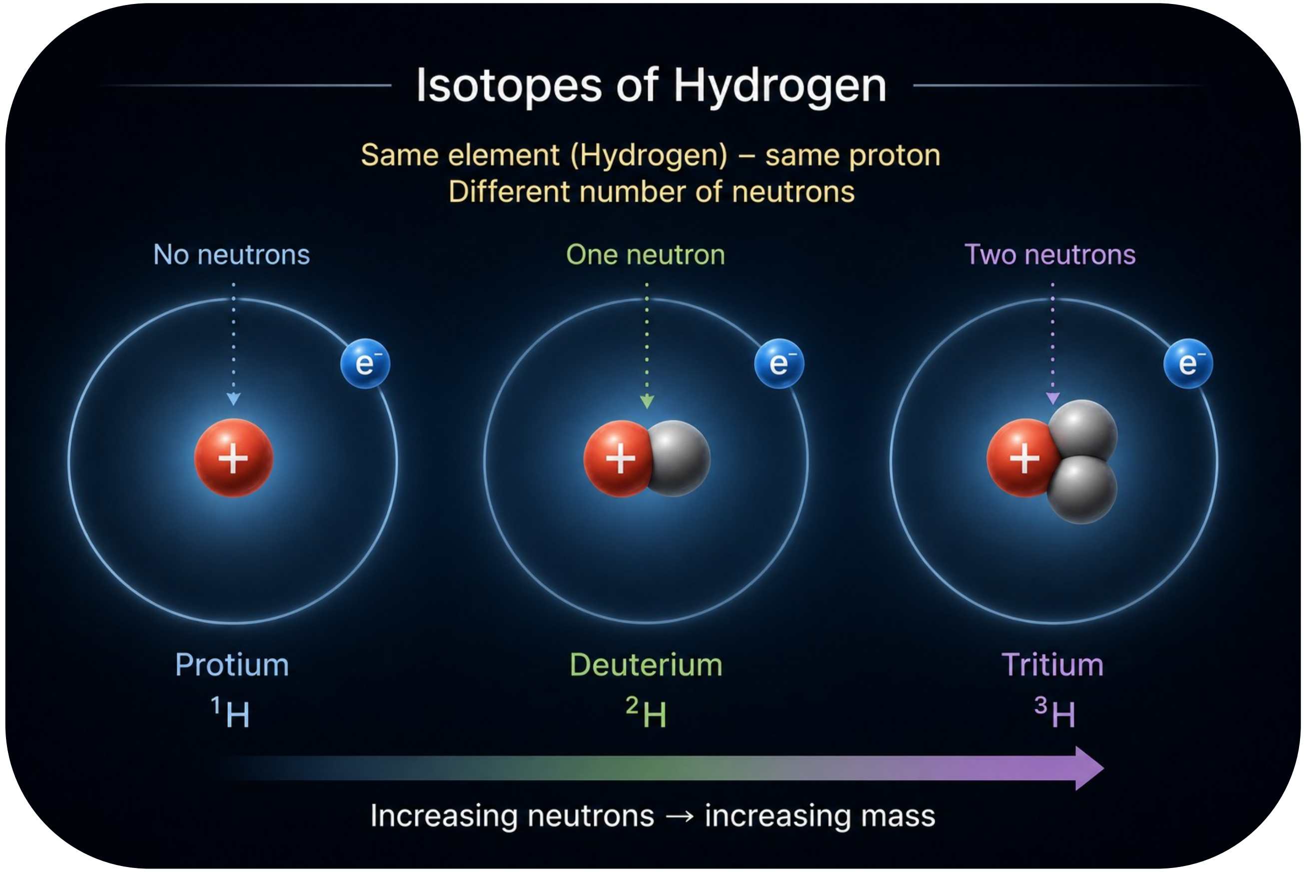
A hydrogen nucleus always contains

- one proton.

But it may contain

- no neutrons
- one neutron
- two neutrons

These are different isotopes of hydrogen.



The Three Isotopes of Hydrogen

Protium

- 1 proton
- 0 neutrons

Deuterium

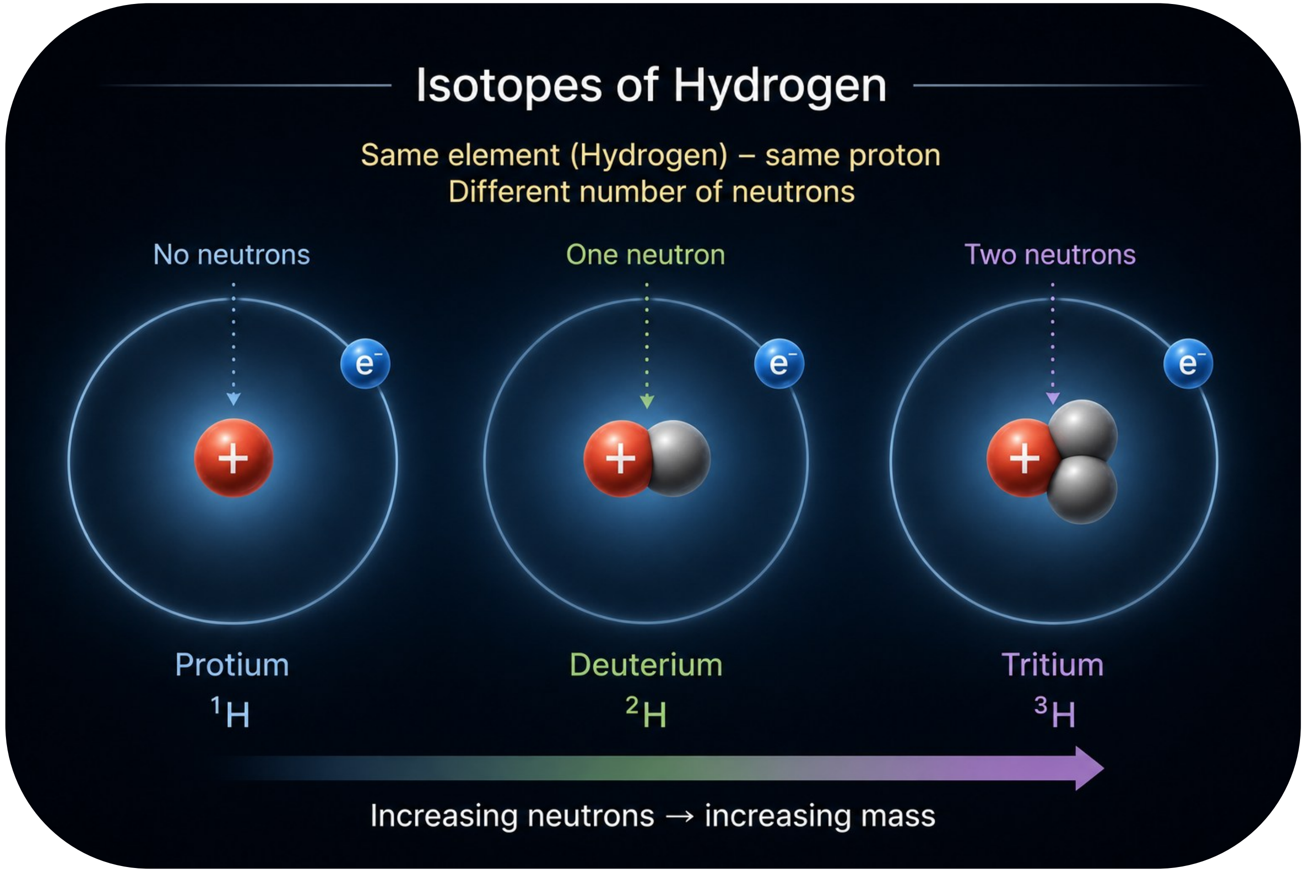
- 1 proton
- 1 neutron

Tritium

- 1 proton
- 2 neutrons

All three are isotopes of hydrogen.

- **Changing the number of neutrons changes the isotope—not the element.**
- **Unless otherwise specified, "hydrogen" refers to protium (^1H).**



The Three Isotopes of Hydrogen

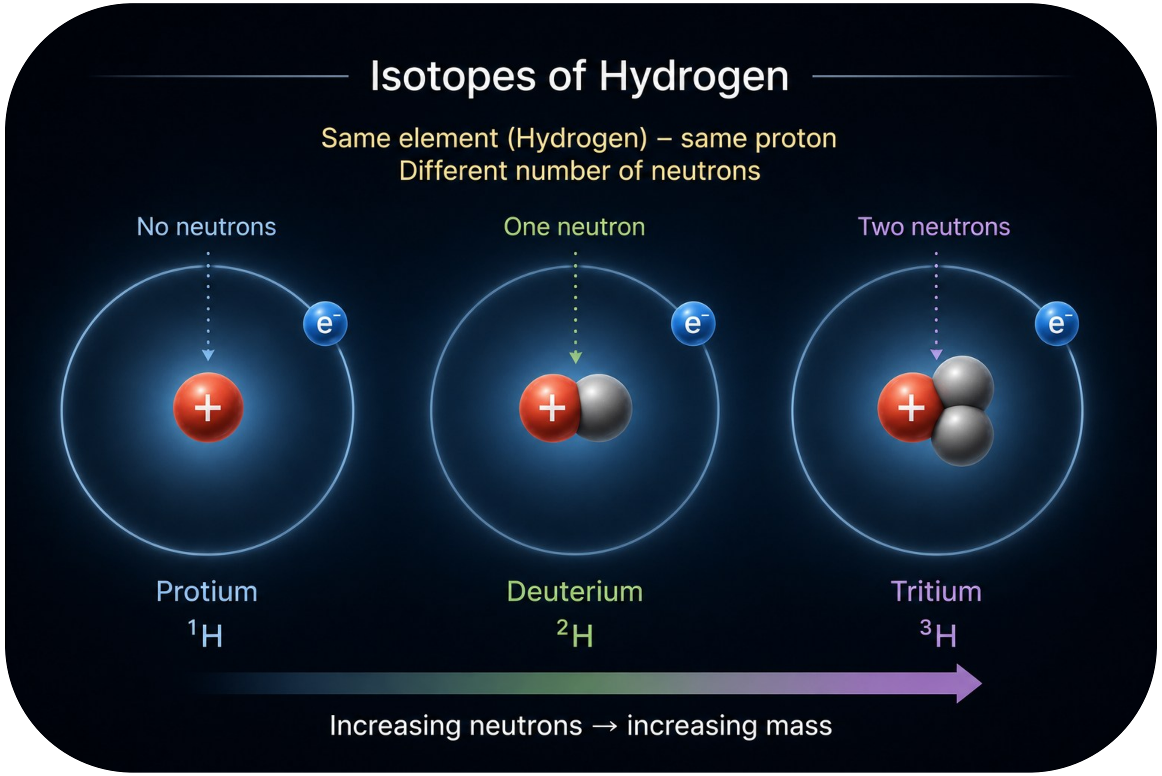
The element with one proton is called hydrogen.

- **Adding a neutron does not create a new element.**
- **Instead, it creates a new isotope.**

However, the naming convention is:

- **One proton → Hydrogen**
- **One proton + one neutron → Deuterium**
- **One proton + two neutrons → Tritium**

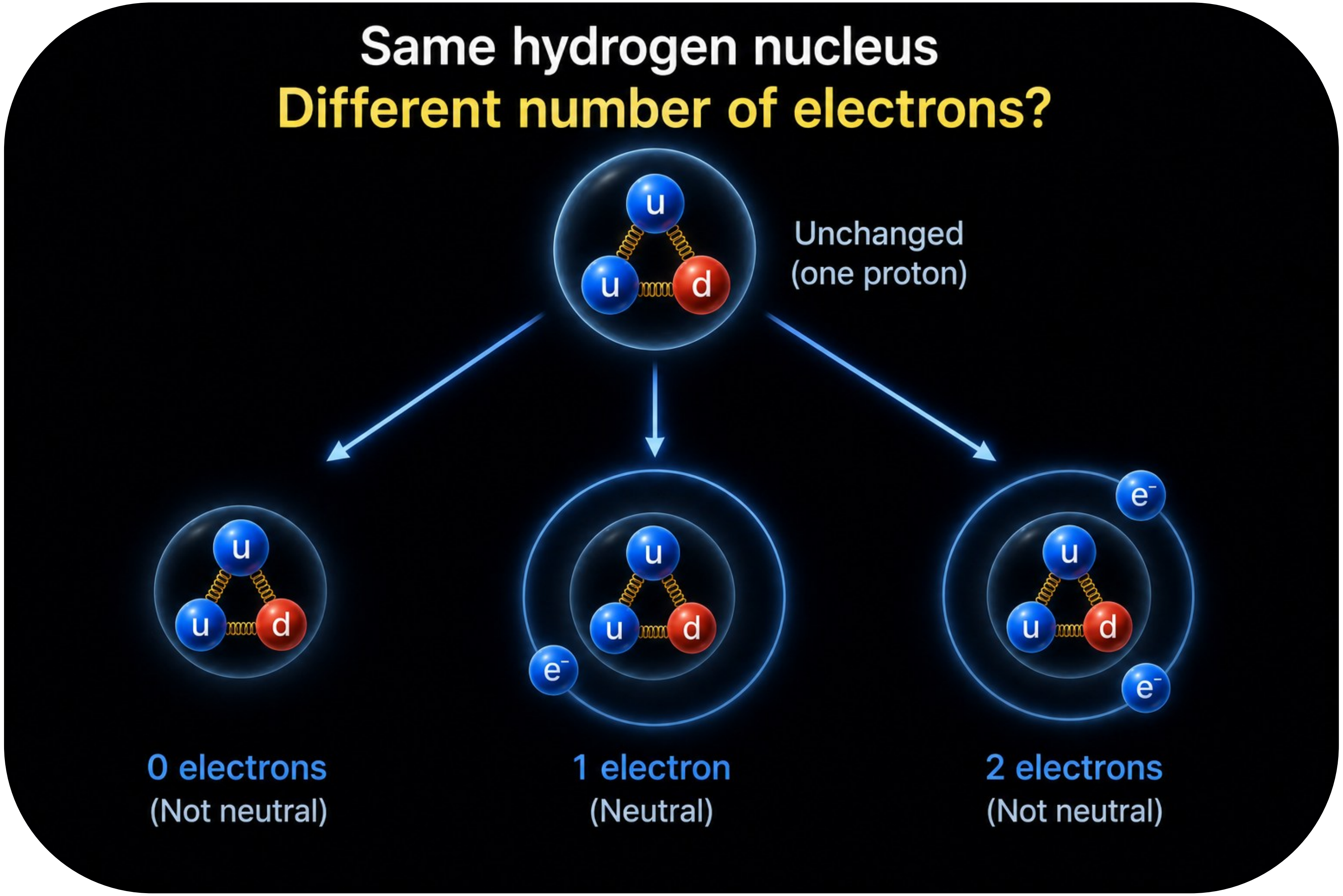
- **The number of protons determines the element.**
- **The number of neutrons determines the isotope.**



A Different Question

Suppose we leave the nucleus completely unchanged.

- Instead...
    - What if we change the number of electrons?
    - Does it become a different element?

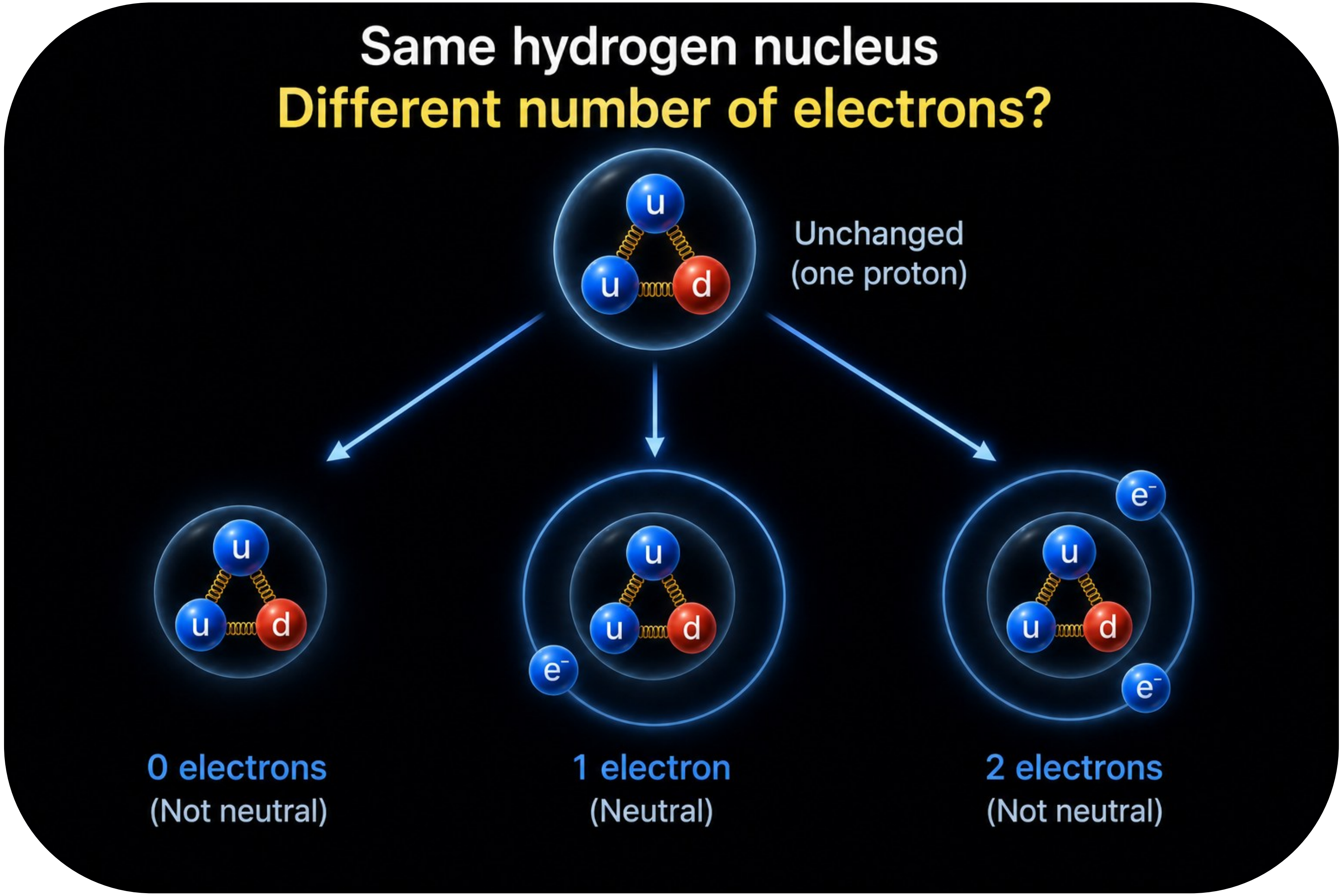


Ionization

A hydrogen nucleus may have:

- no electrons
- one electron
- two electrons.

These are different ionization states.



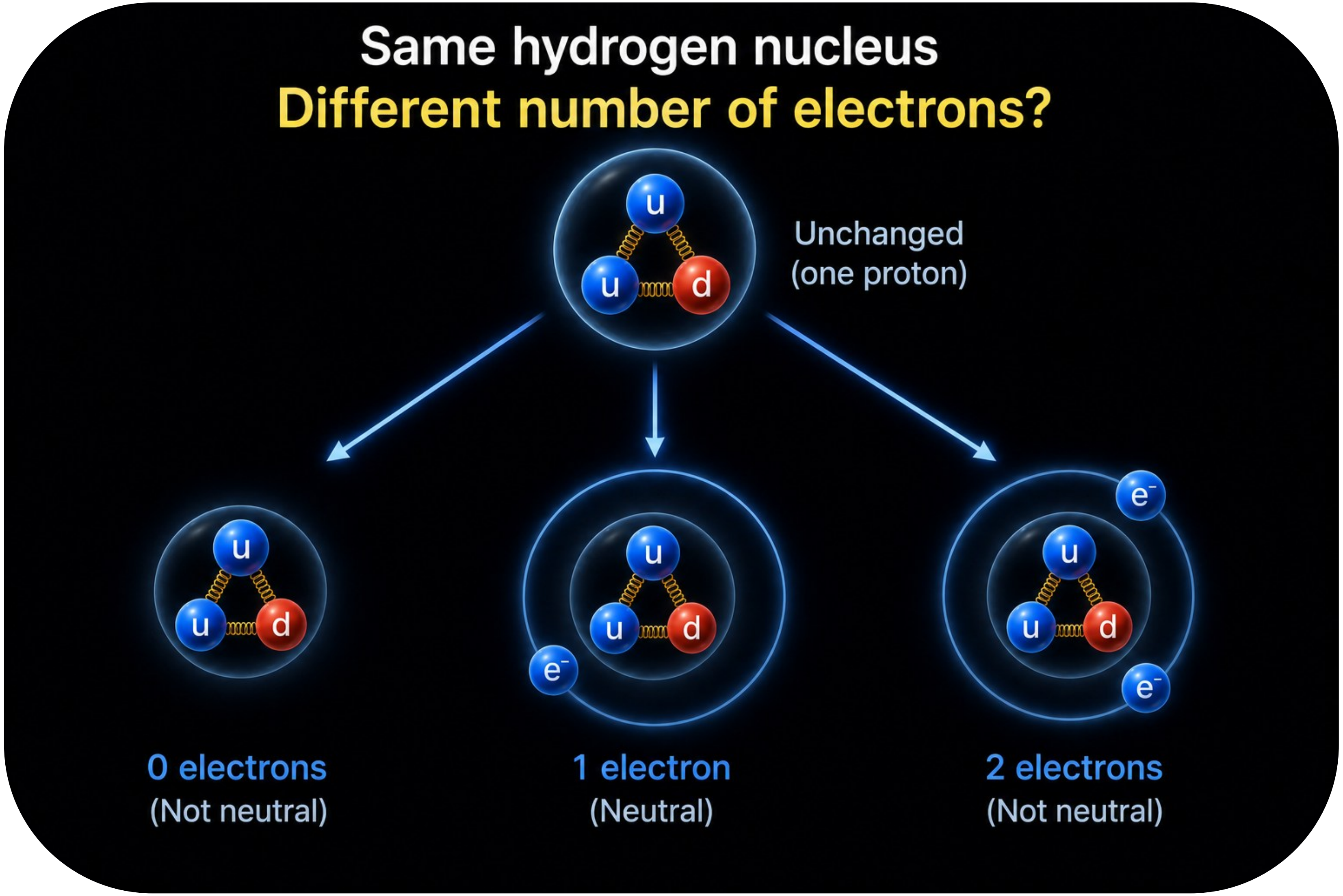
Every hydrogen atom can exist in different ionization states

Ionization

Changing Electrons Changes the Ionization State

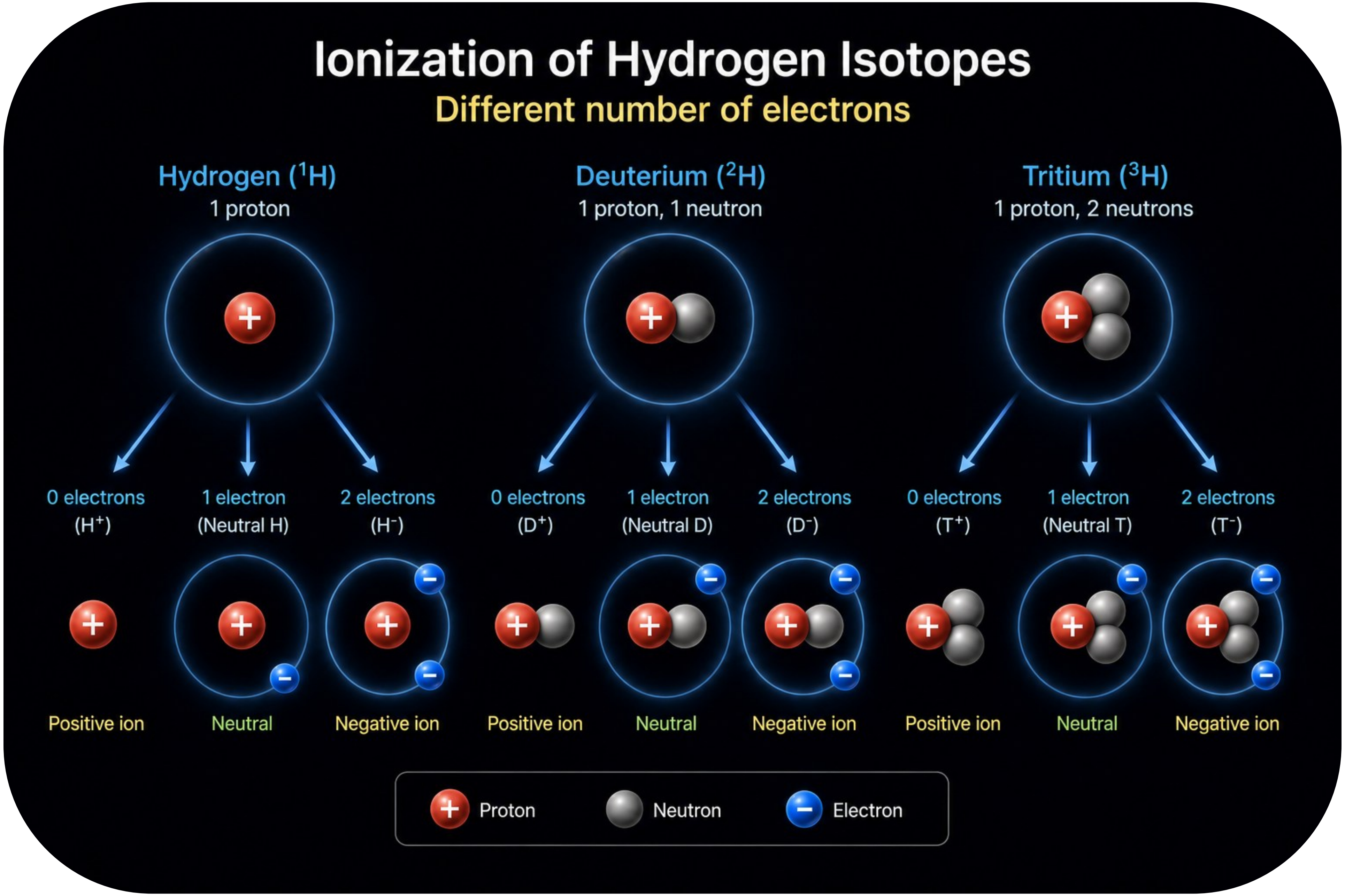
Hydrogen can exist as

- H^+ (no electrons)
- H (one electron)
- H^- (two electrons)



Adding or removing electrons changes the ionization state.

- It does not change the element.



These are different ionization states.

- Hydrogen may be ionized.
- Deuterium may be ionized.
- Tritium may be ionized.

Every hydrogen isotope can exist in different ionization states.

Convention

By convention, the three isotopes of hydrogen are commonly represented as:

- H = ordinary hydrogen (protium, ^{1}H)
  - 1 proton
  - 0 neutrons
  - About 99.98% of naturally occurring hydrogen

D = deuterium (^{2}H)

- 1 proton
- 1 neutron
- Stable
- Often called "heavy hydrogen"

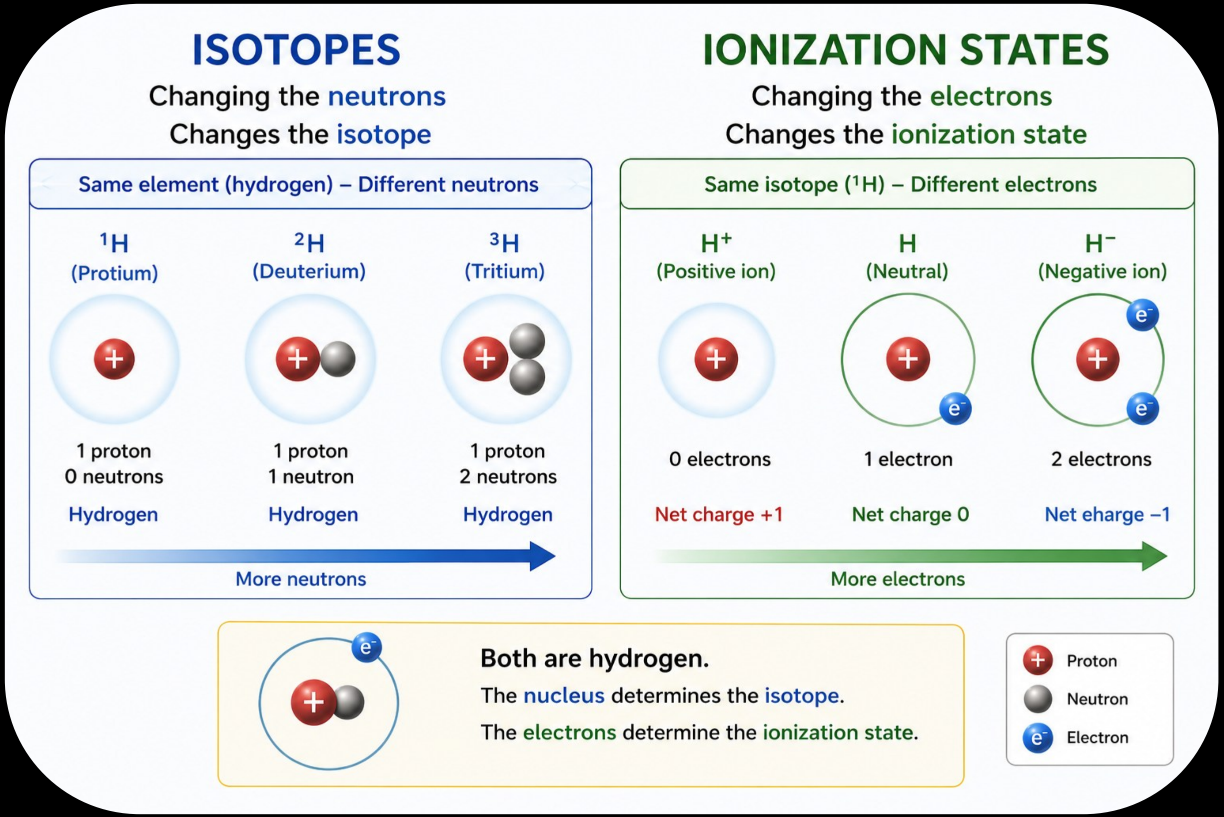
T = tritium (^{3}H)

- 1 proton
- 2 neutrons
- Radioactive, with a half-life of about 12.3 years

Although H, D and T are widely accepted symbols in chemistry and physics, their official isotopic notation are ^{1}H, ^{2}H and ^{3}H.

You'll see all six notations used

Two Different Ideas



Changing the neutrons

- Changes the isotope

Changing the electrons

- Changes the ionization state

Both are hydrogen.

- The nucleus determines the isotope.
- The electrons determine the ionization state.

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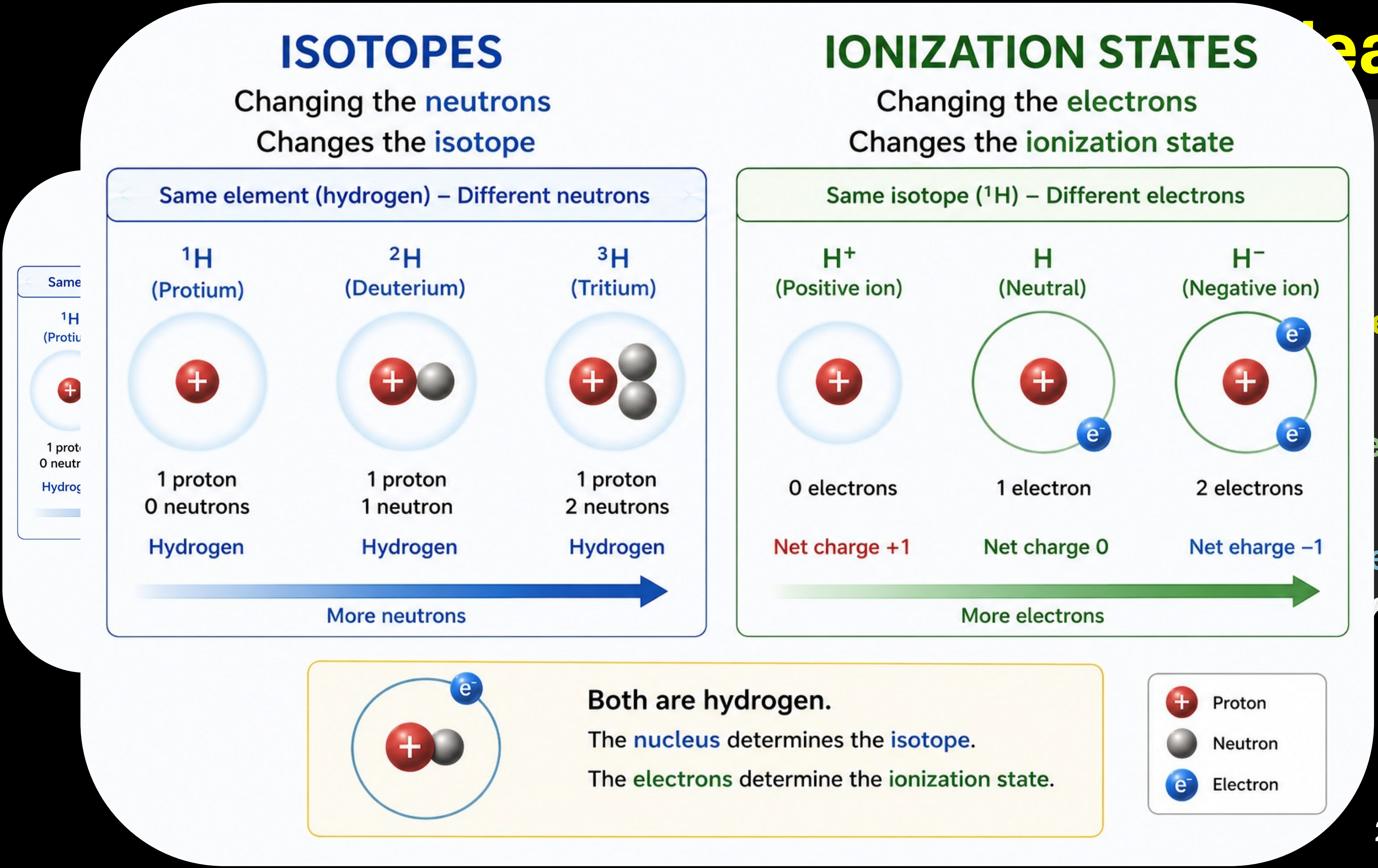
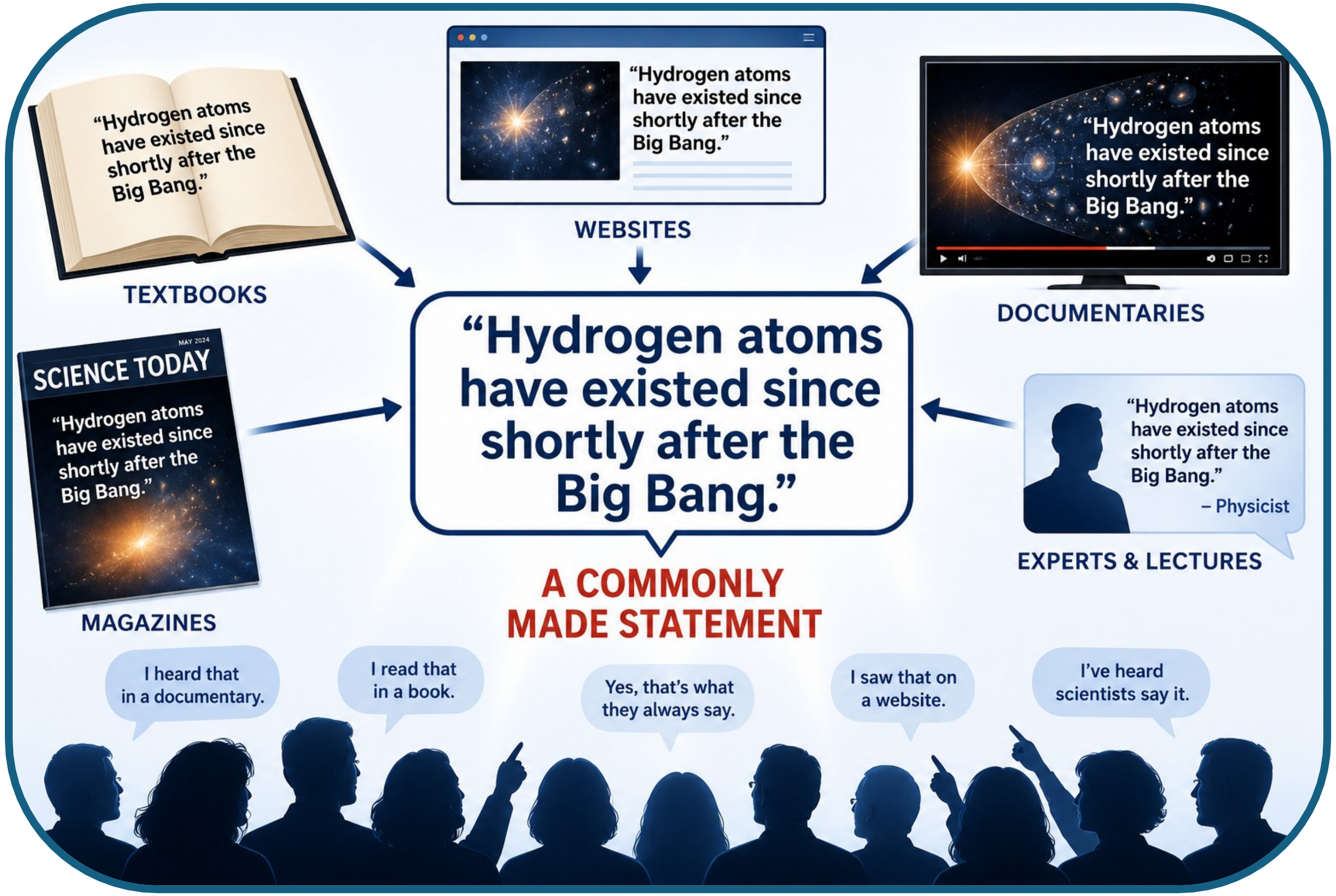


ISOTOPES
Changing the neutrons
Changes the isotope
Same element (hydrogen) – Different neutrons
¹H
(Protium)
1 proton
0 neutrons
Hydrogen
²H
(Deuterium)
1 proton
1 neutron
Hydrogen
³H
(Tritium)
1 proton
2 neutrons
Hydrogen
More neutrons
IONIZATION STATES
Changing the electrons
Changes the ionization state
Same isotope (¹H) – Different electrons
H⁺
(Positive ion)
0 electrons
Net charge +1
H
(Neutral)
1 electron
Net charge 0
H⁻
(Negative ion)
2 electrons
Net eharge −1
More electrons
Both are hydrogen.
The nucleus determines the isotope.
The electrons determine the ionization state.
Proton
Neutron
Electron



A Statement You Have Probably Heard

"Hydrogen atoms have existed since shortly after the Big Bang."

- This statement appears in books, documentaries, websites, and physics discussions.
- You'll hear Nick Lucent make exactly this statement in the video we will show in the next lecture.

What If I Told You That Is a Lie?

What Physicists Really Mean

Here is the actual story:

- Most hydrogen nuclei (that is, single protons) were produced during Big Bang nucleosynthesis a few minutes after the Big Bang.
- Those nuclei have survived for nearly the entire history of the universe.

But that is not quite the same thing as saying:

- "Every hydrogen atom has existed since the Big Bang."

What Is a Hydrogen Atom?

Physicists define hydrogen by its nucleus:

- One Proton
- The electrons determine the ionization state.

Hydrogen can have:

- No electron
- One electron
- Two electrons

It is still hydrogen.

The Real Story

However, Not Every Proton Was Created Long Ago

New protons are created all the time.

- Nature creates new protons in energetic astrophysical environments.
- Physicists routinely create new protons in high-energy particle accelerators.

Therefore:

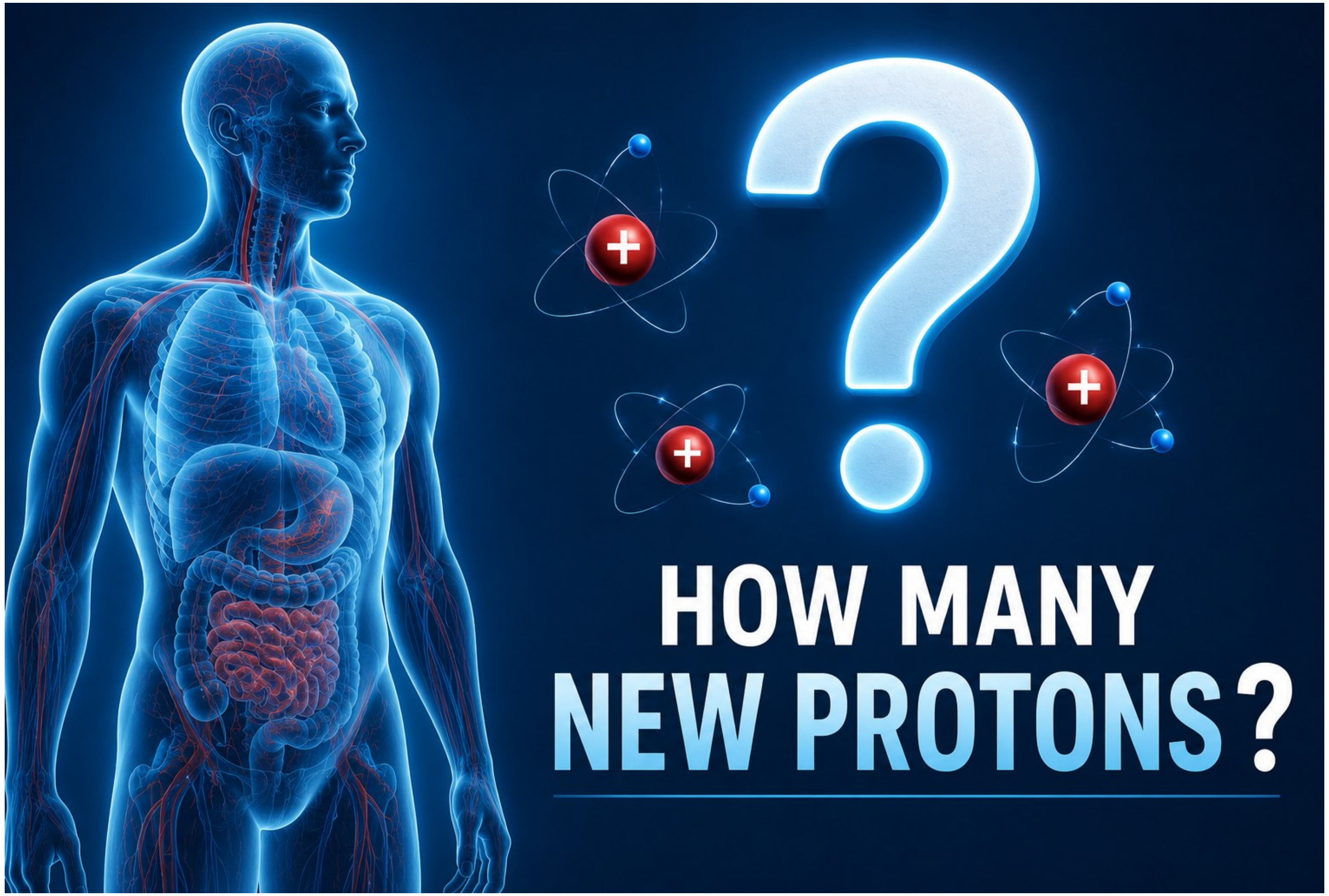
- Not every proton in the universe is 13.8 billion years old.

The Real Story

Most of the hydrogen nuclei around us were created only minutes after the Big Bang.

- **However, hydrogen atoms have repeatedly:**
  - **Lost electrons**
  - **Captured electrons**
  - **Formed molecules**
  - **Been incorporated into stars**
  - **Been recycled through matter**
- **The proton survives.**
- **The hydrogen atom is continually reborn.**

How Many Hydrogen Atoms in Your Body Were NOT Created Minutes After the Big Bang?



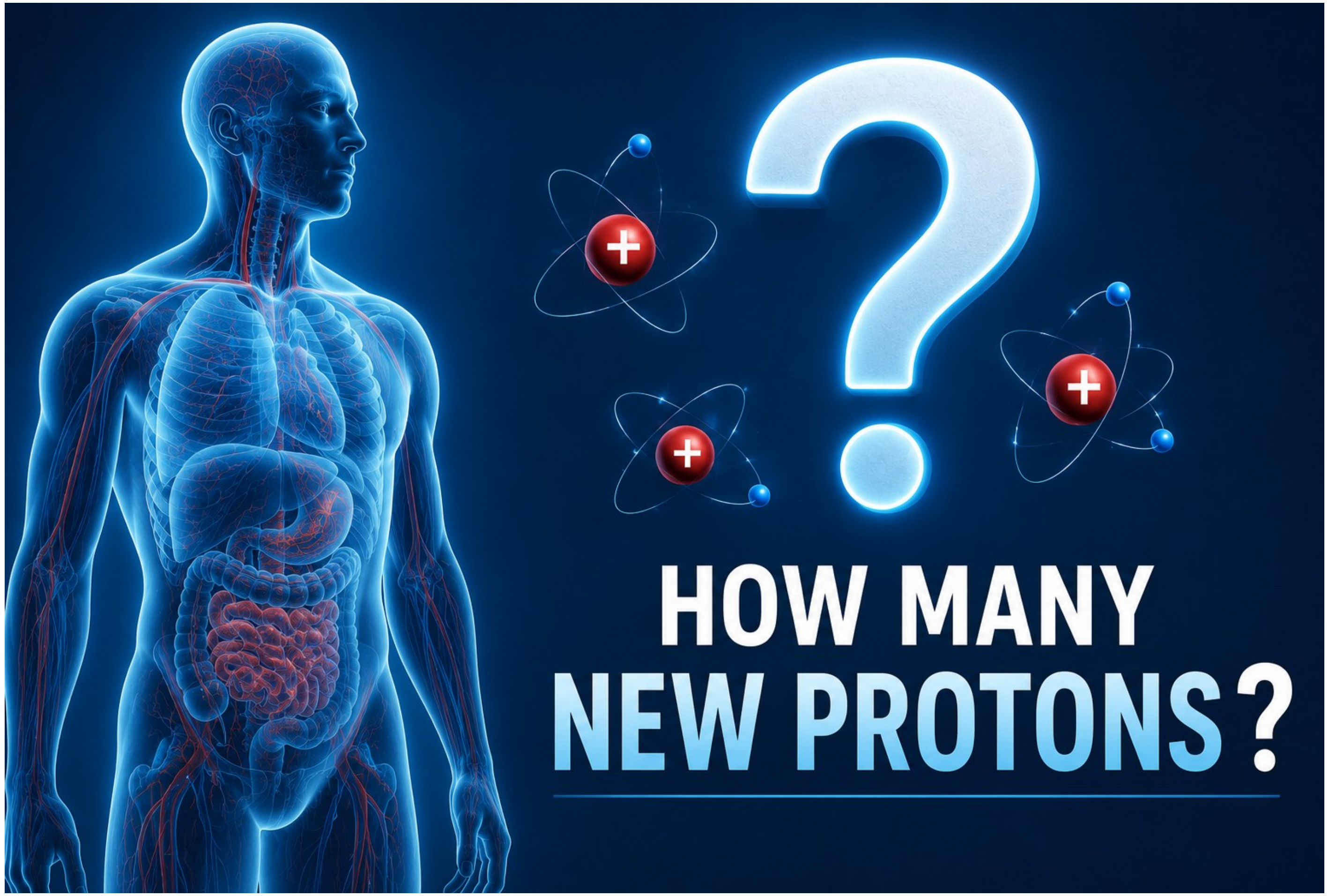
A typical 70 kg (154 lb) adult contains approximately

- 4×10^{27} hydrogen atoms

No one knows exactly what fraction of today's protons were created during Big Bang nucleosynthesis.

- For illustration only, suppose that 99.99999999999% of all protons came from the Big Bang.
- What would that mean?

How Many Hydrogen Atoms in Your Body Were NOT Created Minutes After the Big Bang?



The Answer May Surprise You

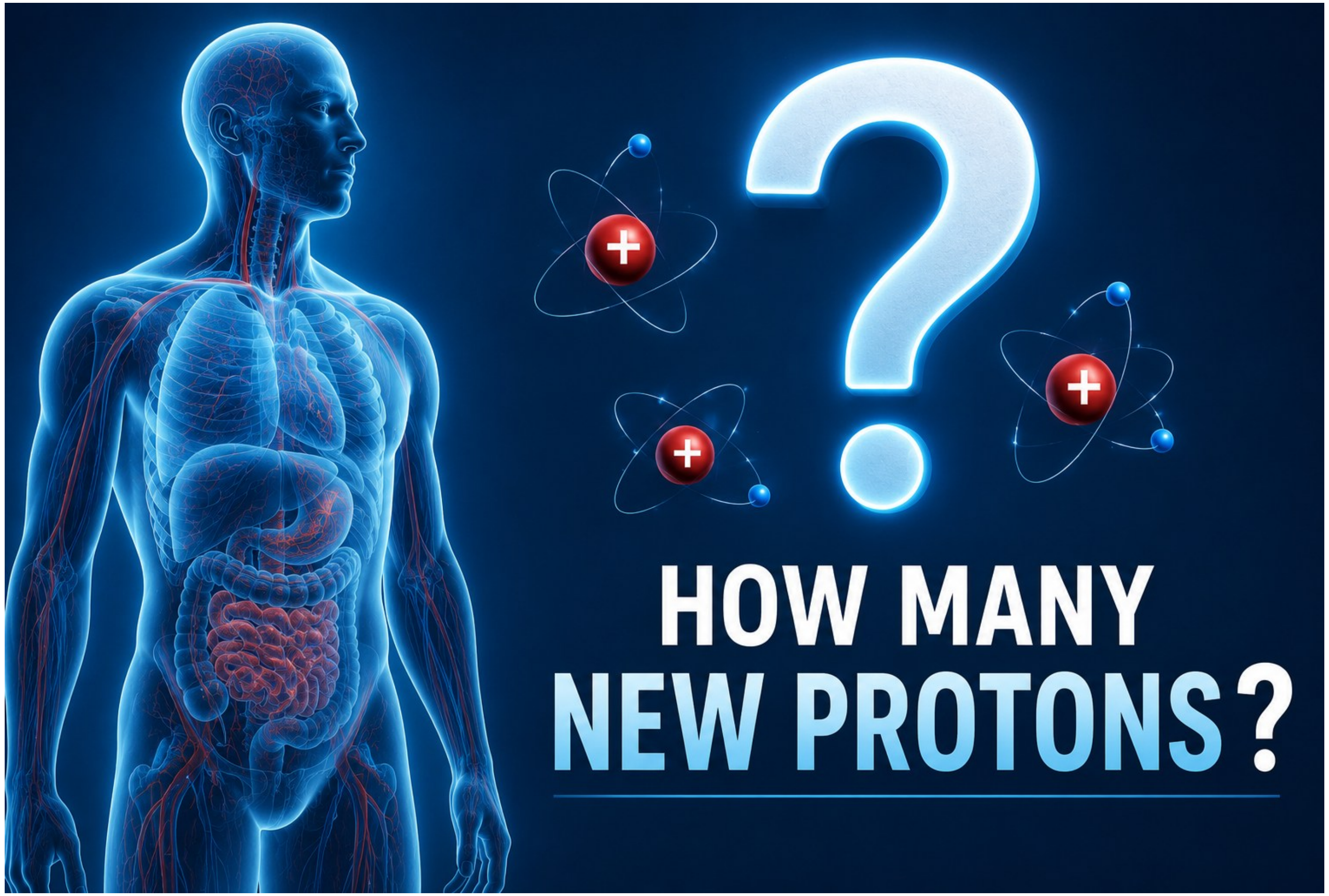
Even with that extraordinarily high percentage...

- **Your body would still contain approximately 40 trillion hydrogen atoms that were NOT created minutes after the Big Bang.**

Why?

- **Because a tiny percentage of an enormous number is still an enormous number.**

How Many Hydrogen Atoms in Your Body Were NOT Created Minutes After the Big Bang?



The "Big Lie" is Actually a "Small Lie"

All of the hydrogen atoms in your body were created minutes after the Big Bang.

...that statement cannot be literally true.

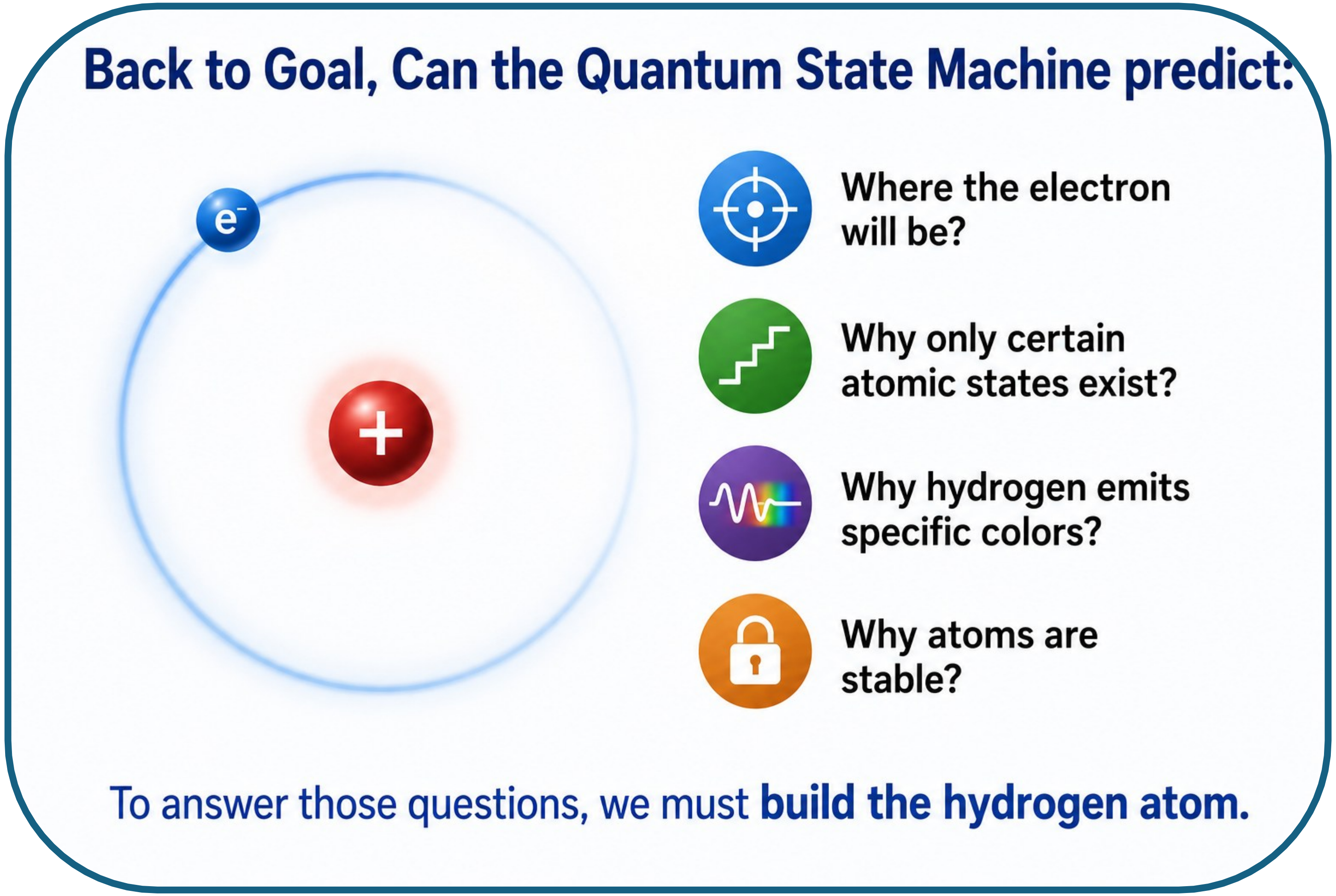
- **It is an excellent approximation.**
- **It is not an exact statement.**

Back to Our Goal

Can the Quantum State Machine predict:

- **Where the electron will be?**
- **Why only certain atomic states exist?**
- **Why hydrogen emits specific colors?**
- **Why atoms are stable?**

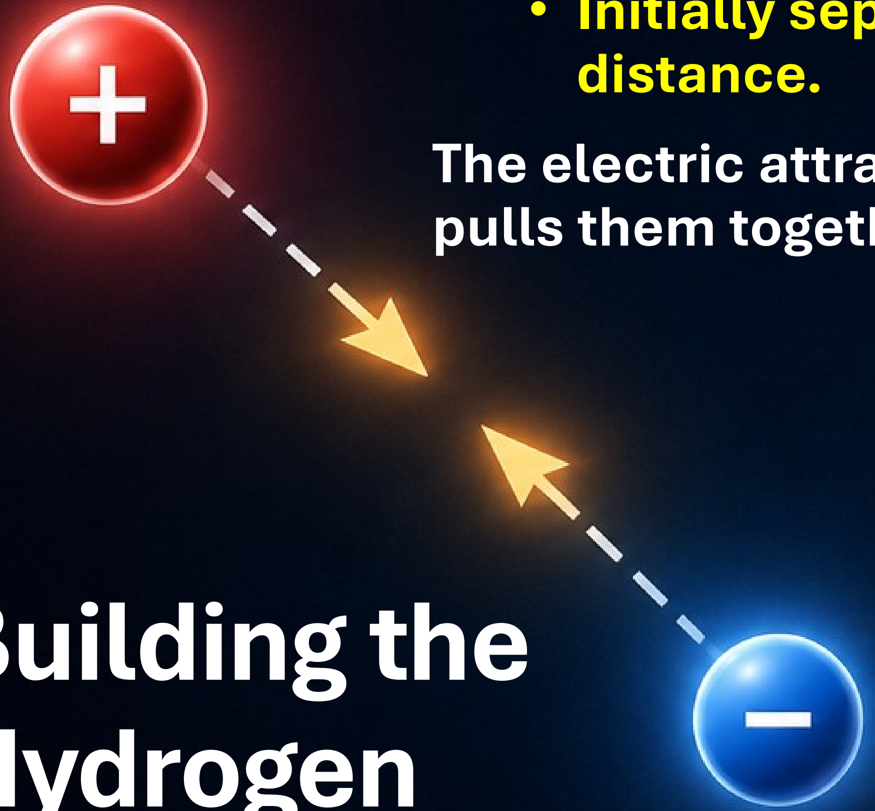
To answer those questions, we must build the hydrogen atom.



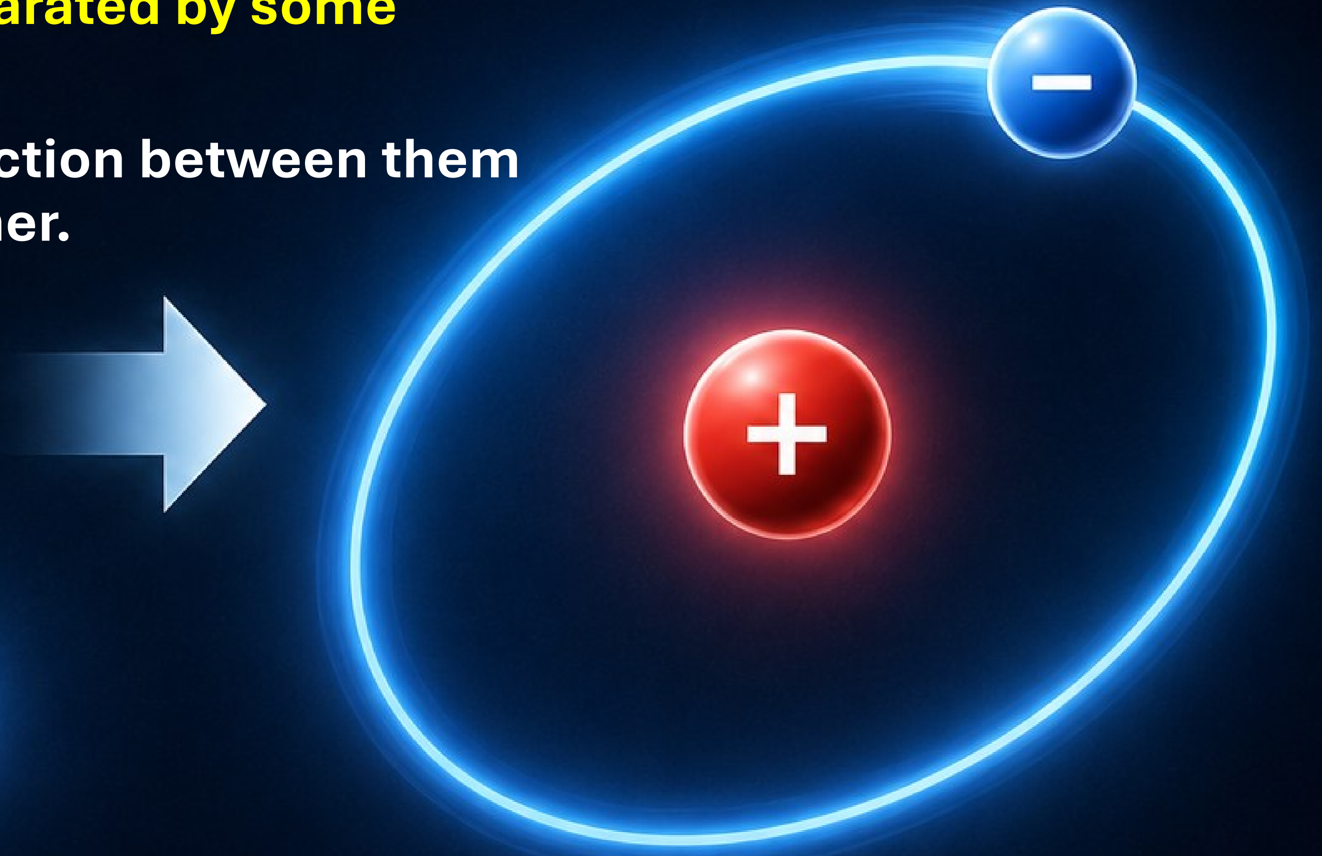
Suppose we begin with:

- One proton
- One electron
- Initially separated by some distance.

The electric attraction between them pulls them together.



Building the Hydrogen Atom



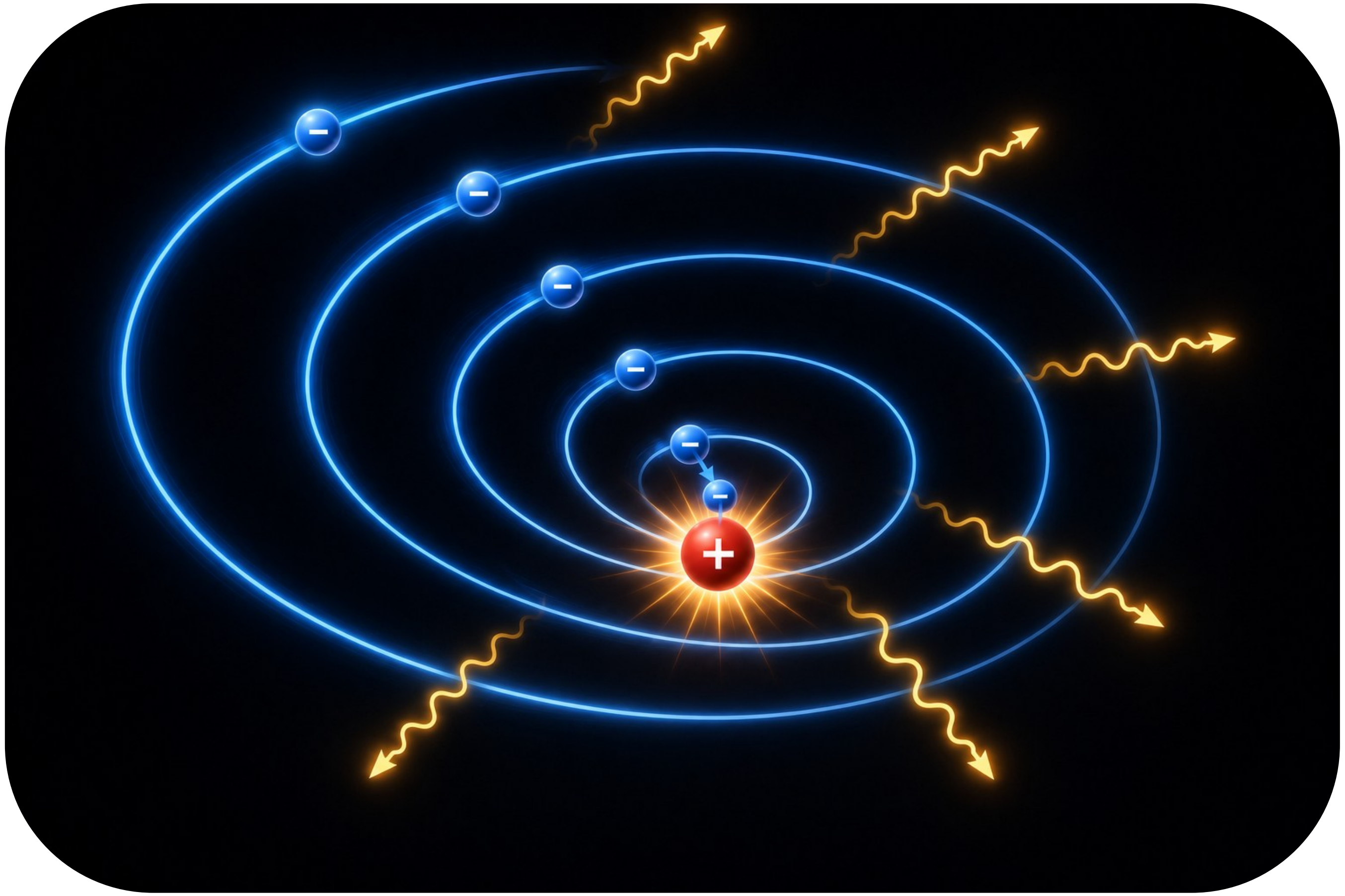
What happens next?

The Classical Prediction

According to classical physics:

- Opposite charges attract.
- The electron accelerates toward the proton.
- An accelerating electric charge radiates energy.
- The electron loses energy and spirals inward.

Eventually the electron crashes into the proton.



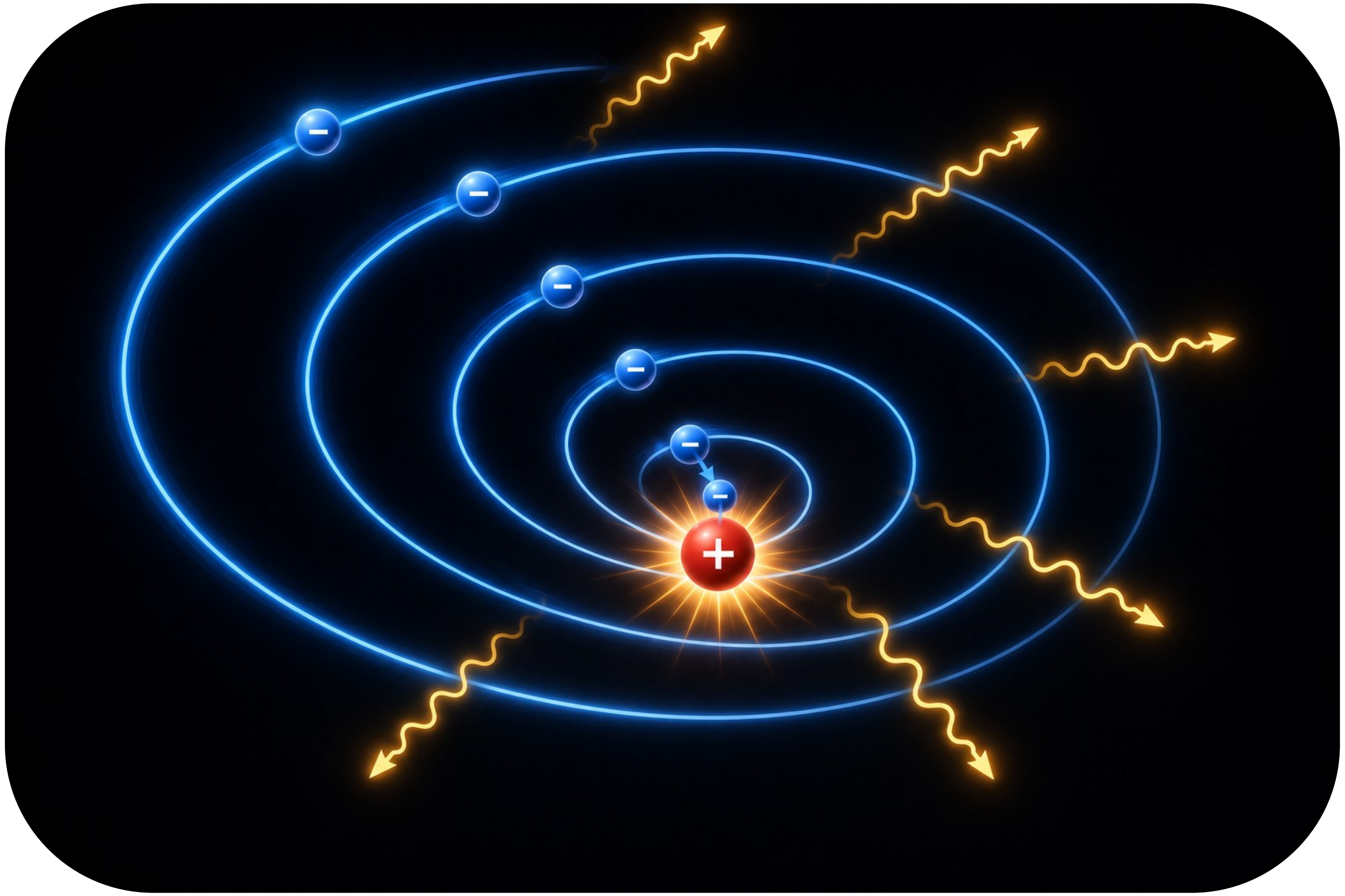
The Classical Conclusion

Classical physics predicts:

- Stable hydrogen atoms cannot exist.
- Stable chemistry cannot exist.
- Stable matter cannot exist.

Yet atoms clearly do exist.

- Classical physics predicts the wrong universe.
- If classical physics were correct, we would not exist!



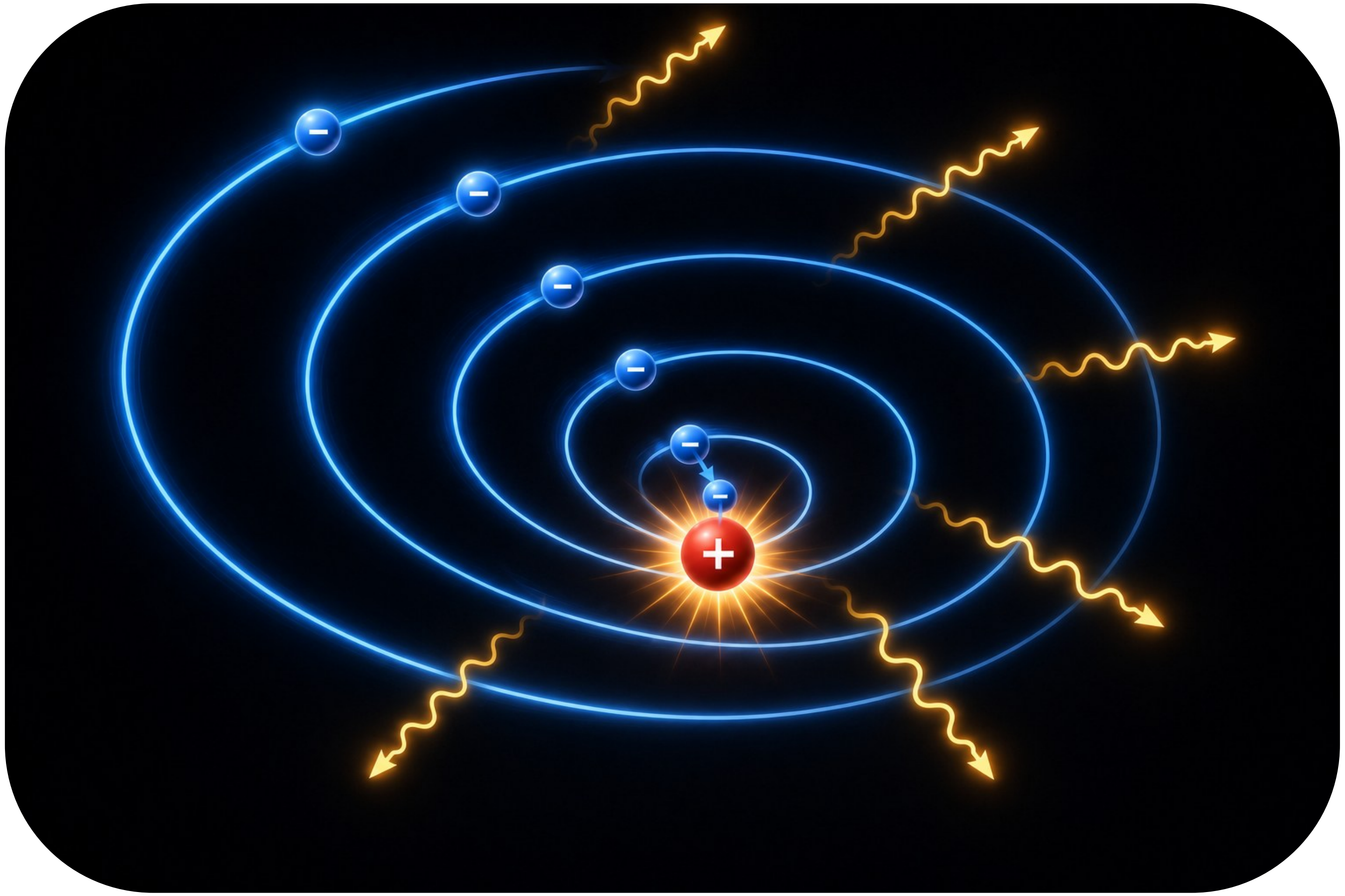
What Went Wrong?

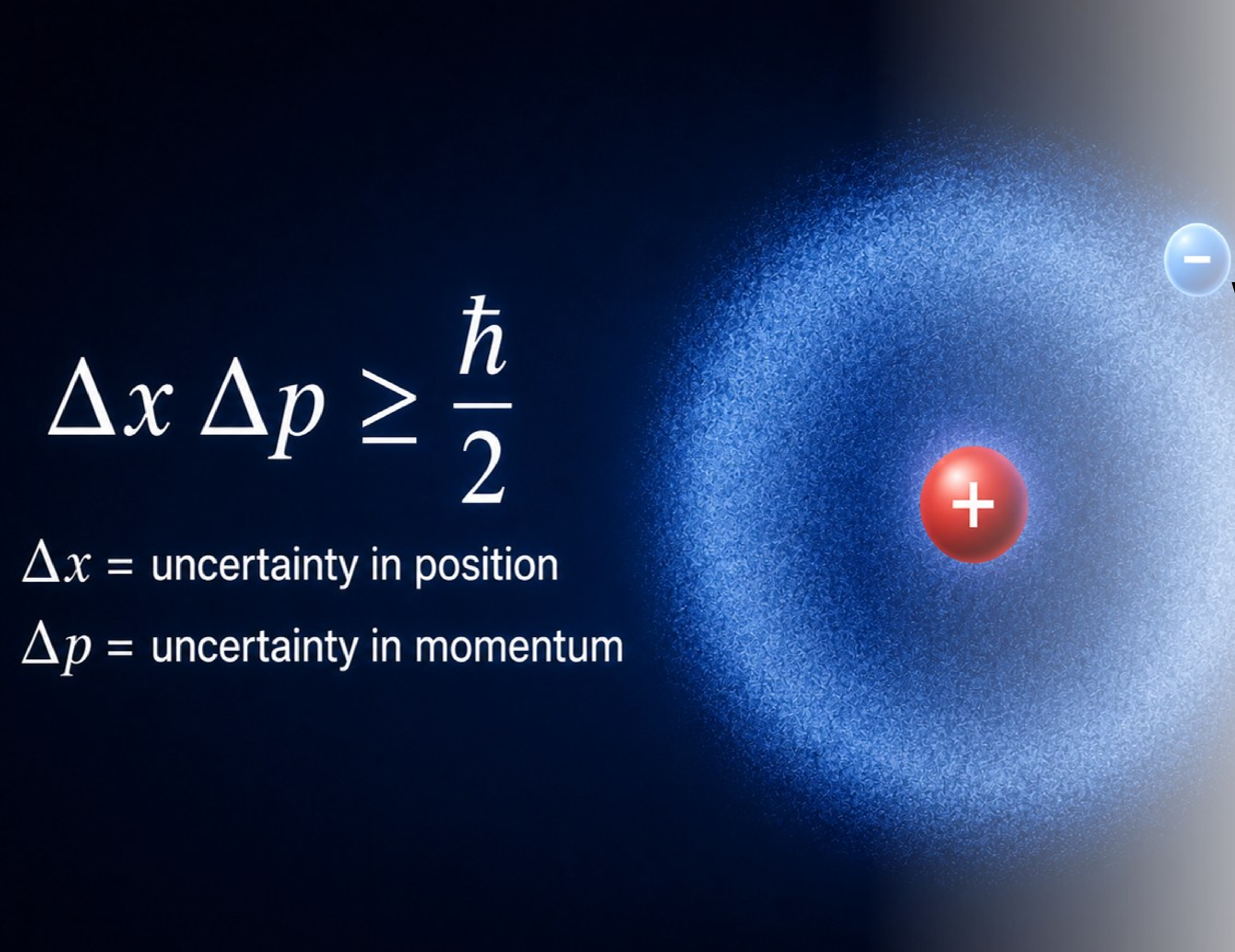
Everything seems correct:

- The electric attraction is correct.
- The mathematics of classical mechanics is correct.

The prediction is wrong because

- classical physics ignores the quantum nature of matter.
- A new principle is required.





Heisenberg's Answer

Werner Heisenberg proposed

- **The Uncertainty Principle**

$$\Delta x \, \Delta p \geq \frac{\hbar}{2}$$

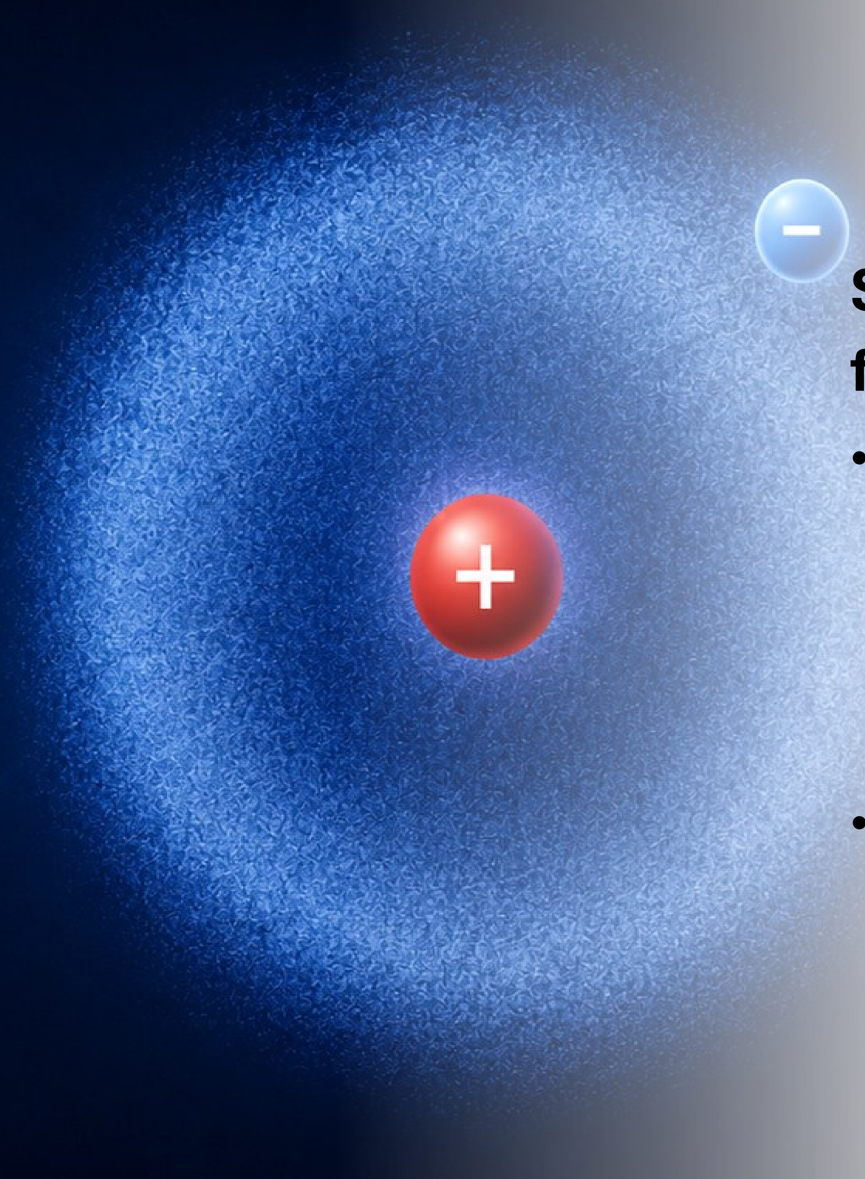
- **Position and momentum cannot both be known with unlimited precision.**

Why the Electron Cannot Collapse

$$\Delta x \, \Delta p \geq \frac{\hbar}{2}$$

Δx = uncertainty in position

Δp = uncertainty in momentum



Suppose the electron is forced into the proton.

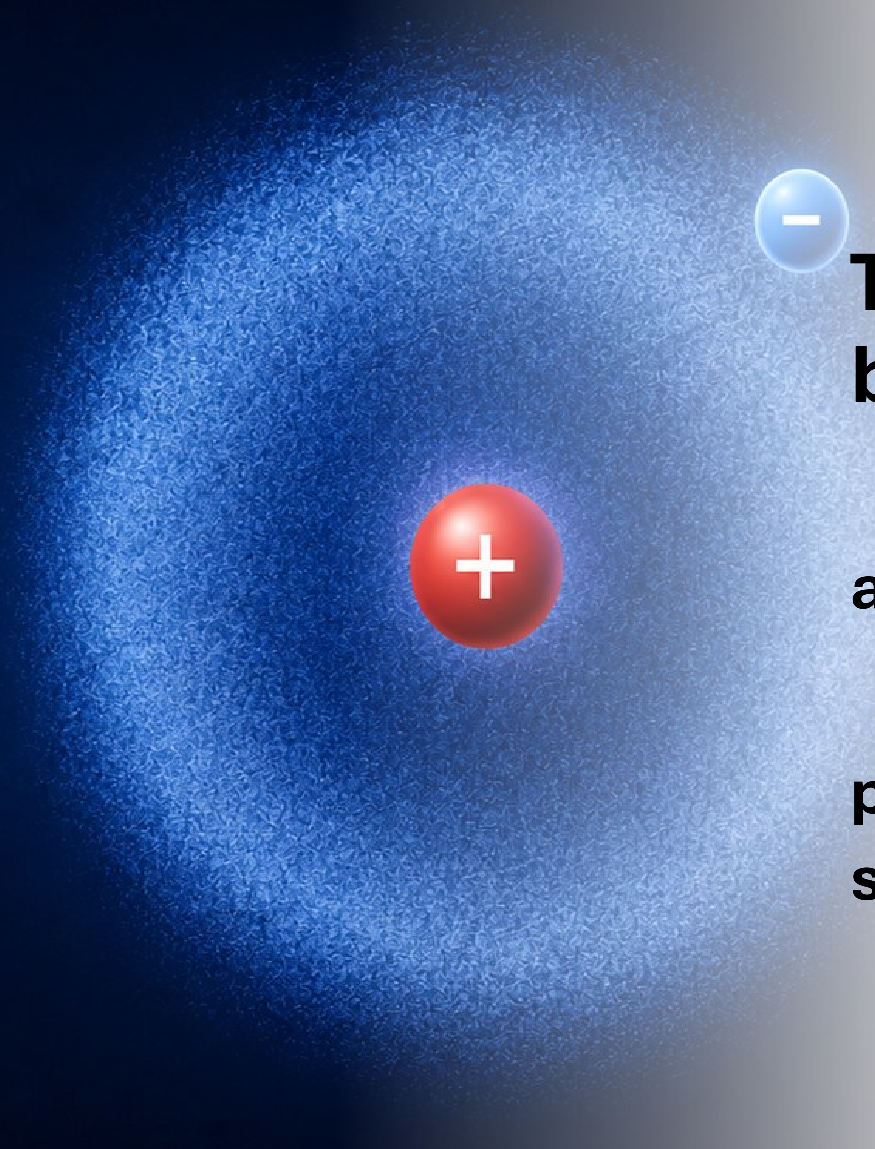
- Then
    - Position uncertainty becomes extremely small.
    - Momentum uncertainty becomes extremely large.
- Kinetic energy becomes enormous.
    - The enormous kinetic energy prevents collapse.
    - The electron is confined to a shell around the proton
    - The atom remains stable.

The Electron Shell Emerges

$$\Delta x \, \Delta p \geq \frac{\hbar}{2}$$

Δx = uncertainty in position

Δp = uncertainty in momentum



The competition between

- electrical attraction

and

- quantum uncertainty

produces a stable electron shell.

- The Uncertainty Principle correctly predicts
- that atoms can exist.

But Heisenberg Doesn't Tell the Whole Story

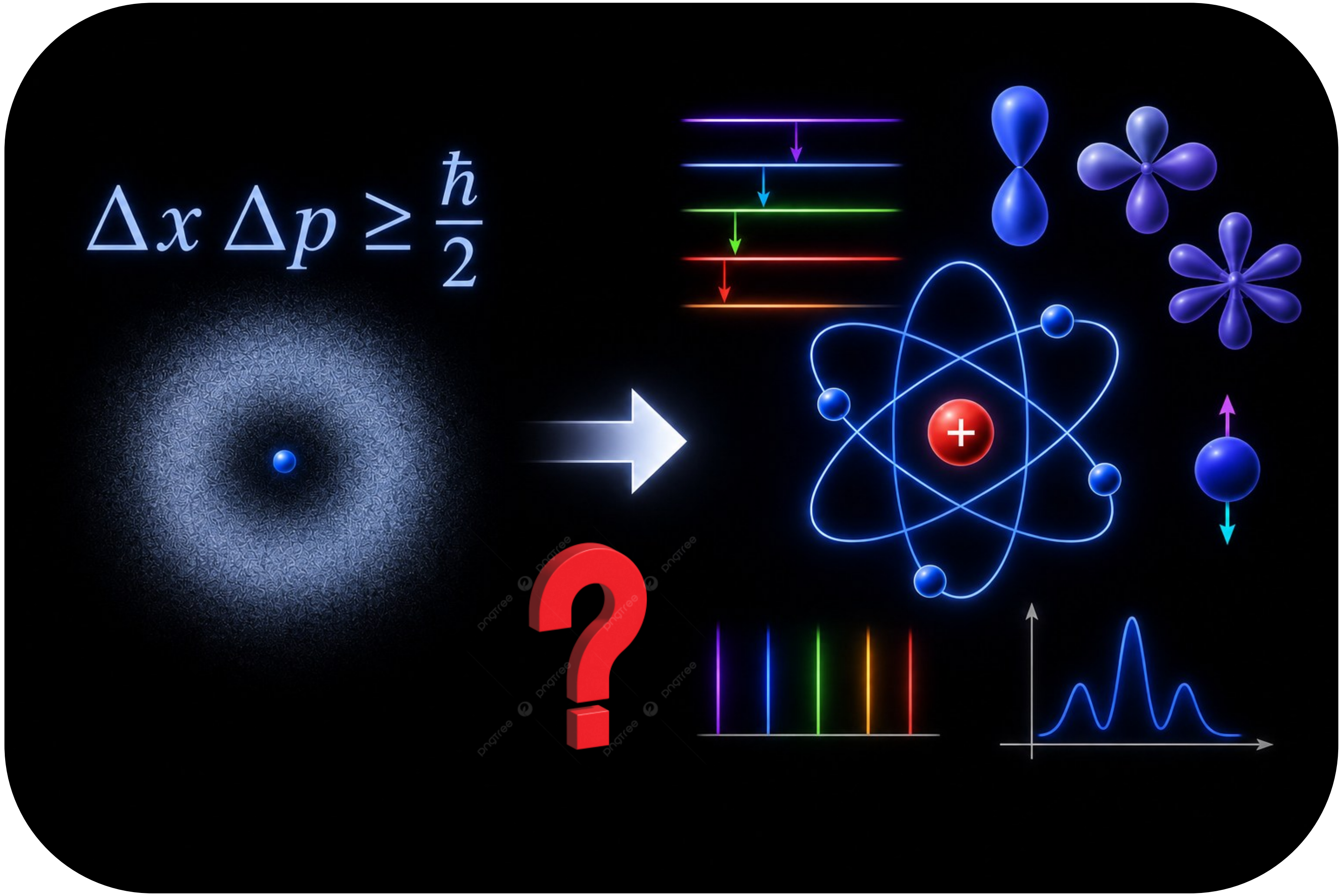
The Uncertainty Principle explains

- why atoms are stable.

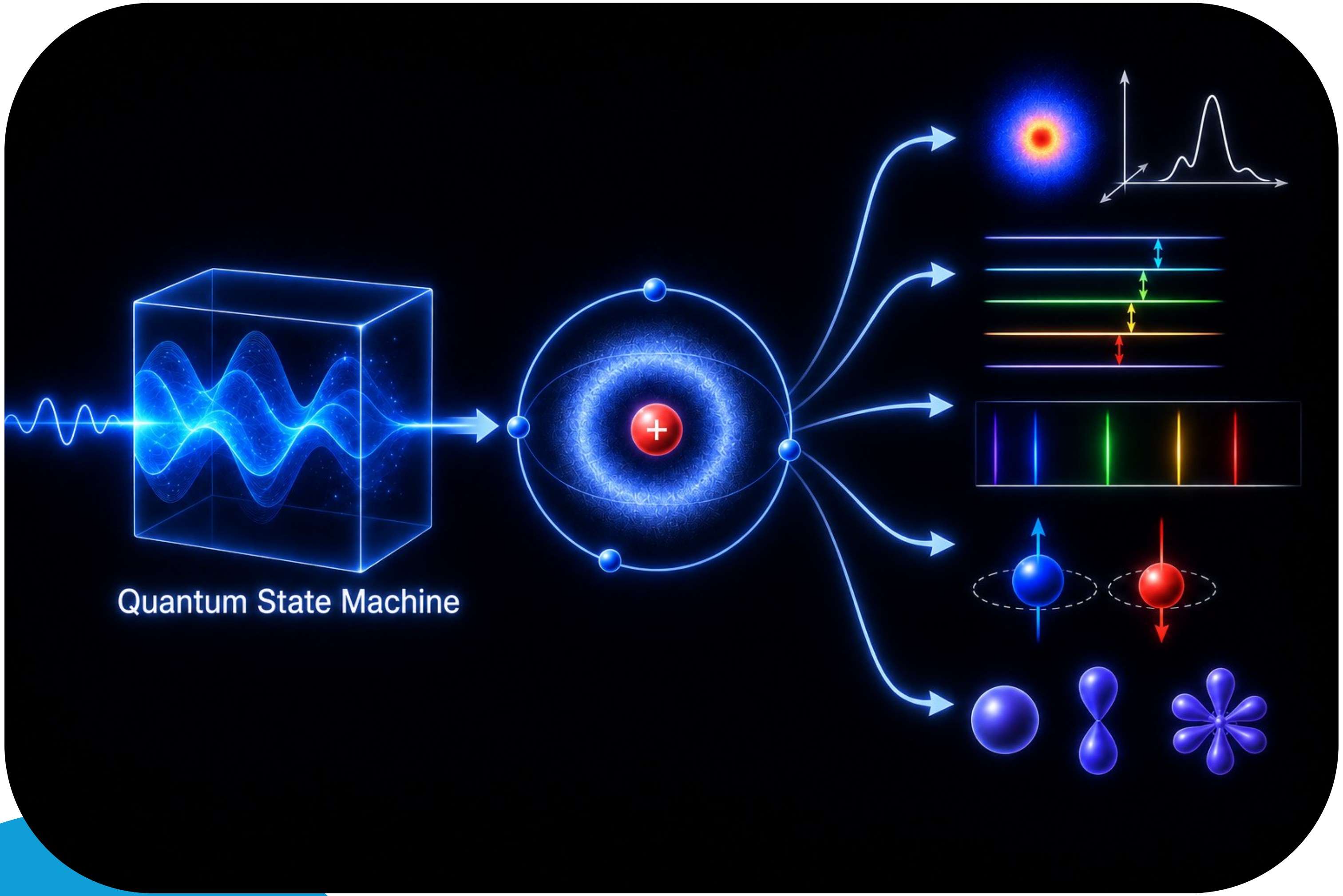
It does not predict

- the exact electron probability distribution
- the allowed energy levels
- the spectral lines
- electron spin
- orbital shapes

For that we need something more powerful.



The Quantum State Machine



Starting with

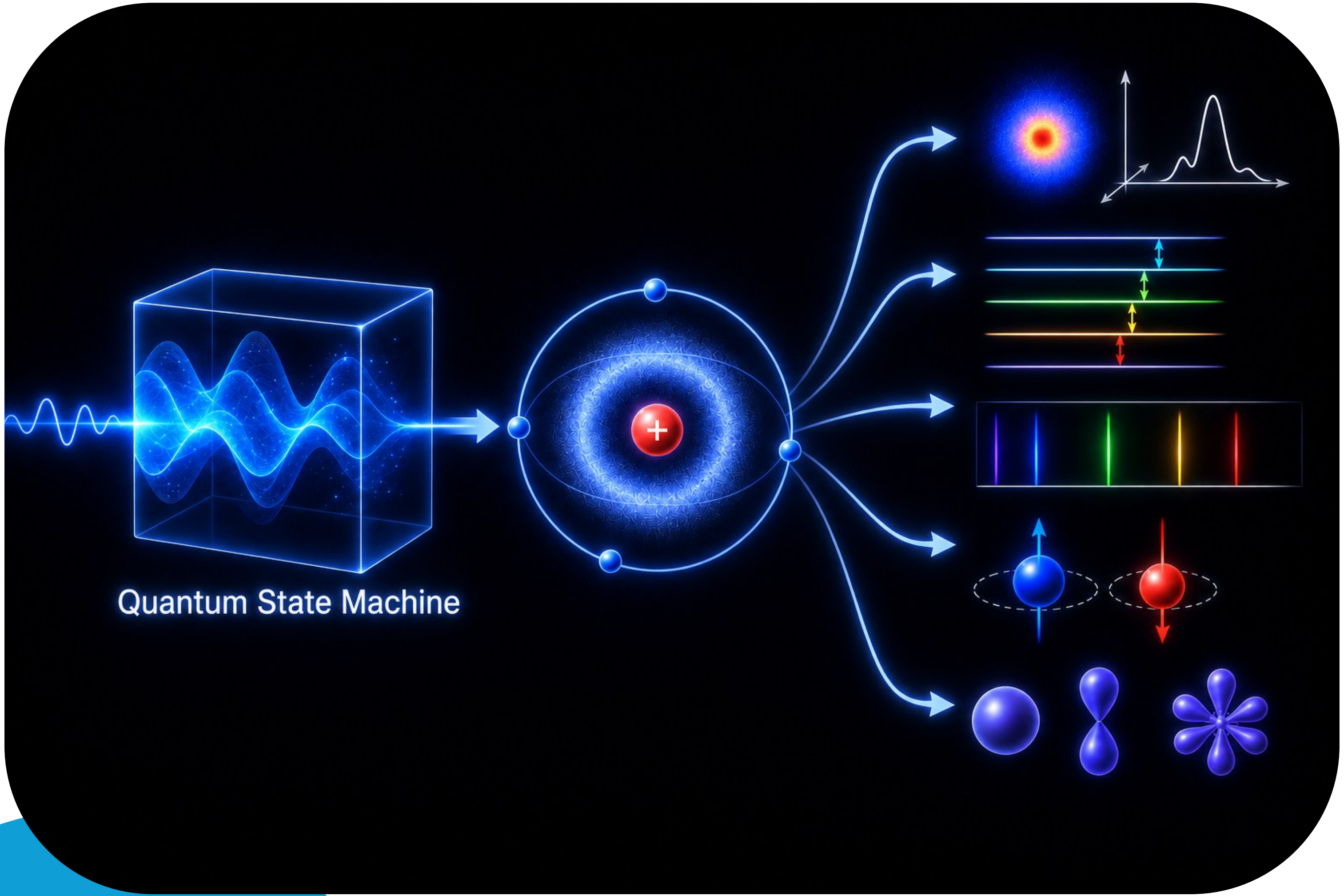
- one proton
- one electron

the Quantum State Machine predicts

- the electron probability distribution
- the stable bound states
- the allowed energy levels
- angular momentum
- spin
- transition probabilities
- the hydrogen emission spectrum

Using exactly the same Quantum State Machine we used to predict all of our other experimental results.

The Quantum State Machine



The Quantum State Machine predicts

- the radius of the electron cloud
- the orbital structure
- the hydrogen spectrum
- fine structure
- hyperfine structure
- Zeeman splitting
- and every experimentally observed property of hydrogen.

The agreement with experiment is extraordinary.

Looking Through the Process Lens

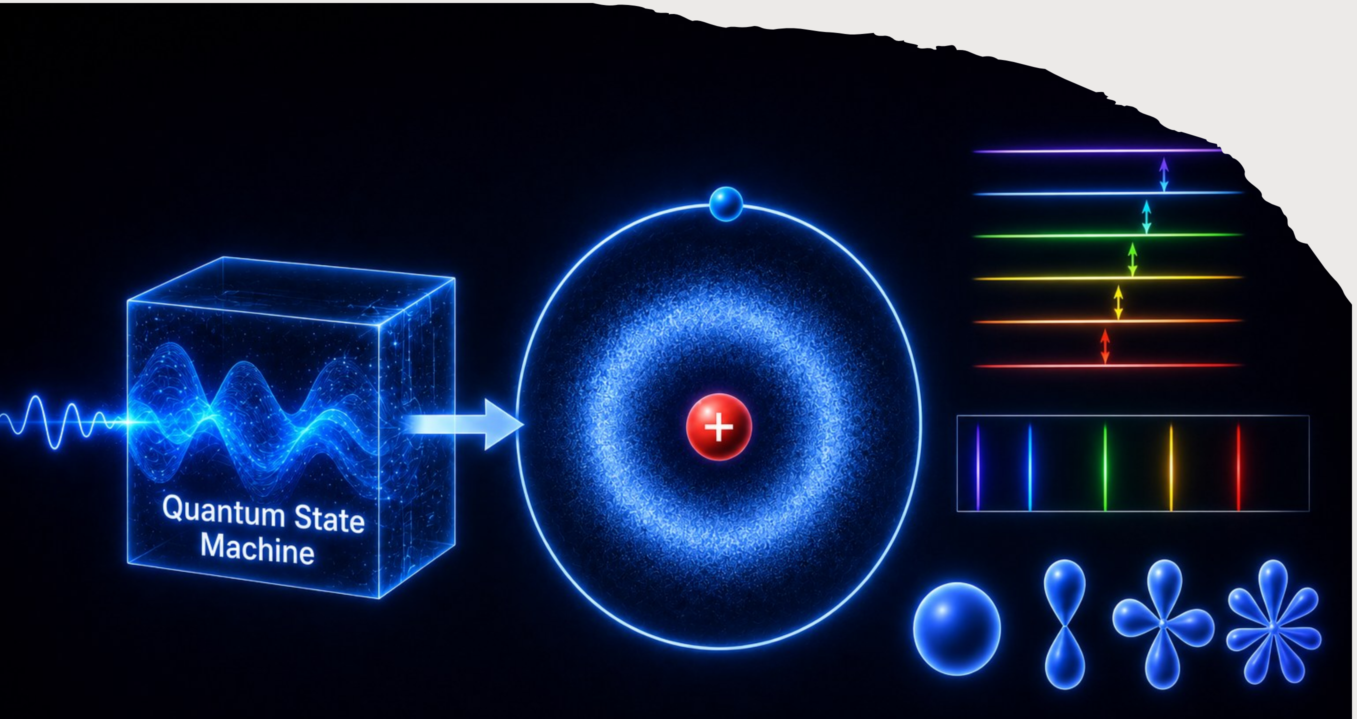
Stable atoms are not permanent objects.

- They are enduring patterns maintained by the laws of physics.

The hydrogen atom is another example of:

- Stable Matter → Enduring Relations
- A society whose order is inherited from one moment to the next.

The Quantum State Machine Has Built an Atom



We began with

- an electron
- a proton

We ended with

- The Hydrogen Atom

The Quantum State Machine has now successfully built

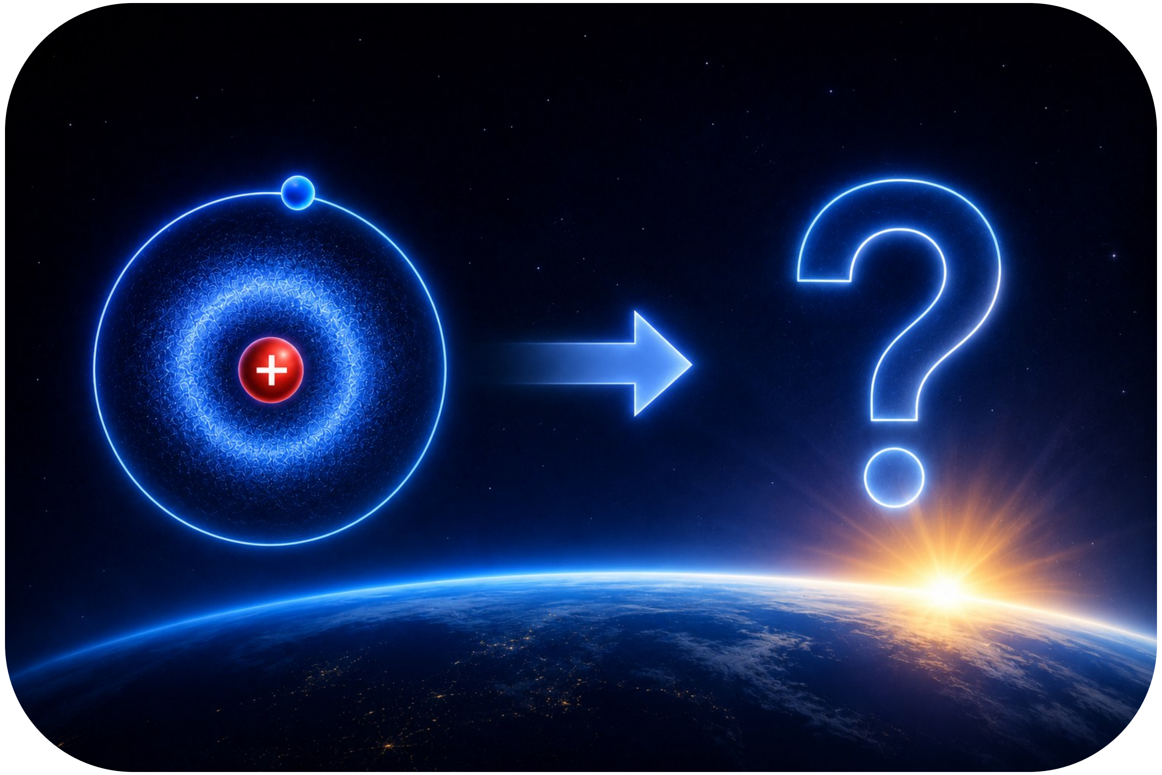
- particles
- hadrons
- nuclei
- atoms

- The journey continues...

Next Week

Our final lecture of the series

- Starting with hydrogen, we'll let the Quantum State Machine build the entire periodic table.
- We'll follow that chemistry into stars, planets, and ultimately life itself.
- We will see where we are headed in the future.




“That’s all Folks!”
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