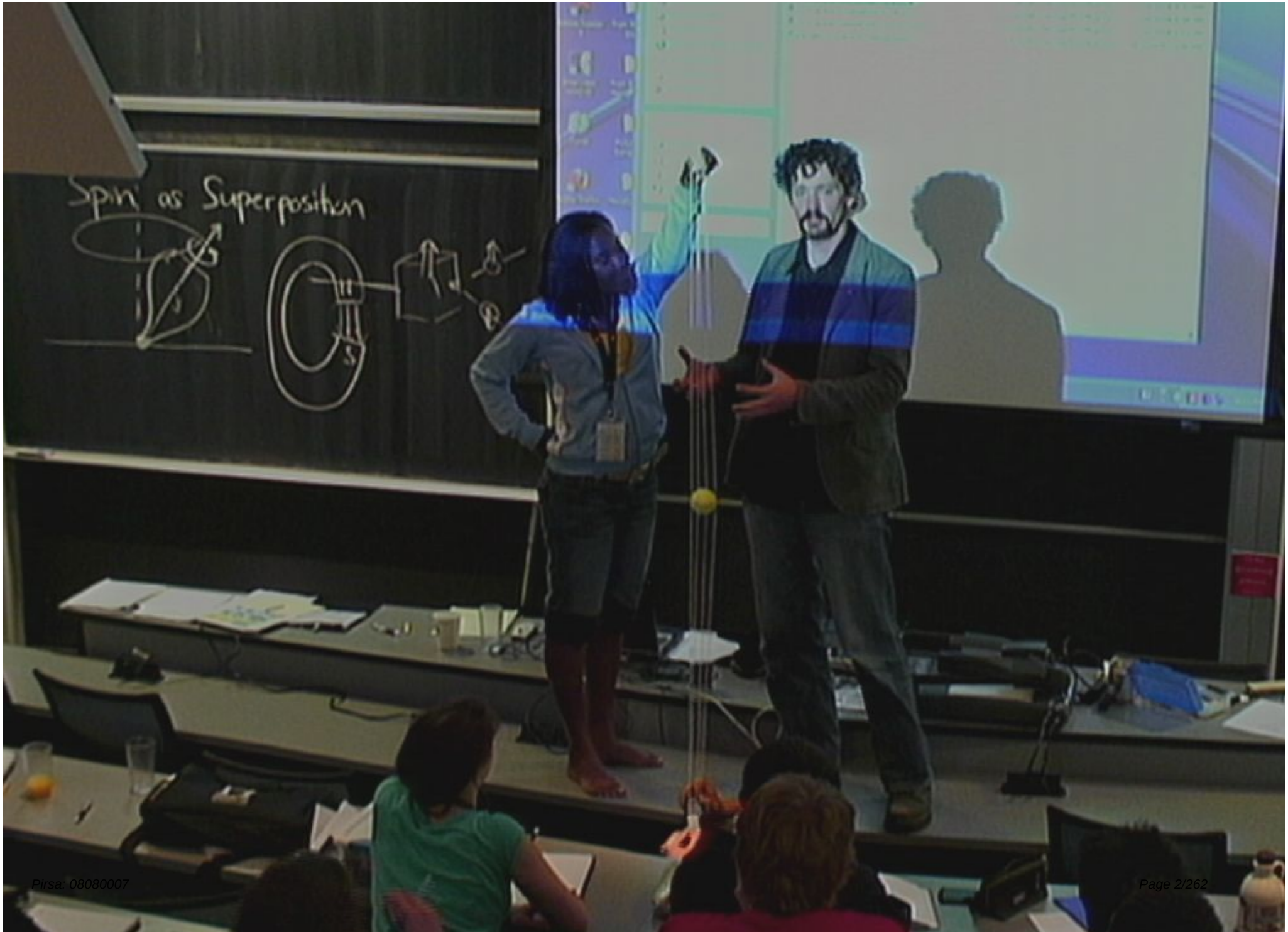
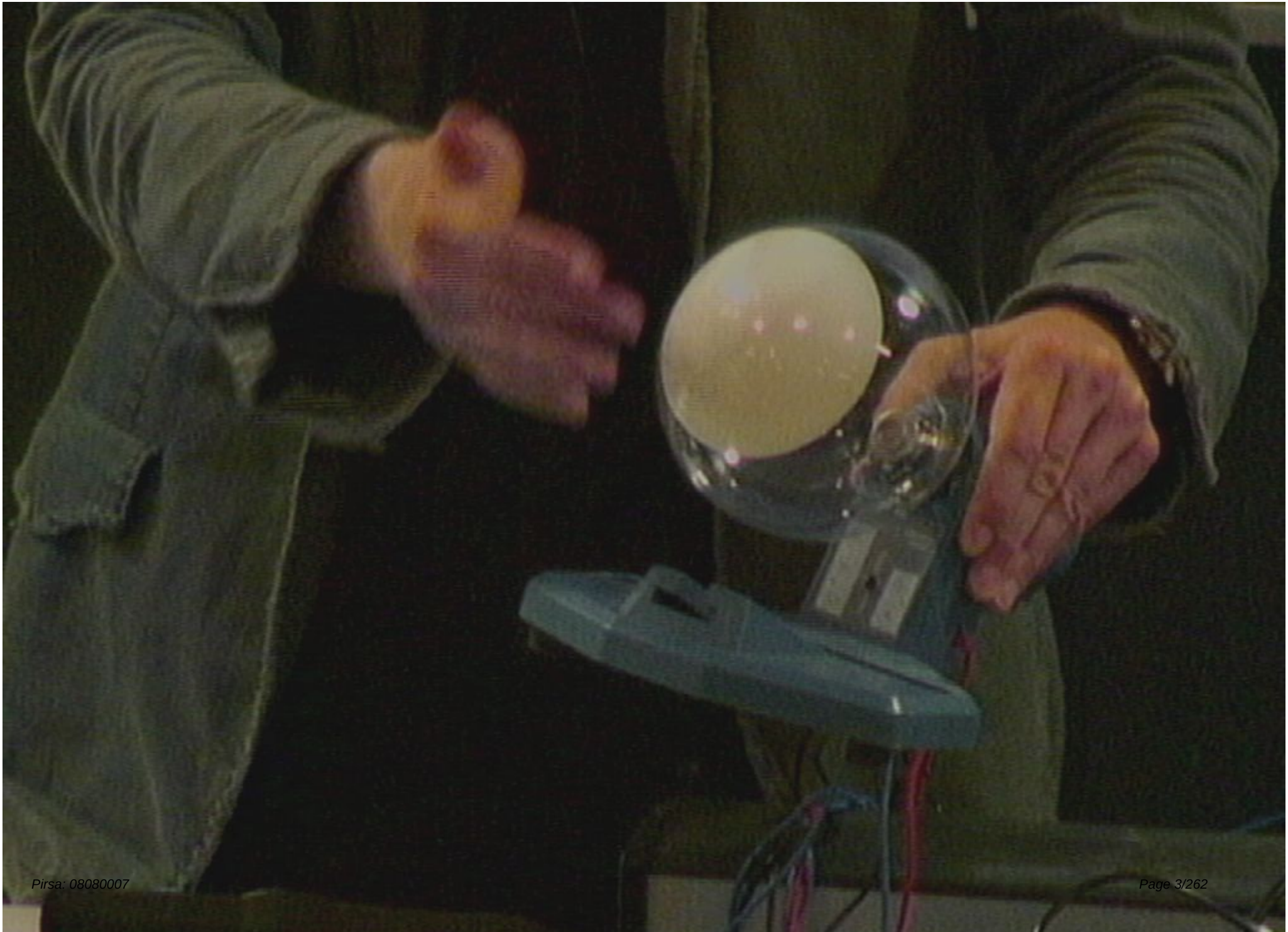
Title: Quantum 6

Date: Aug 01, 2008 03:30 PM

URL: http://pirsa.org/08080007

Abstract:


Spin as Superposition



What's Inside the Tube?

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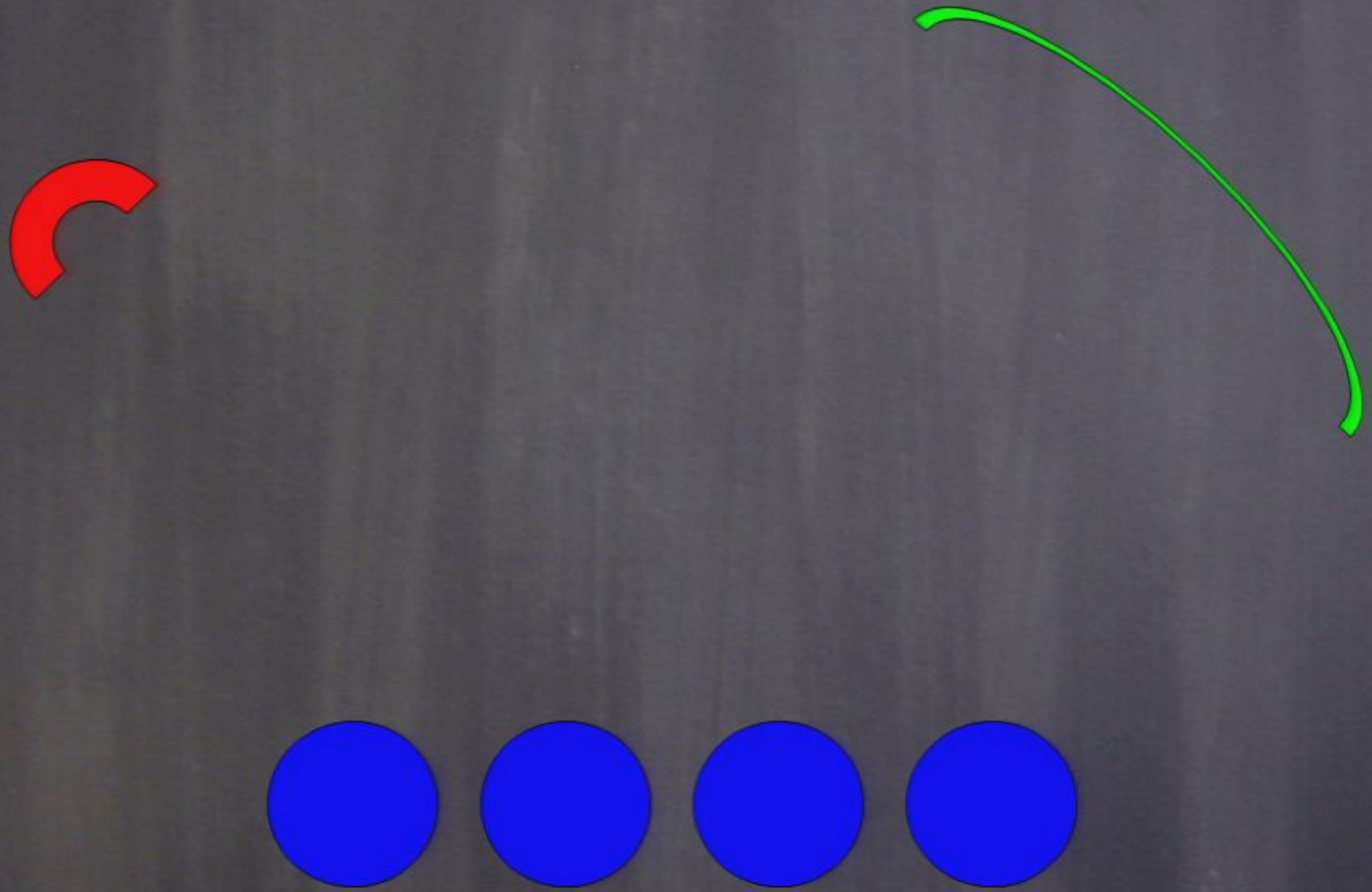

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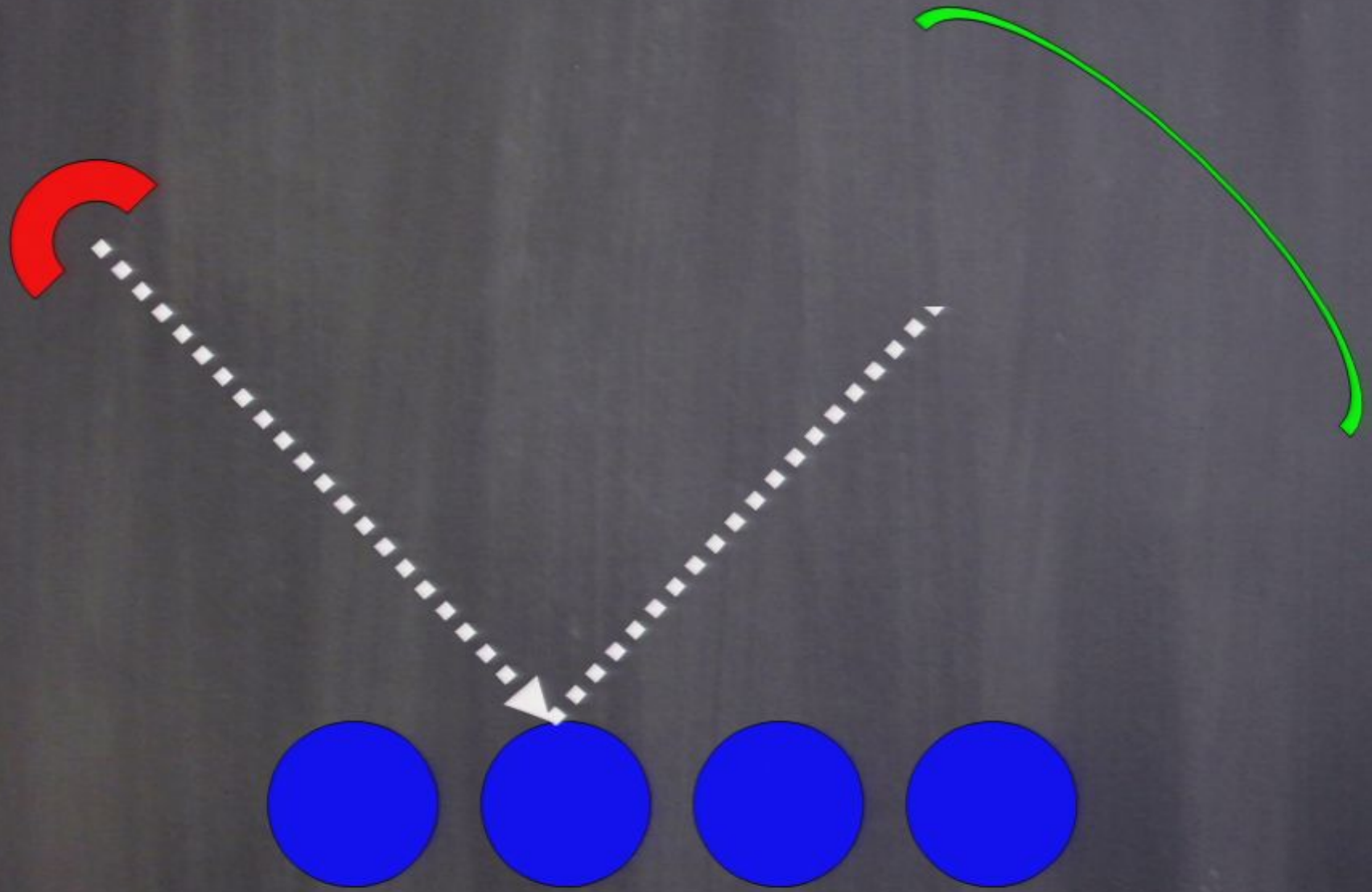

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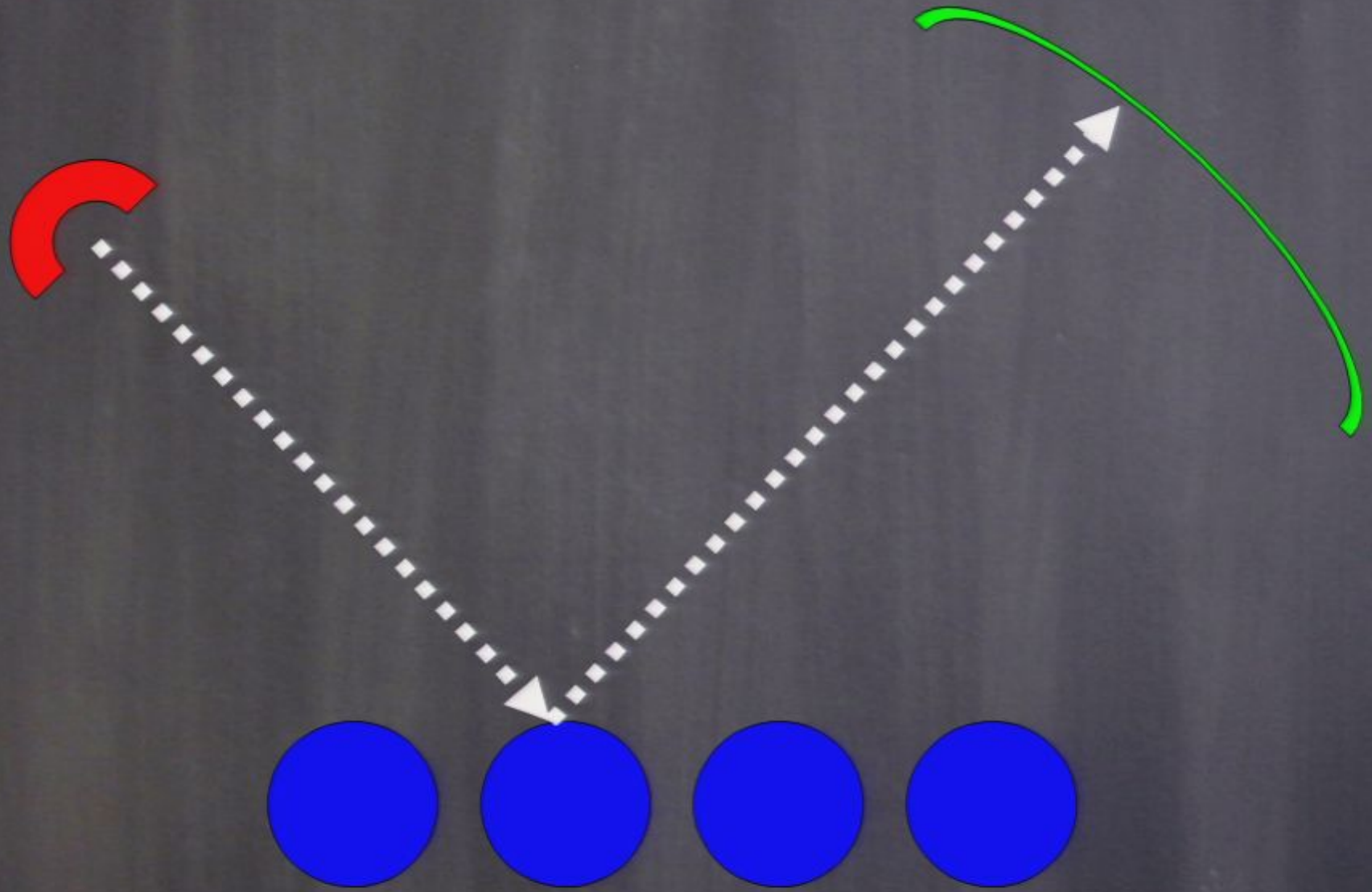

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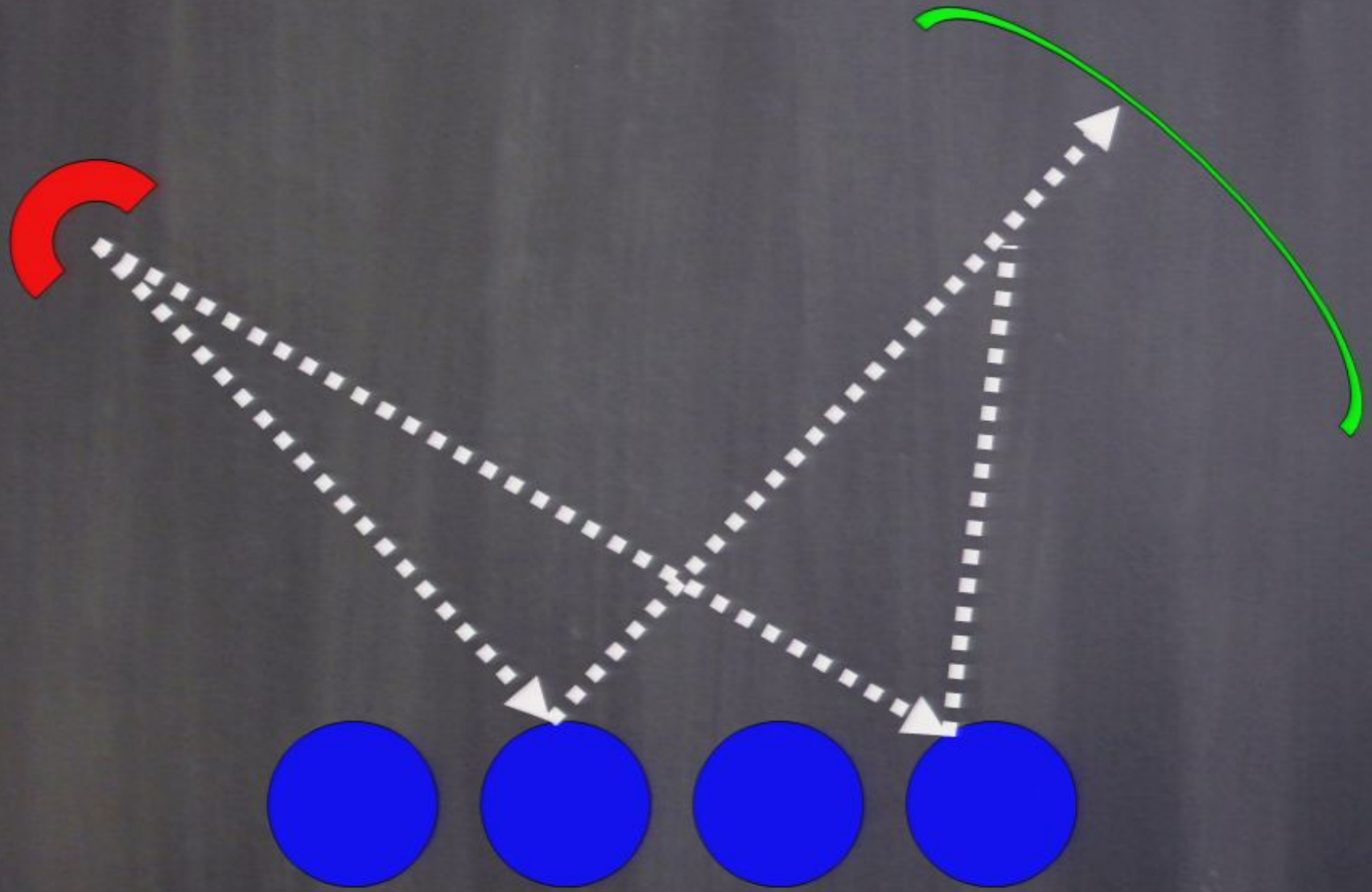

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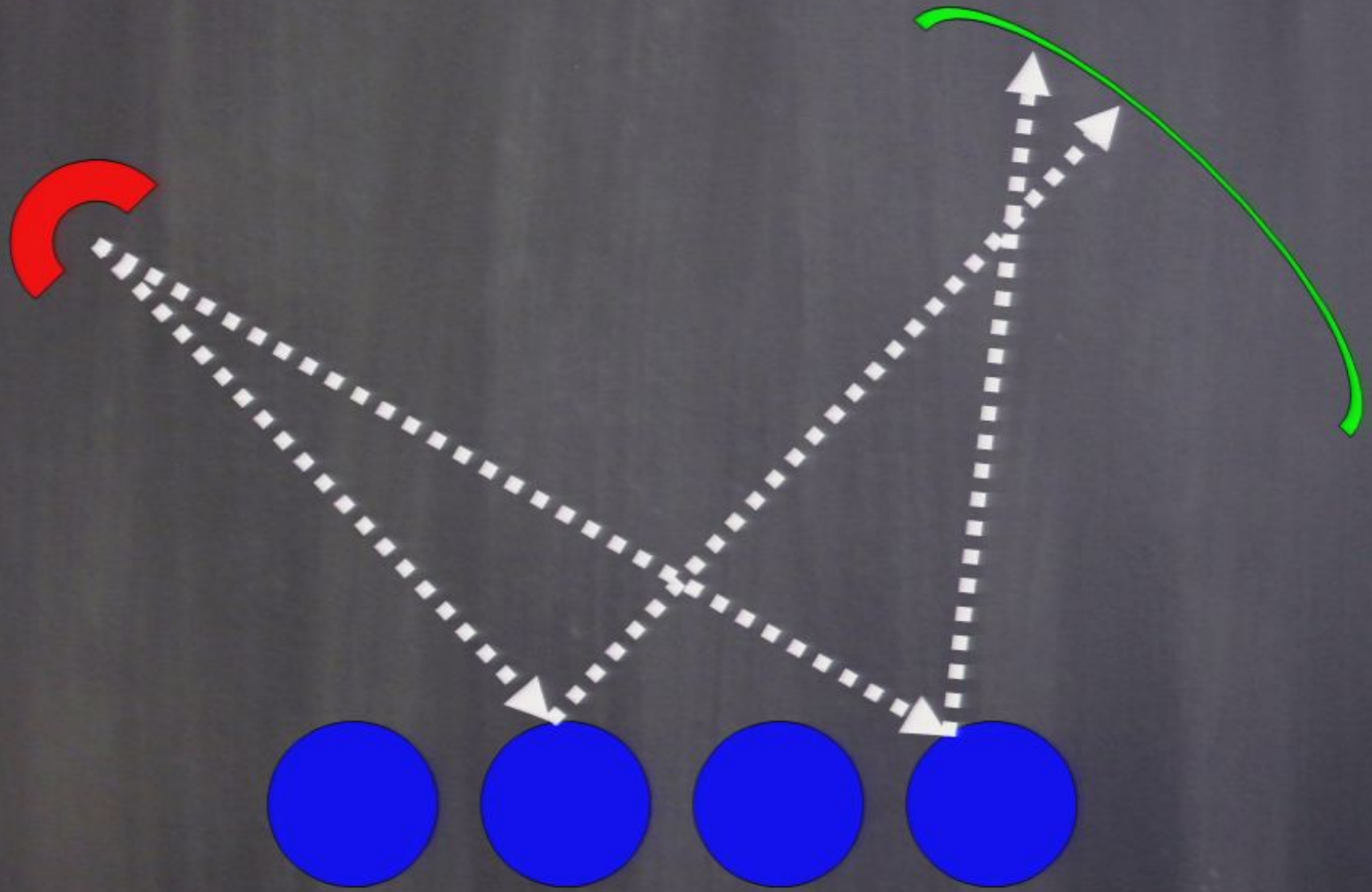

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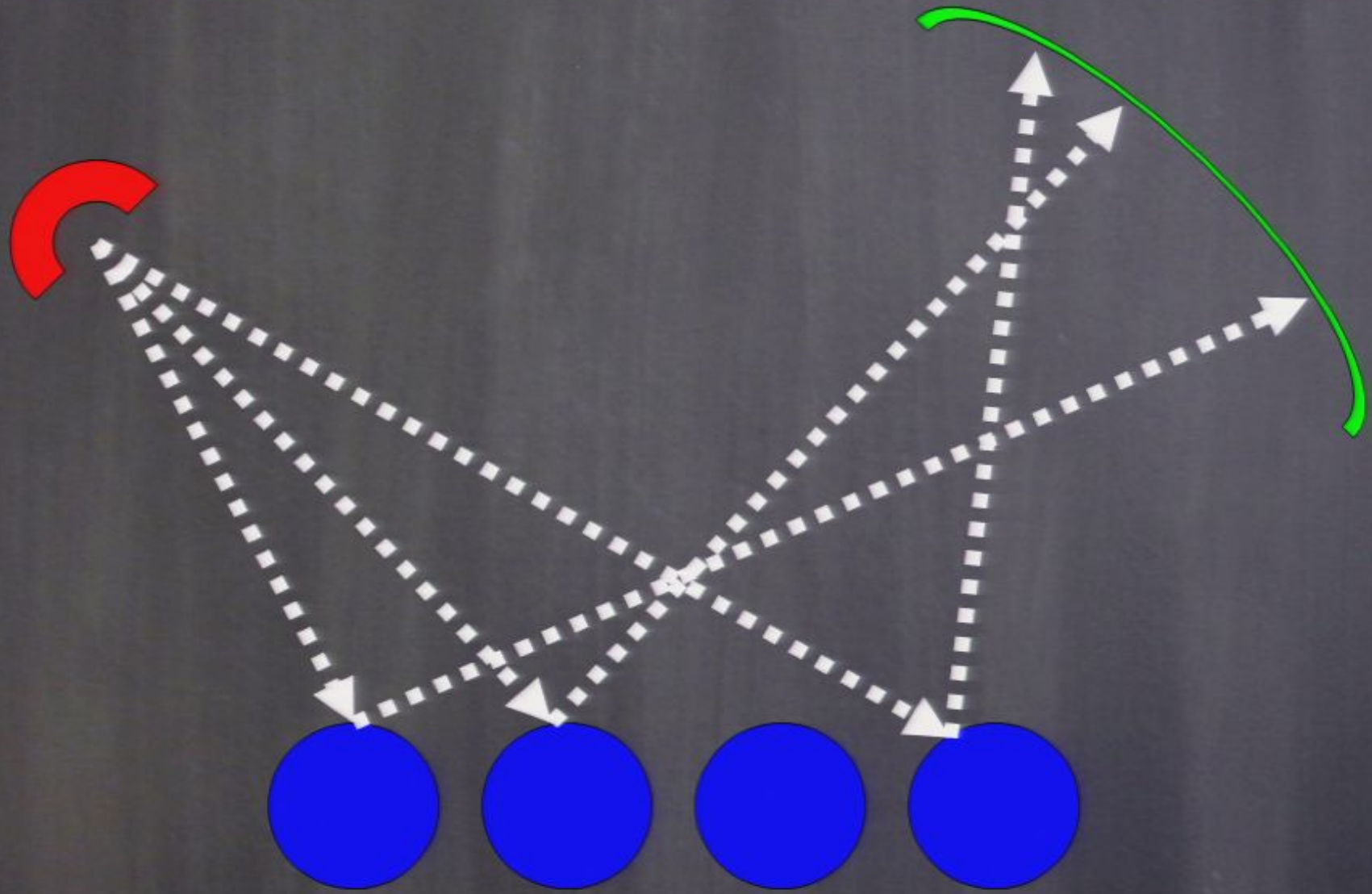
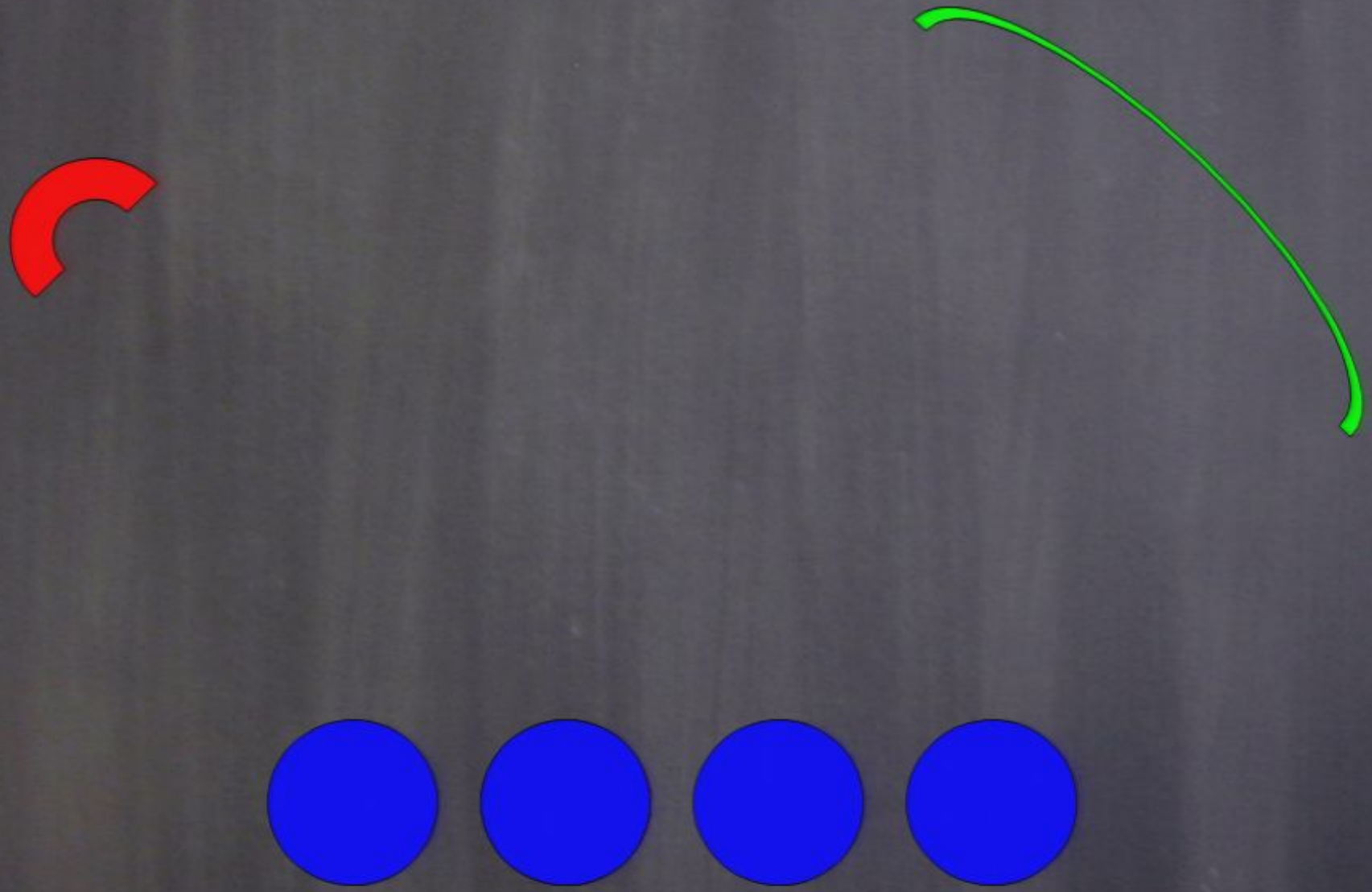


Simplify: Only ONE Atom



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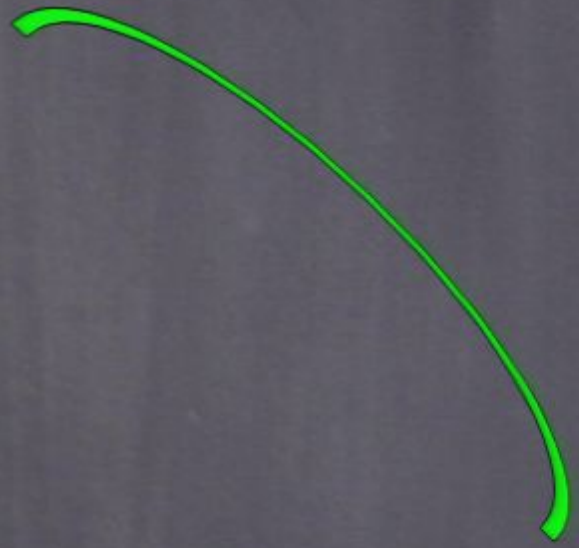

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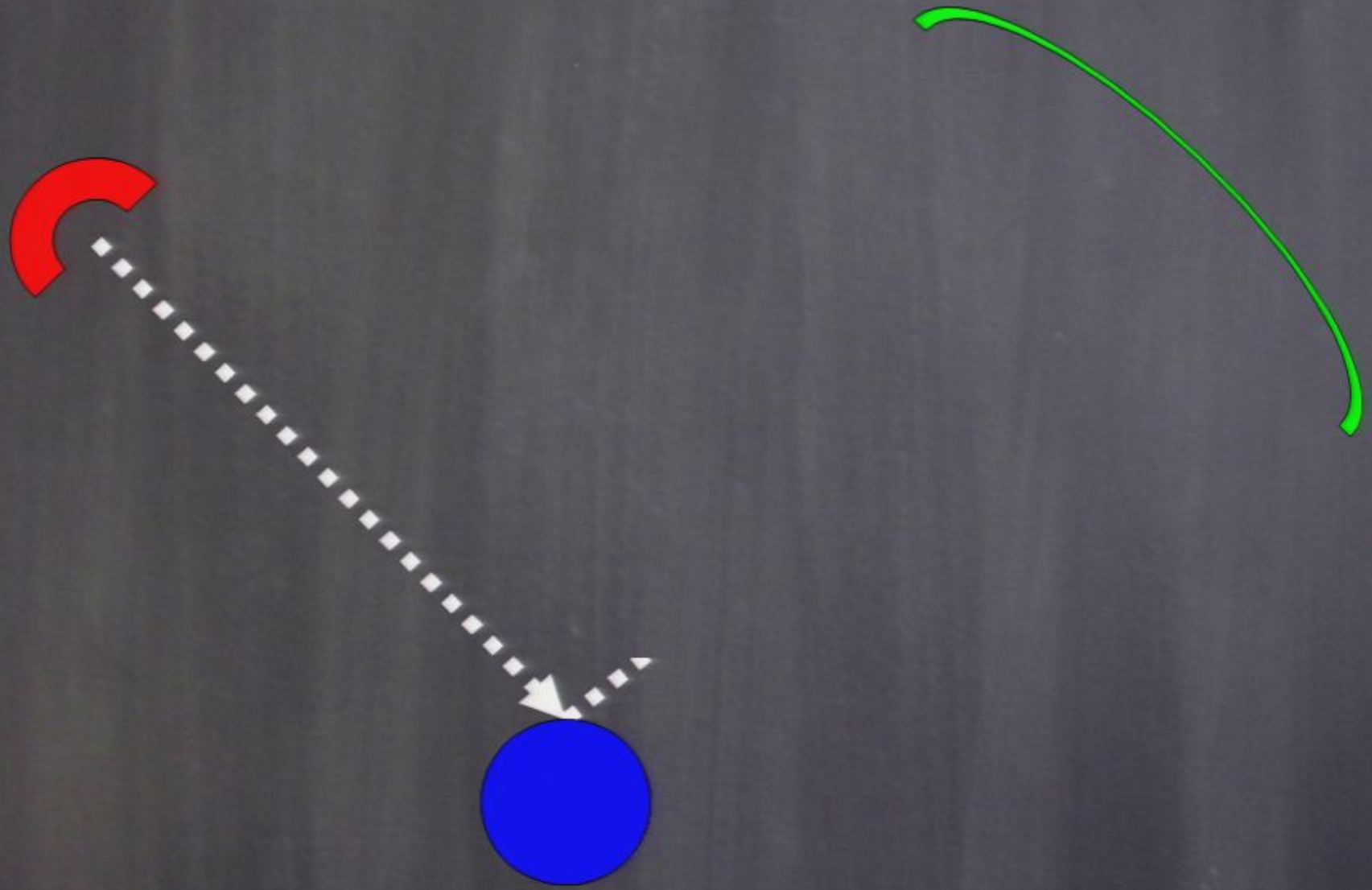

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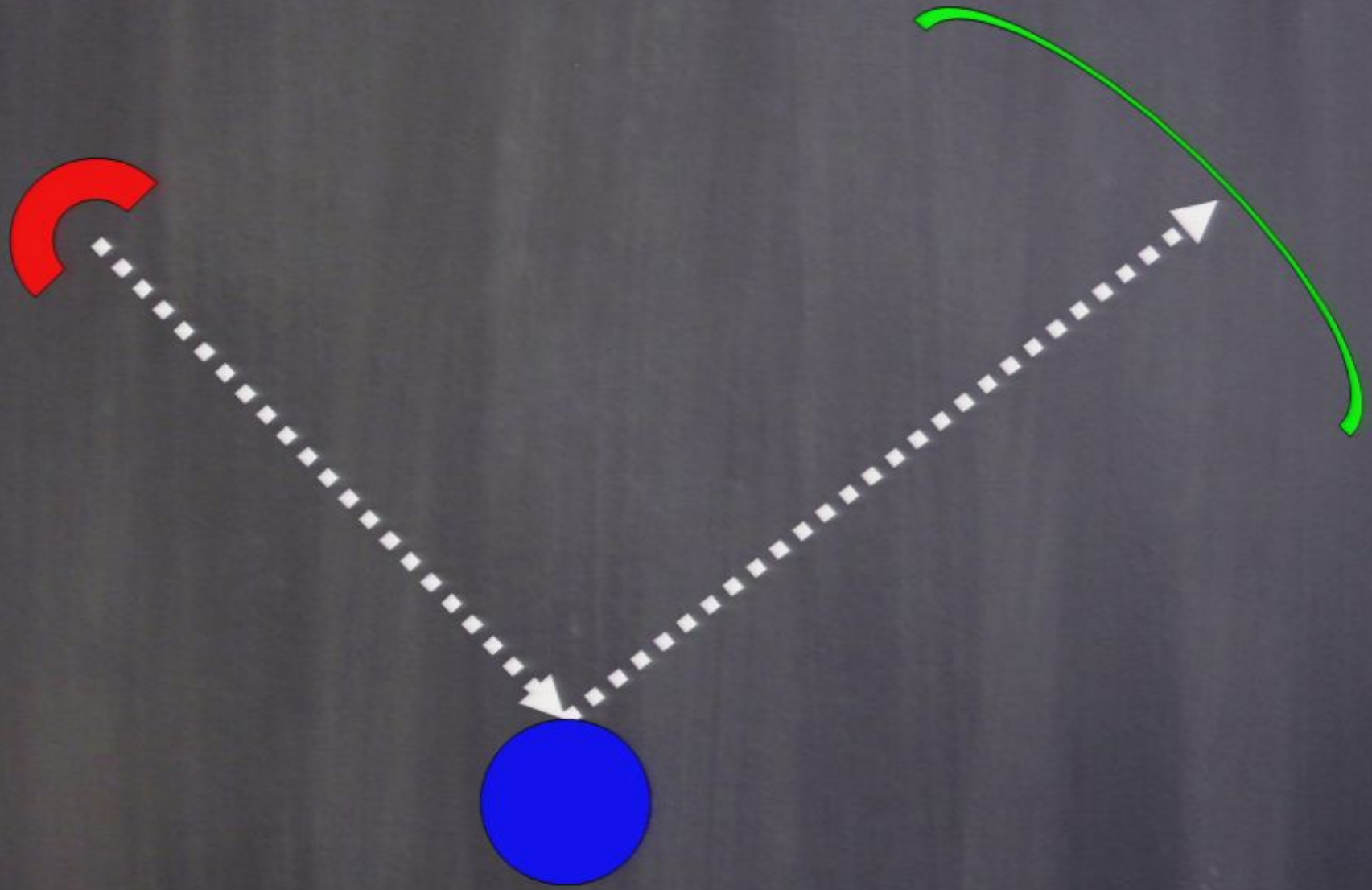

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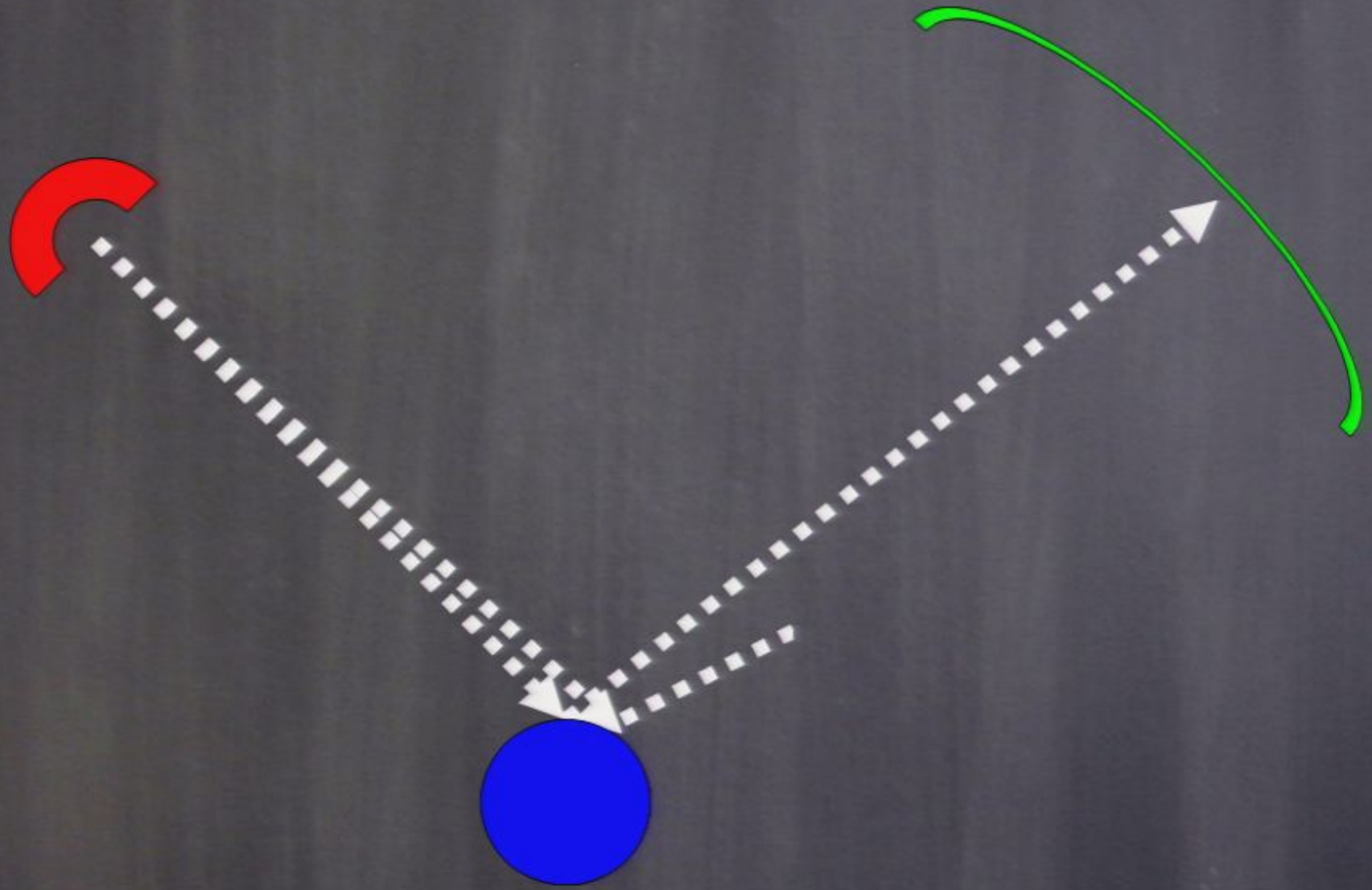

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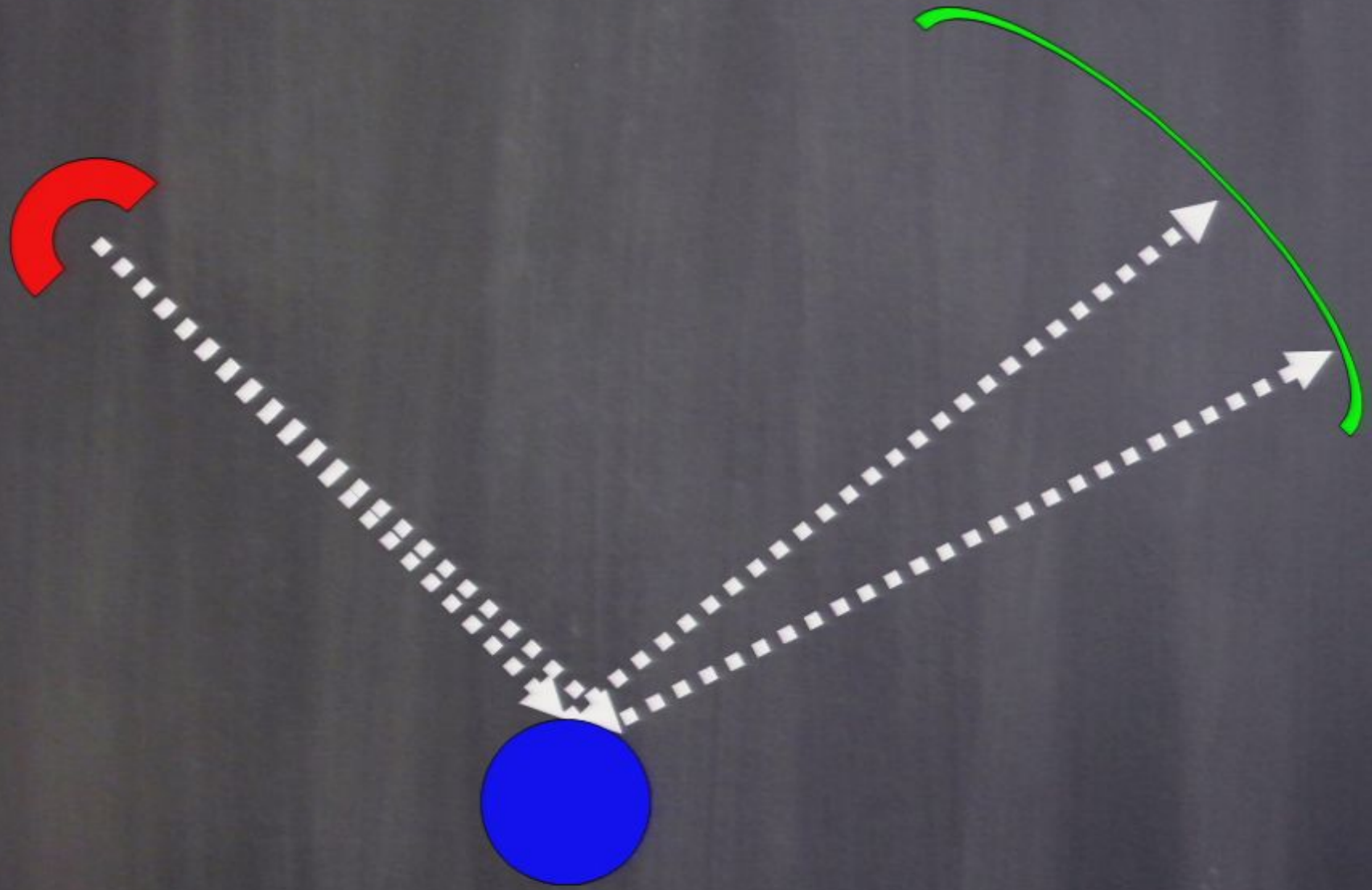

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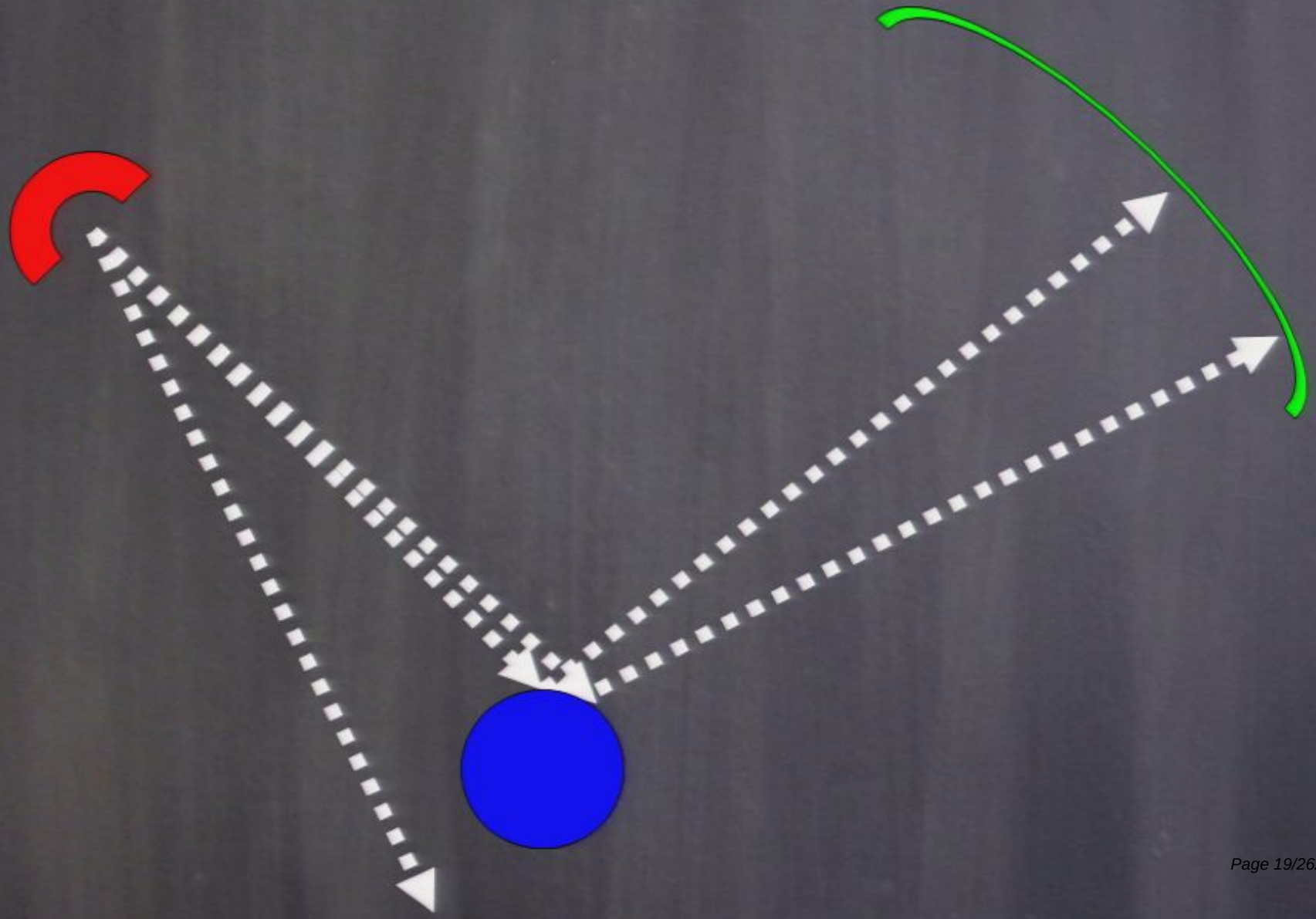

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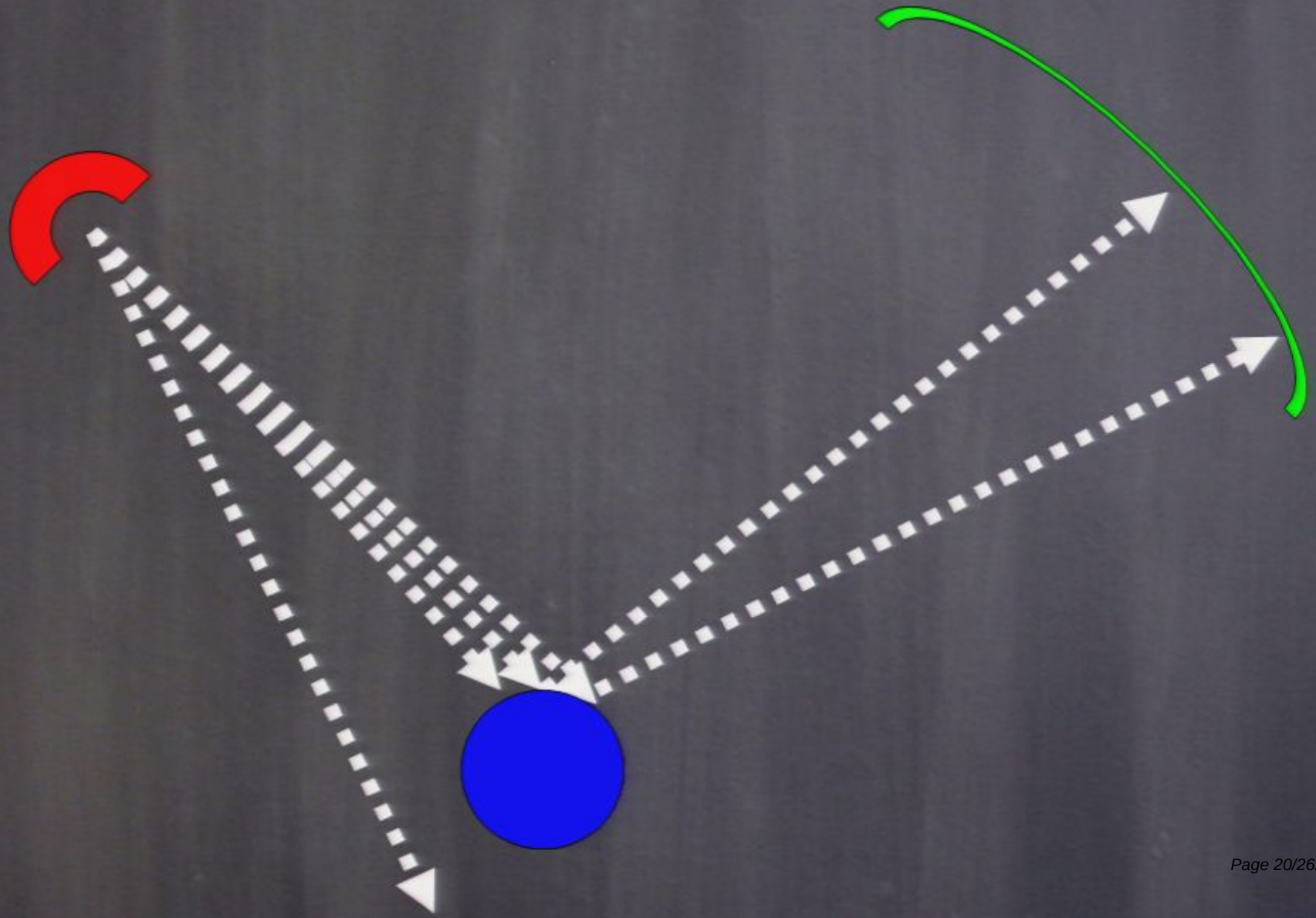

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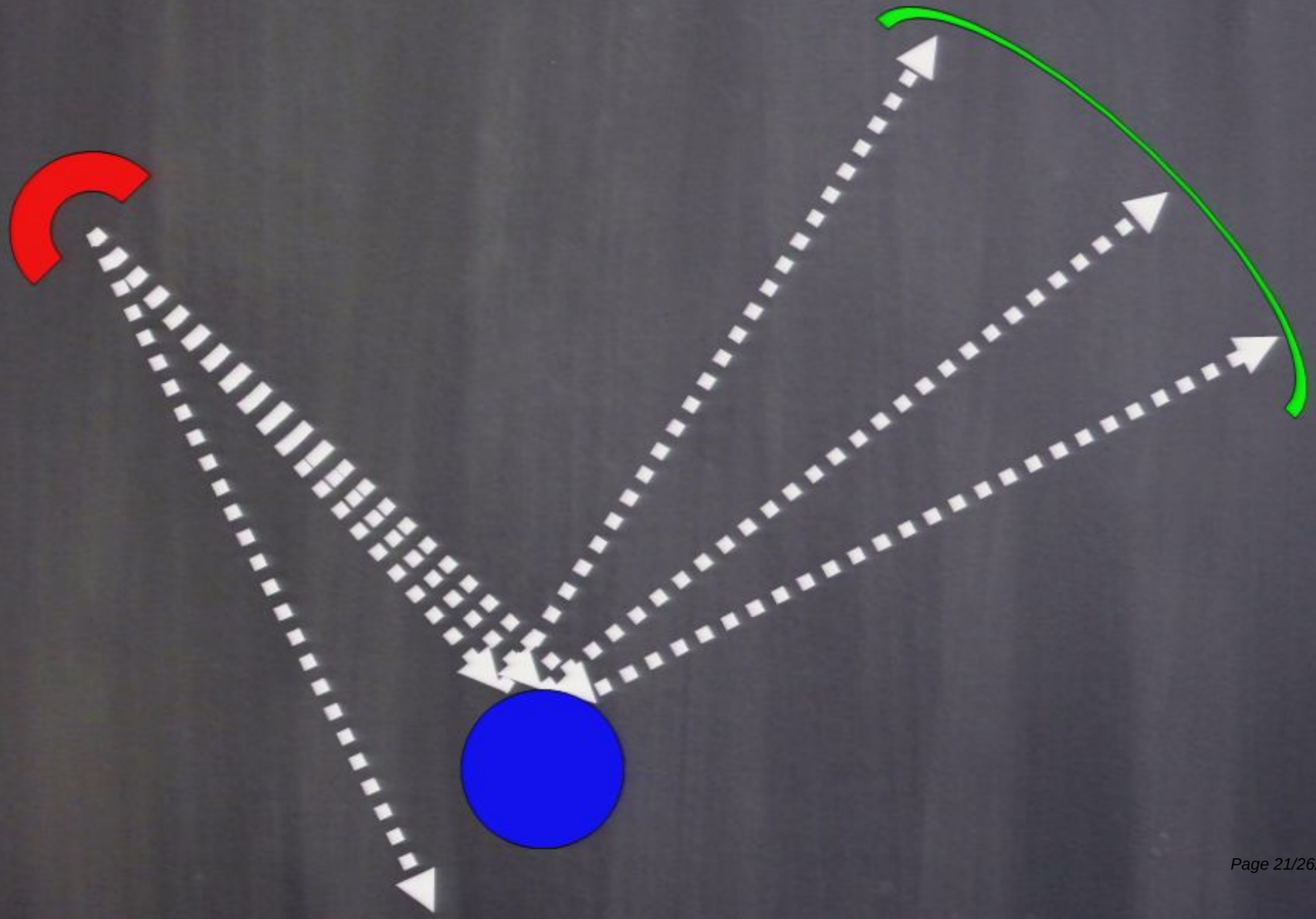

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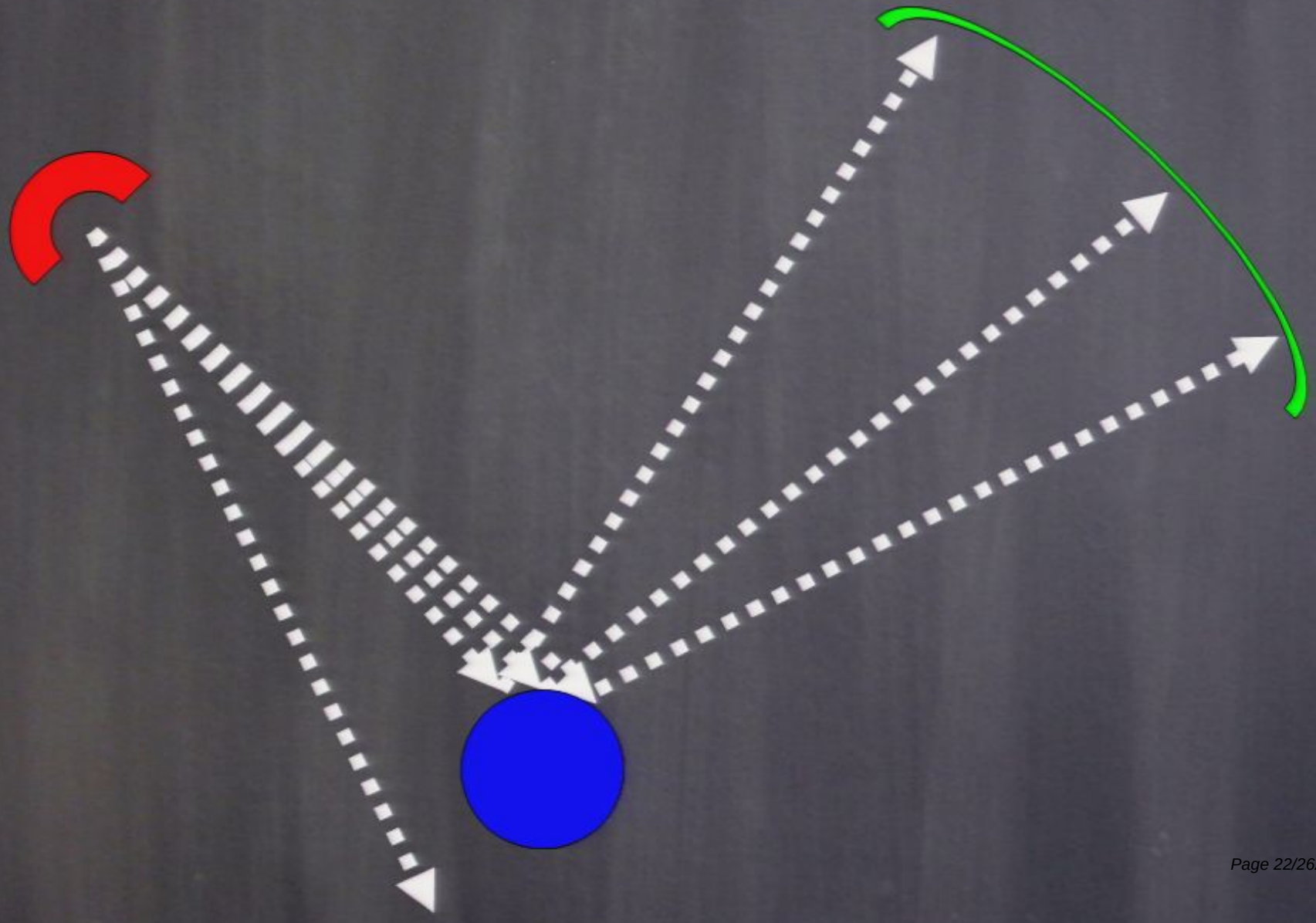

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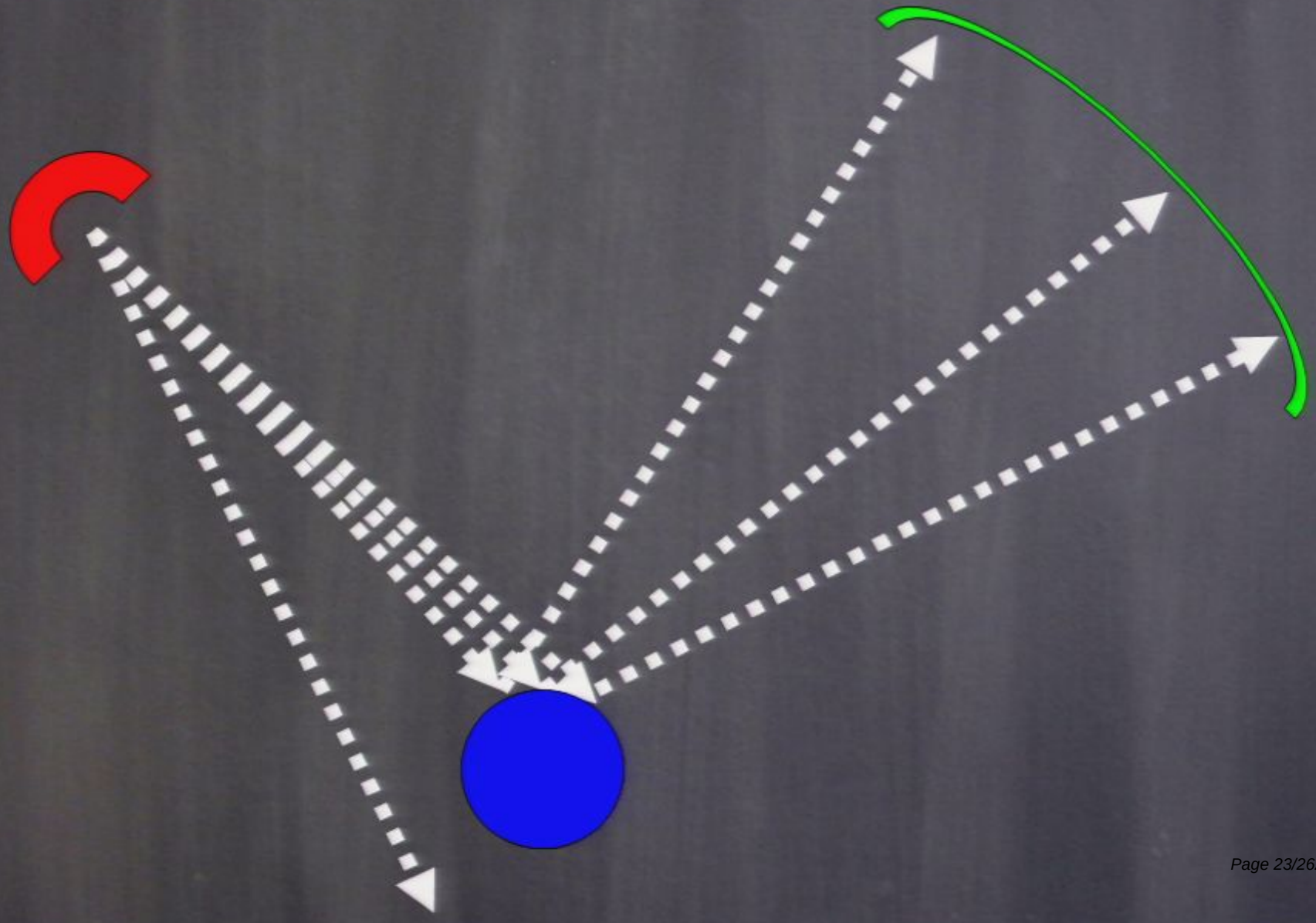
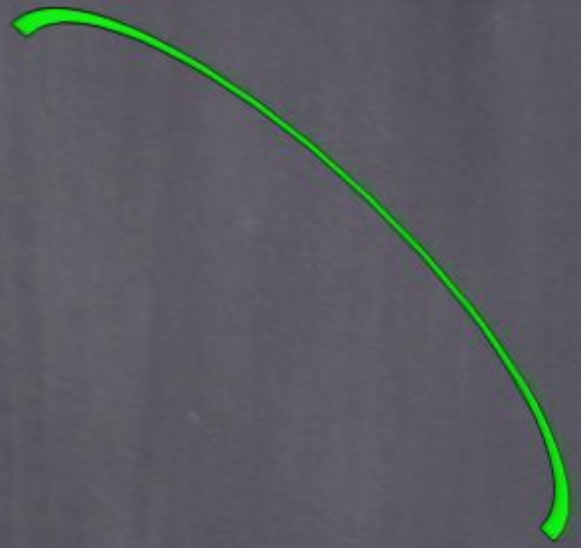


Bring in a SECOND Atom



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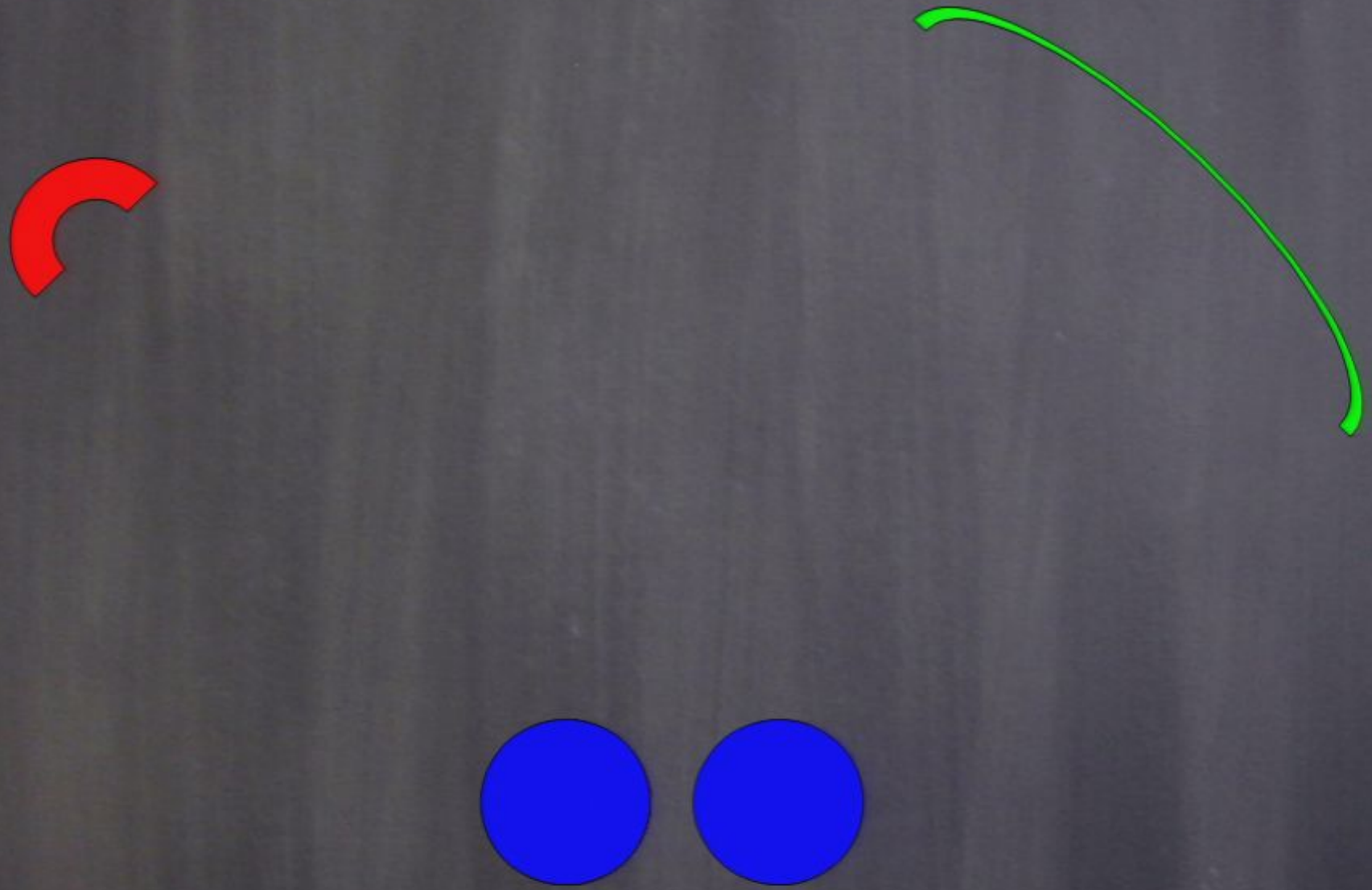

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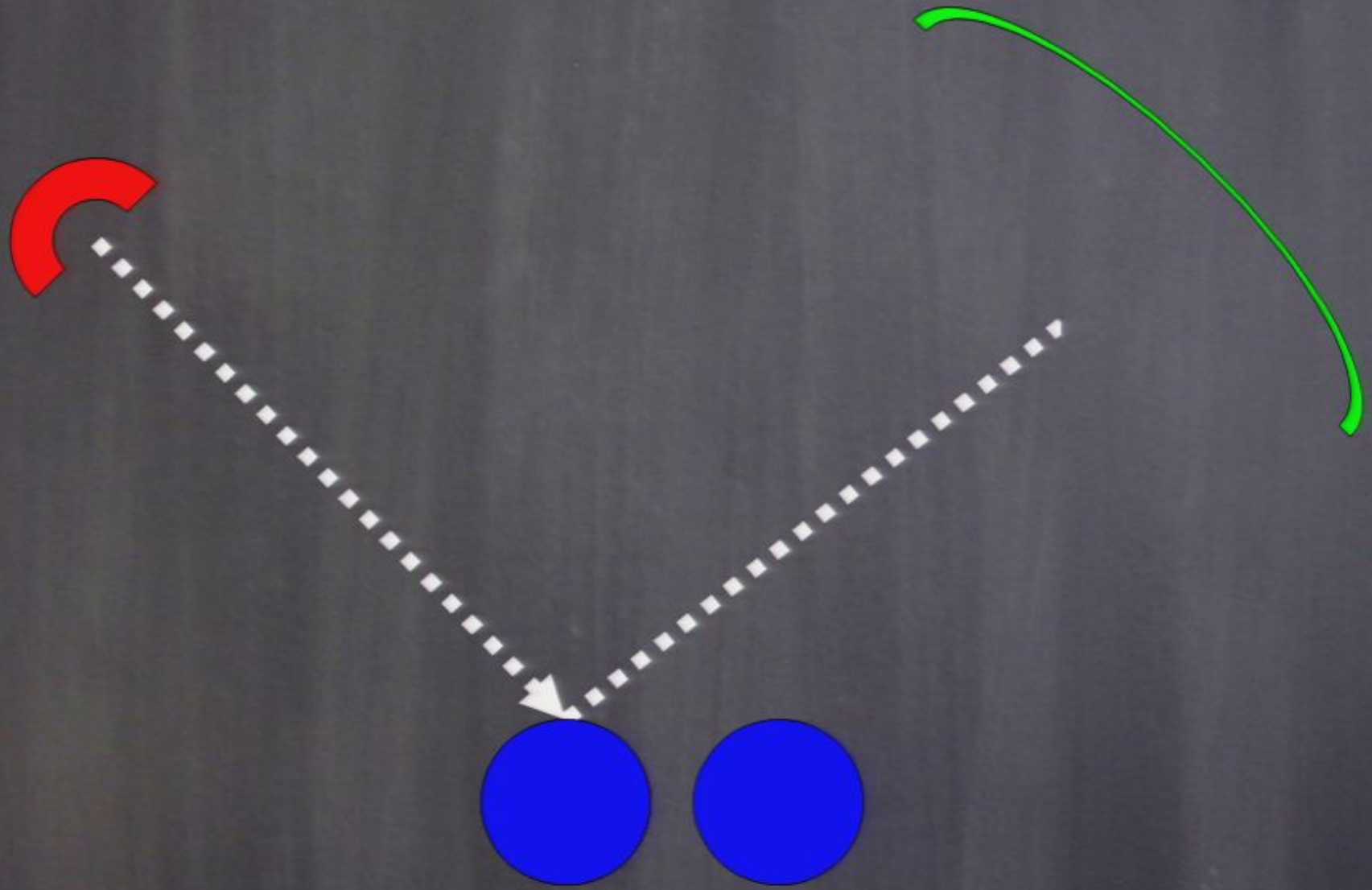

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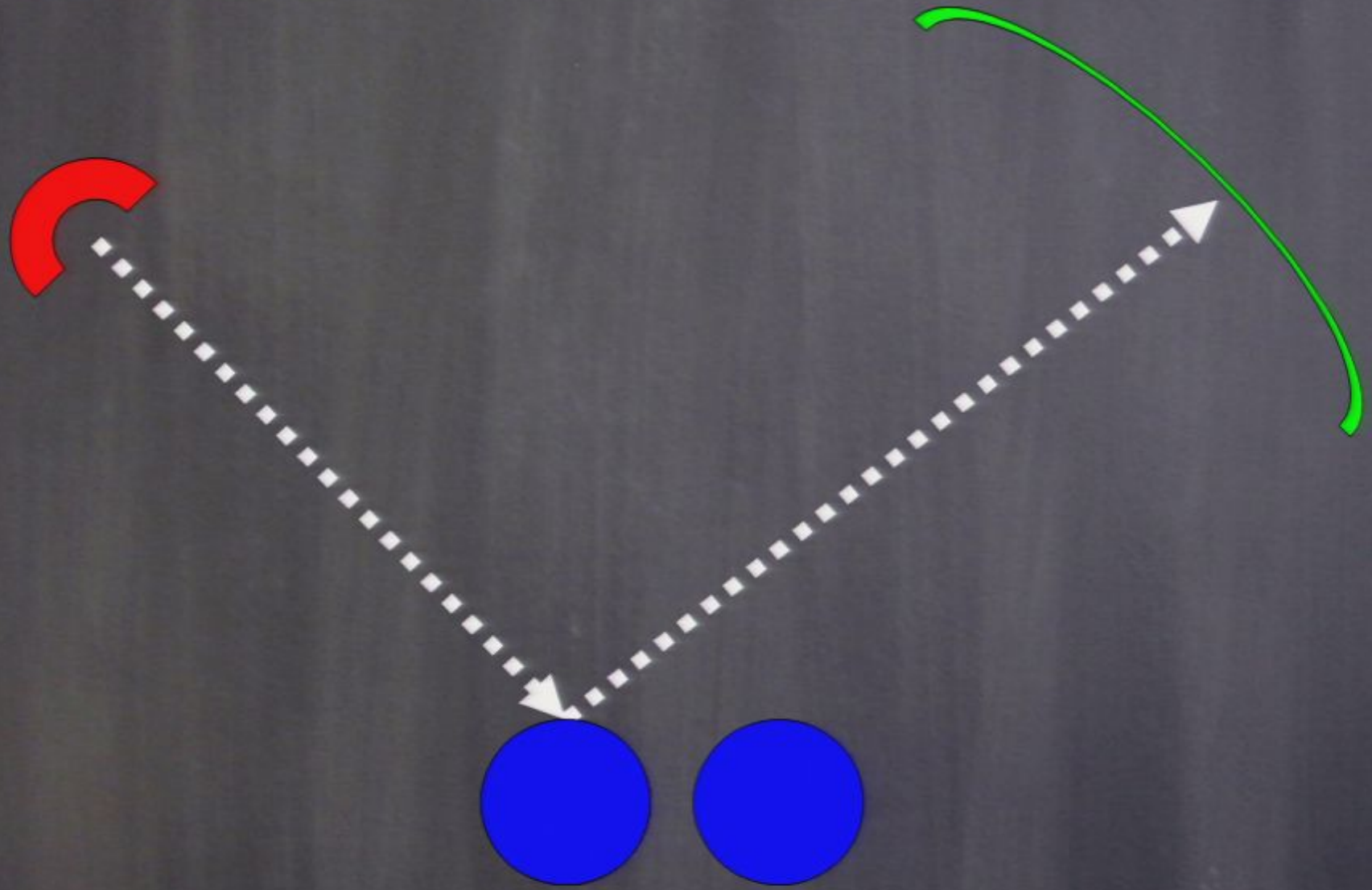

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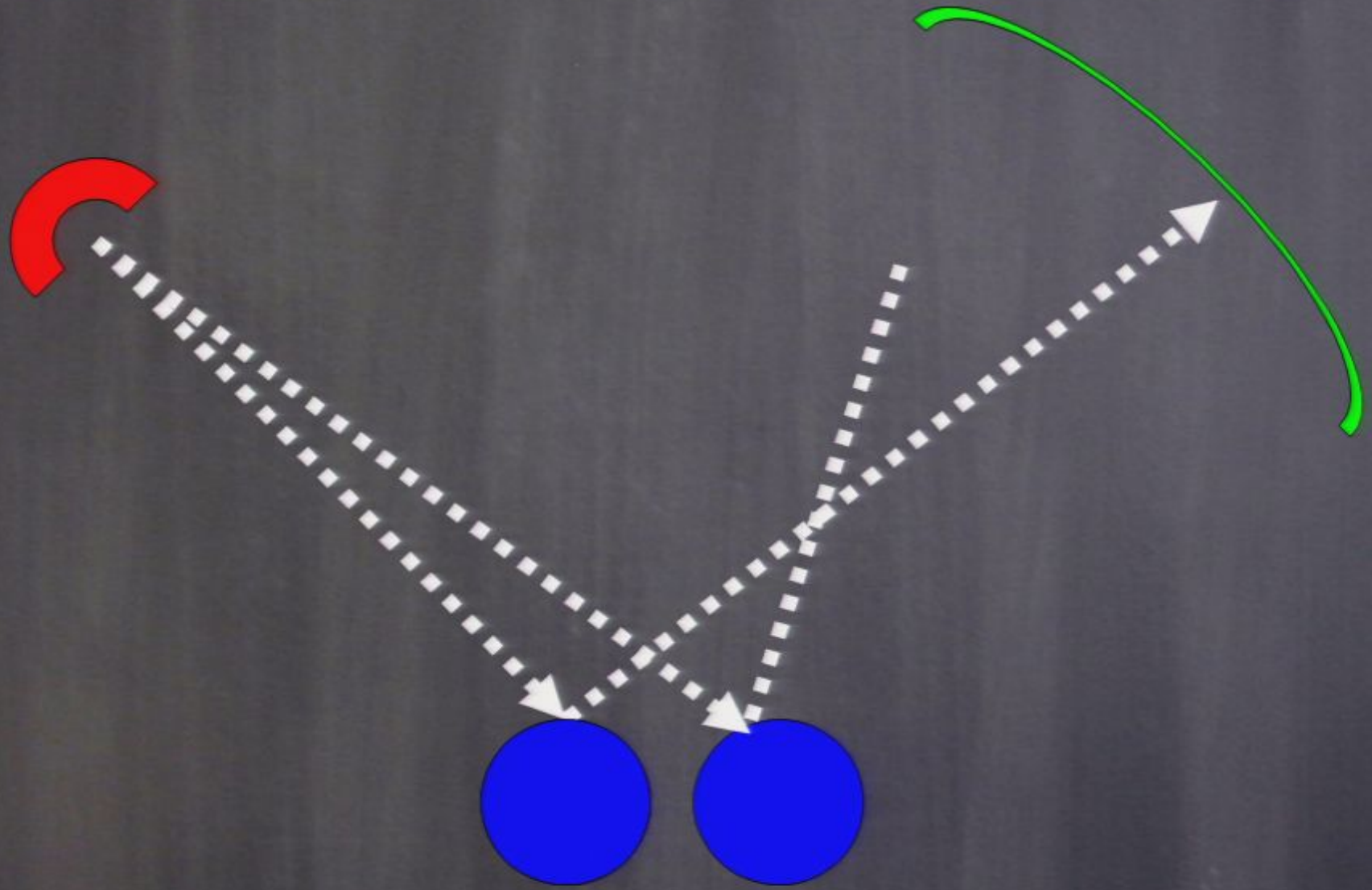

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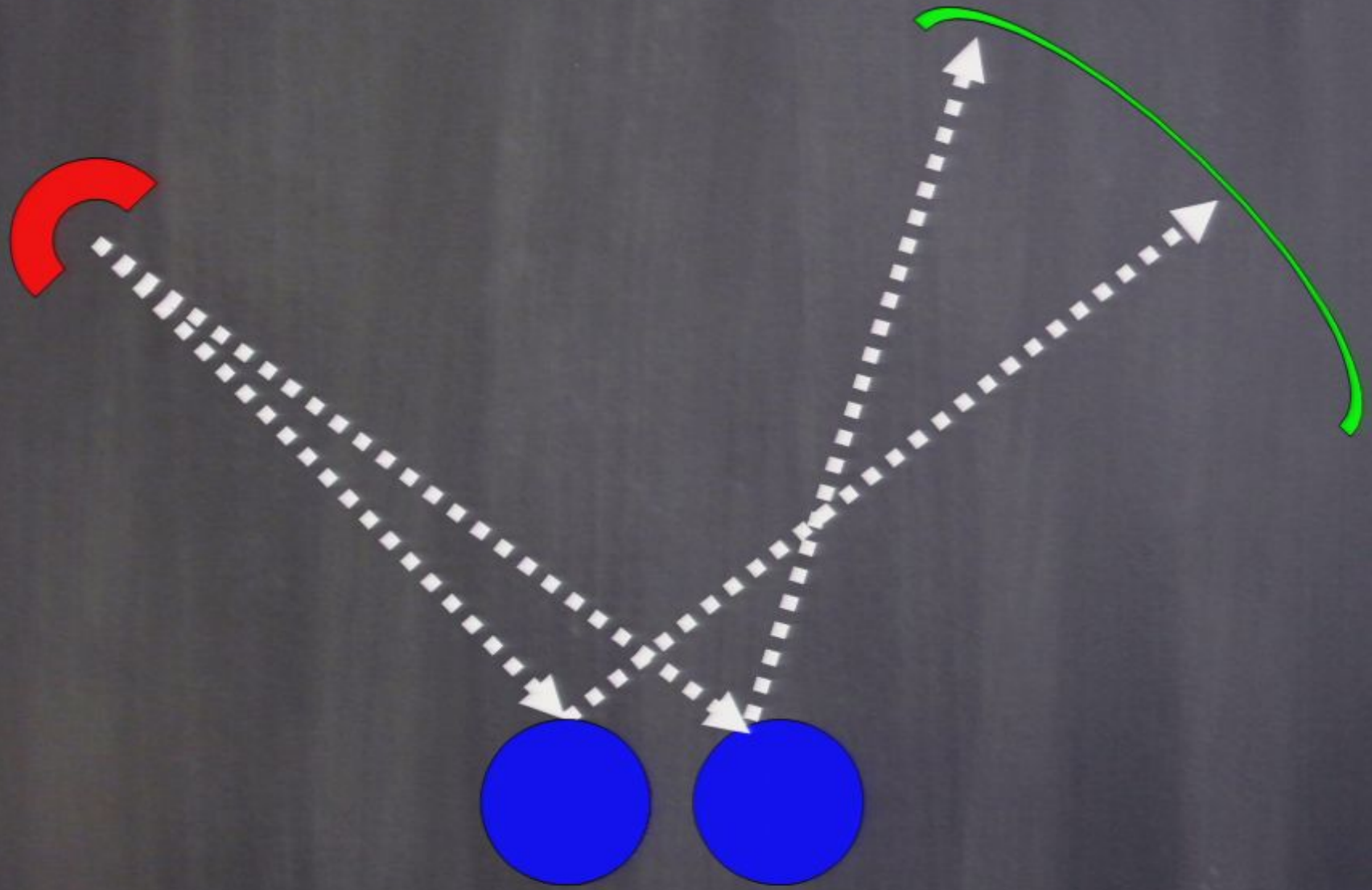

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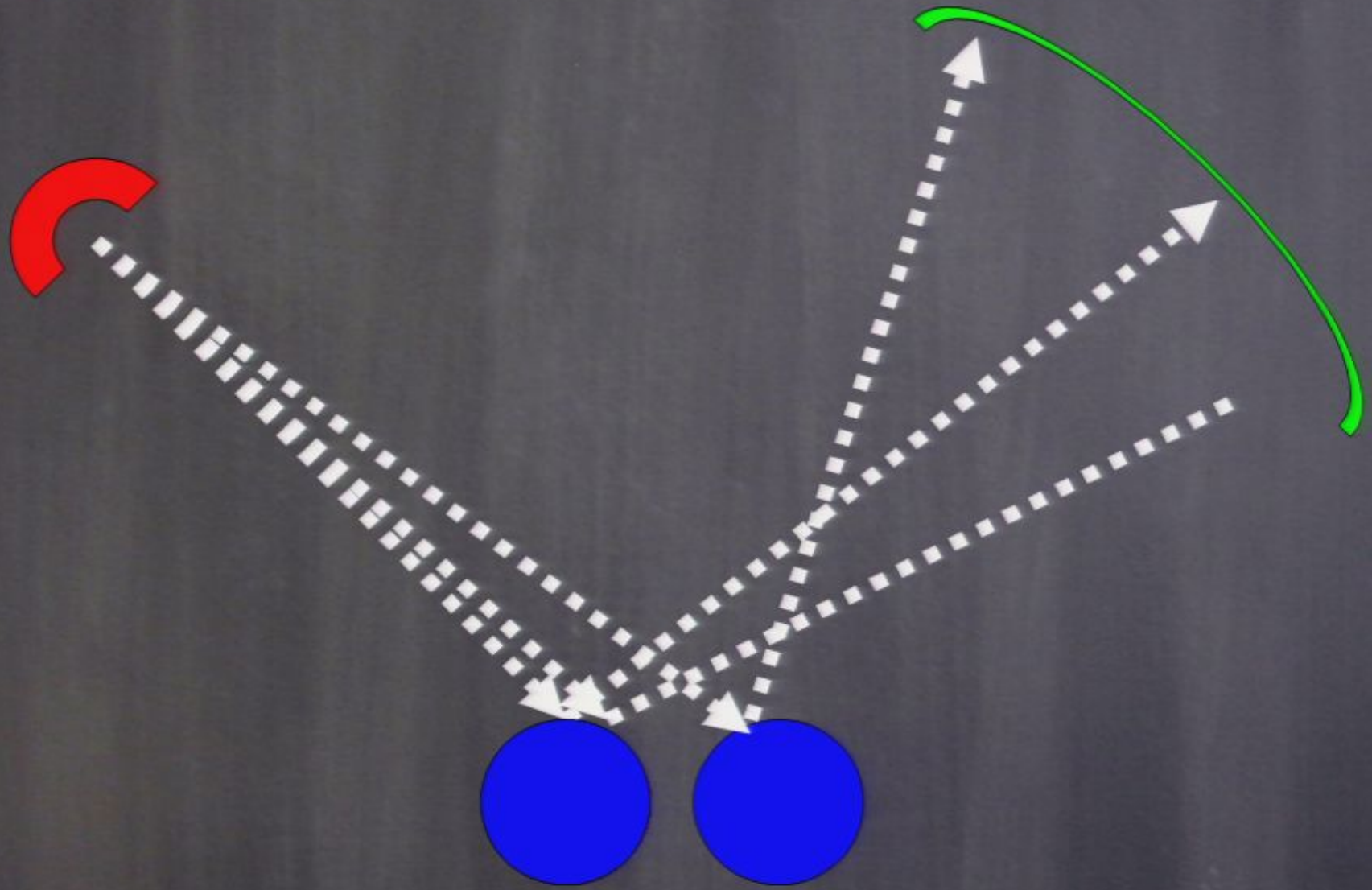

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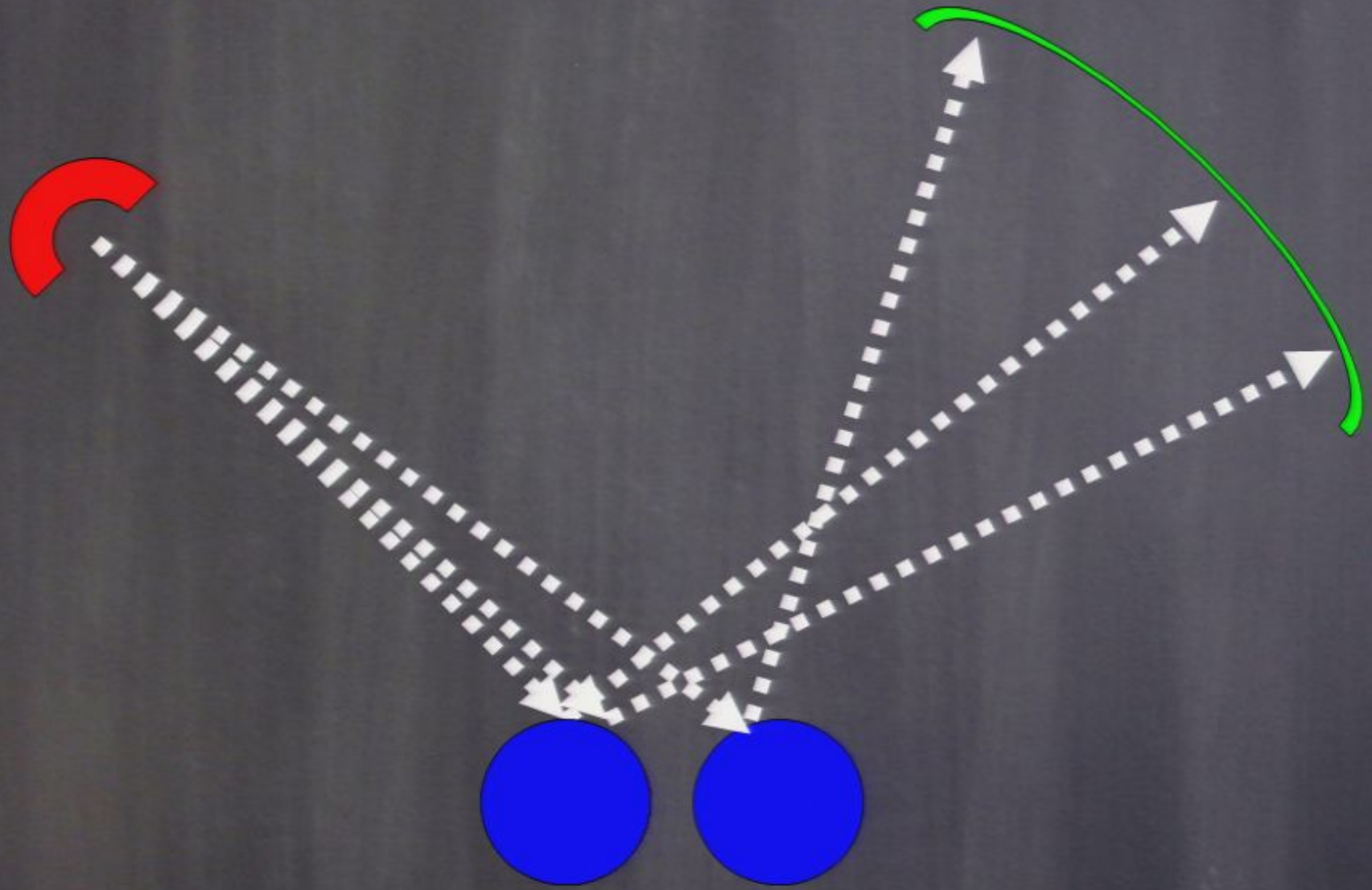

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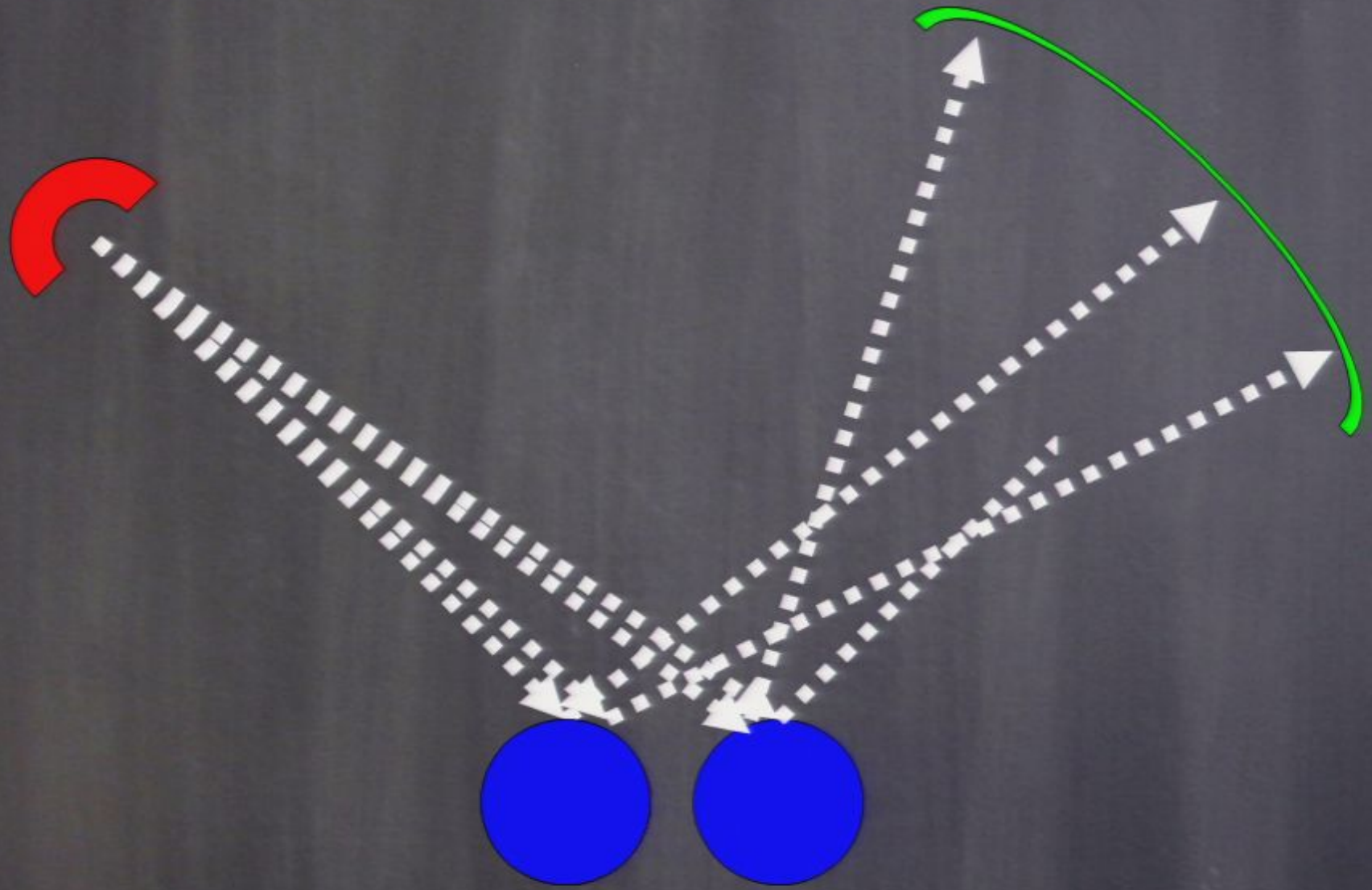

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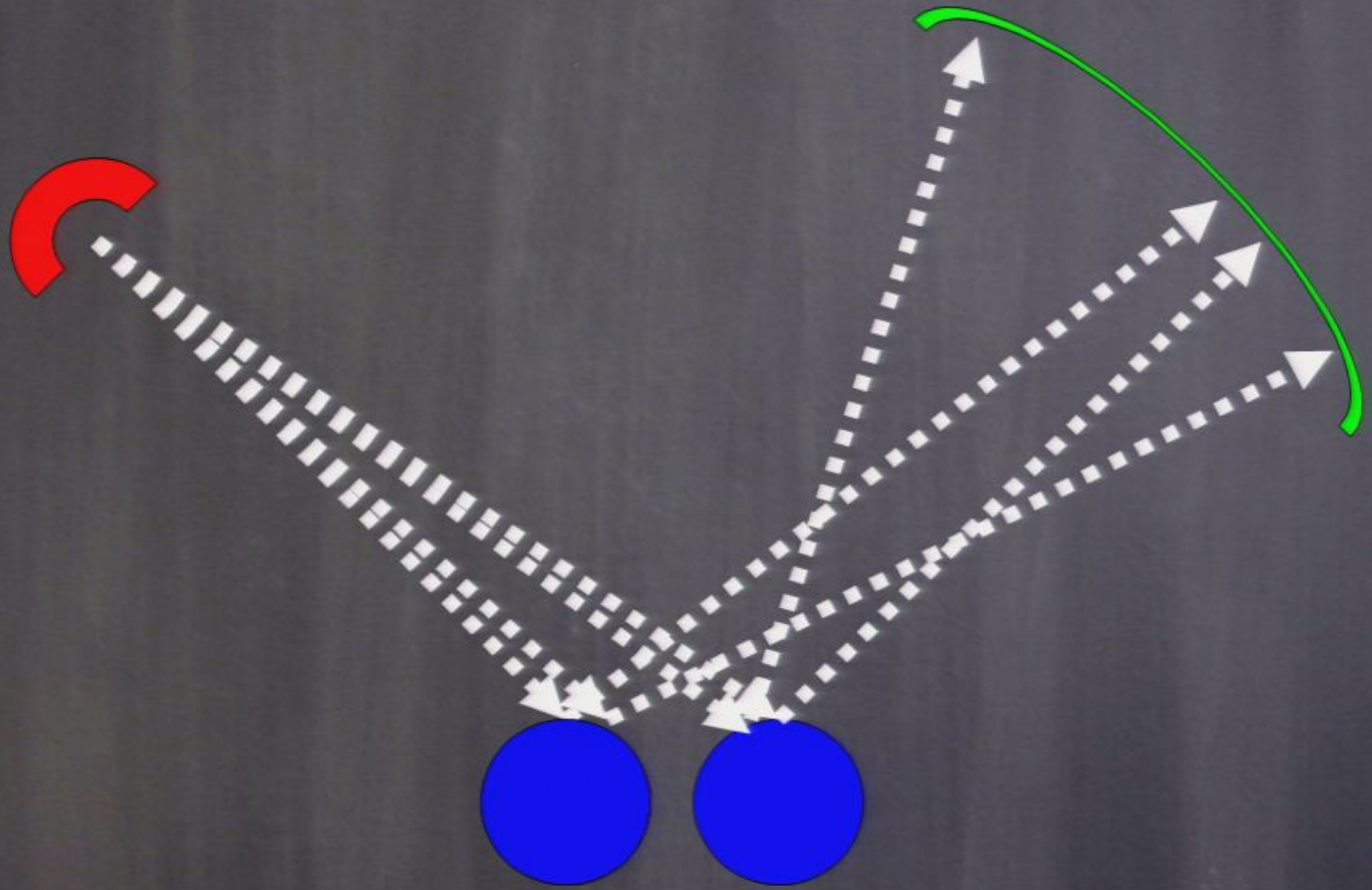
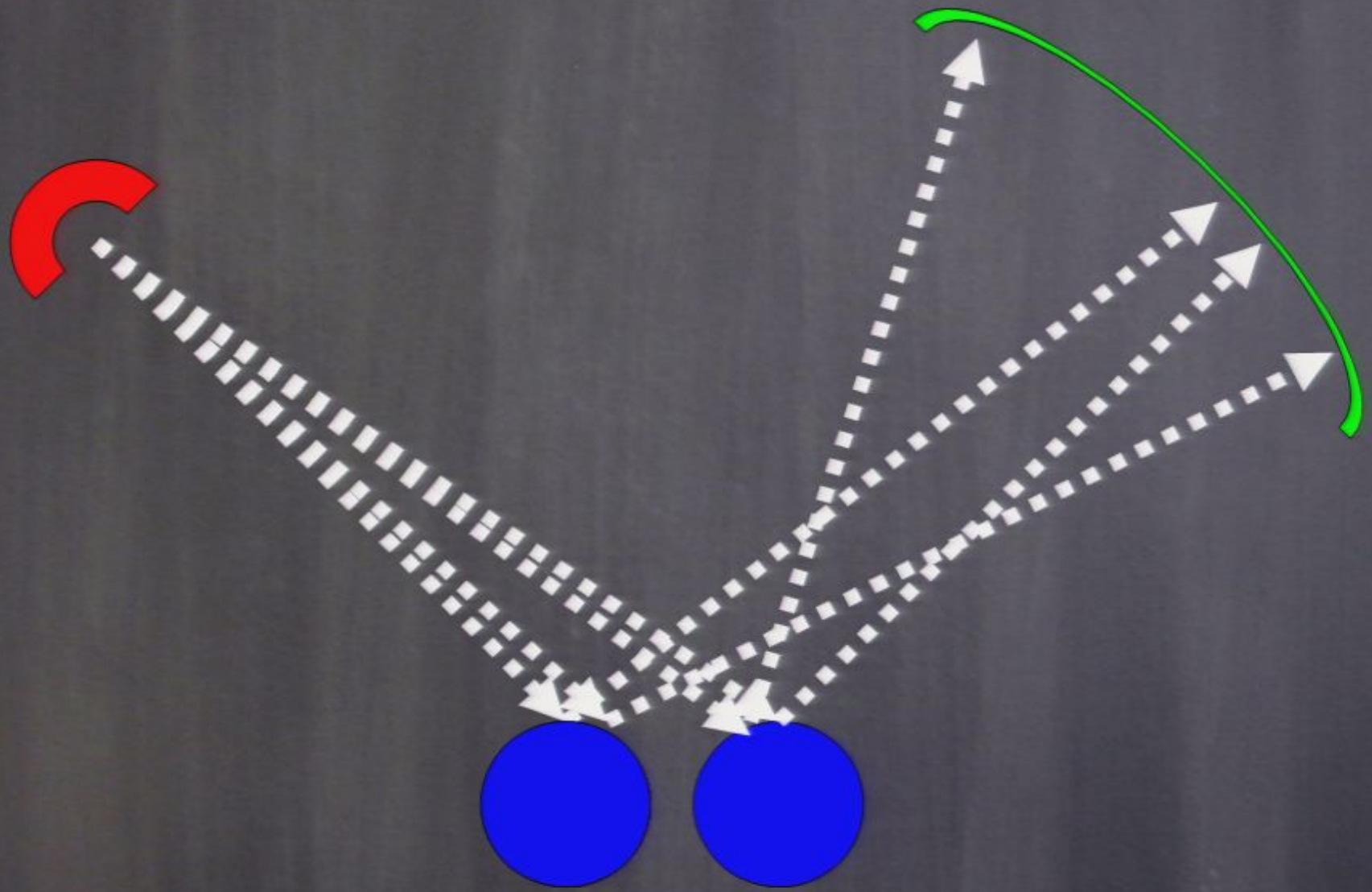


Actual: Pattern of Hits!



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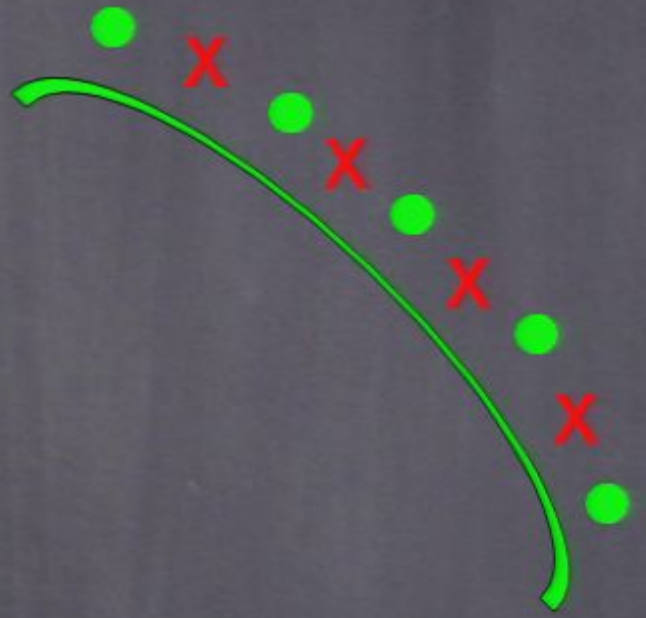
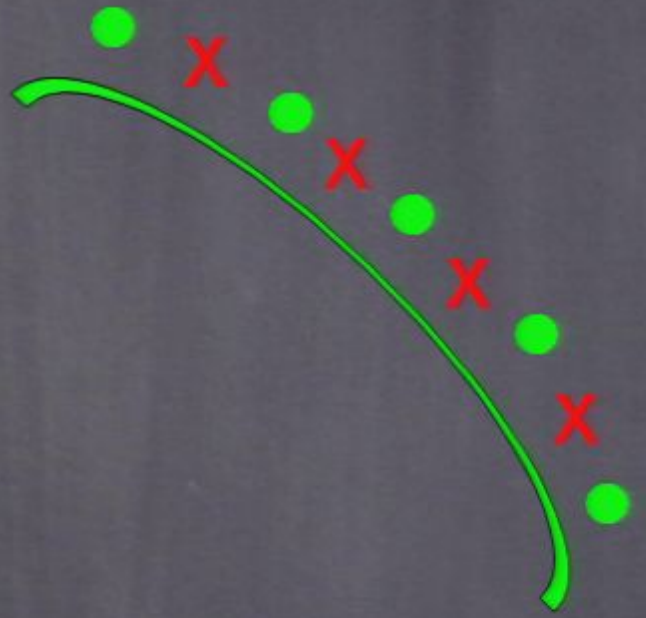


How is this POSSIBLE?



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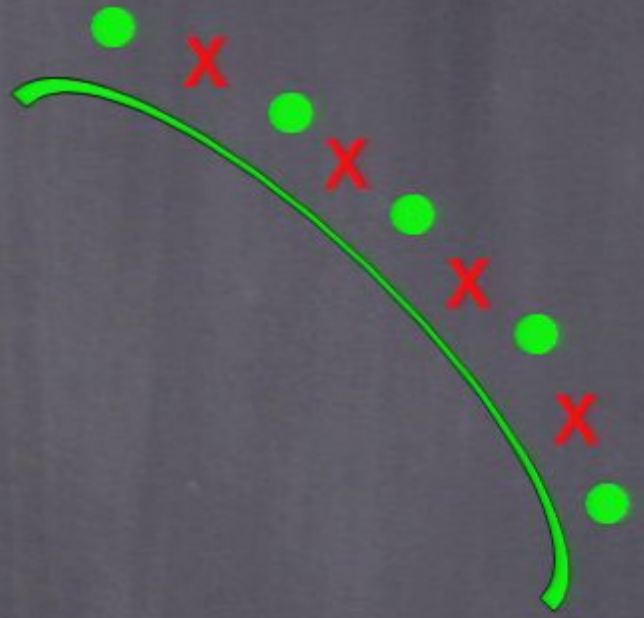

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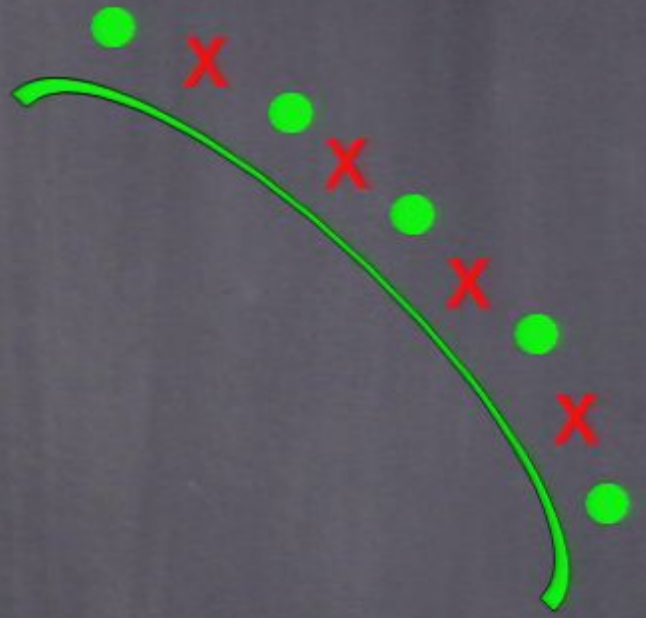

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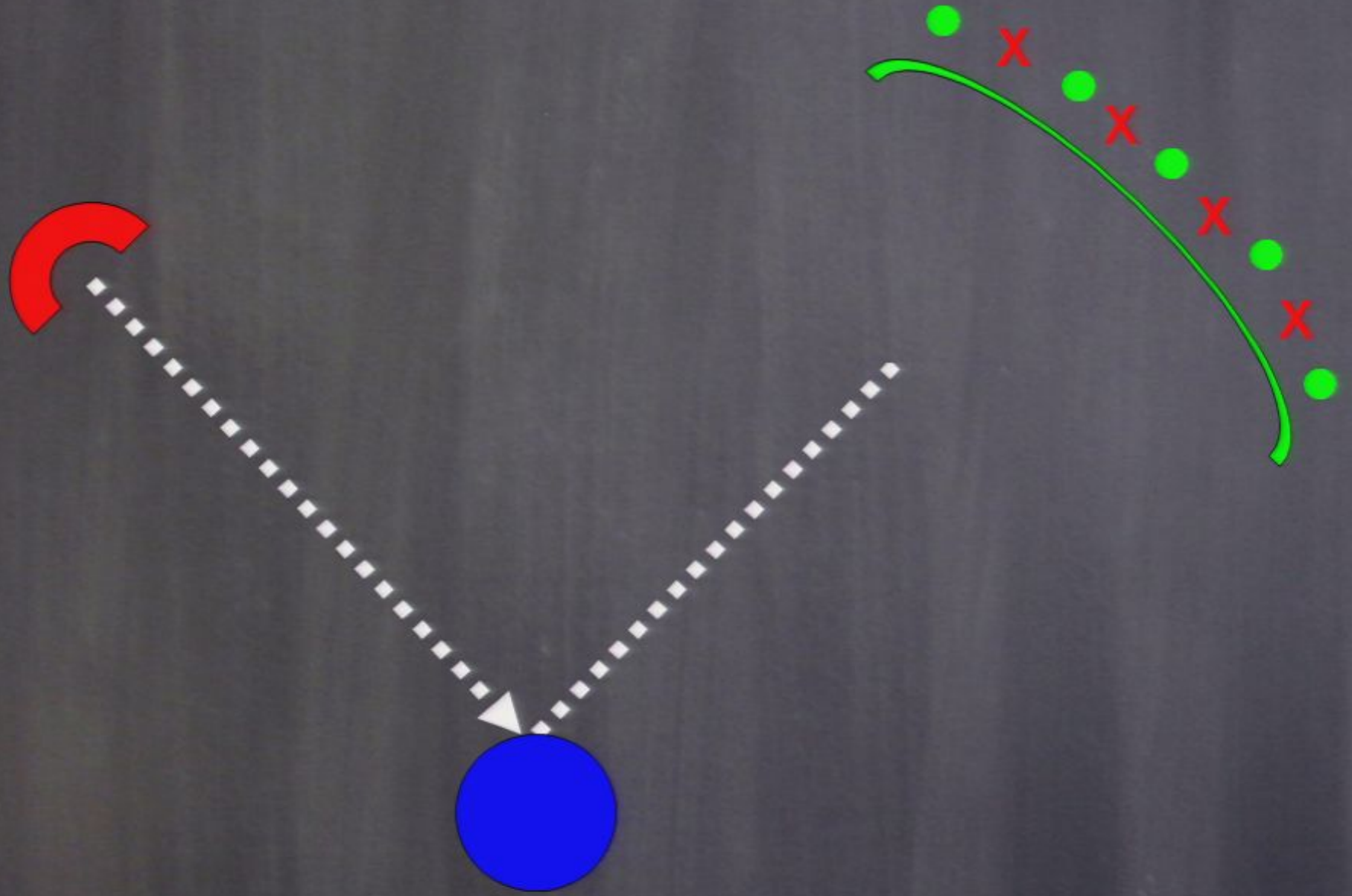

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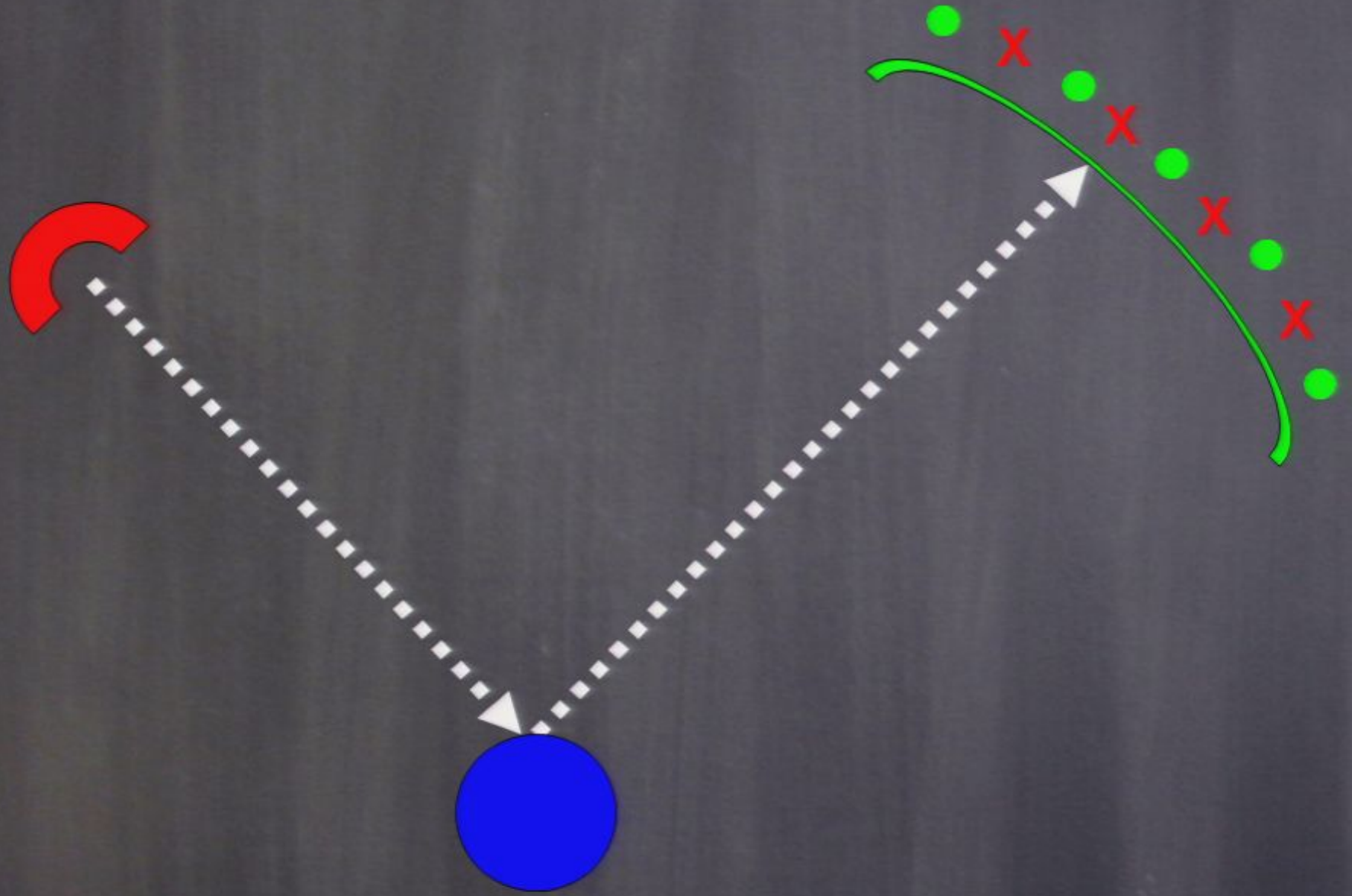

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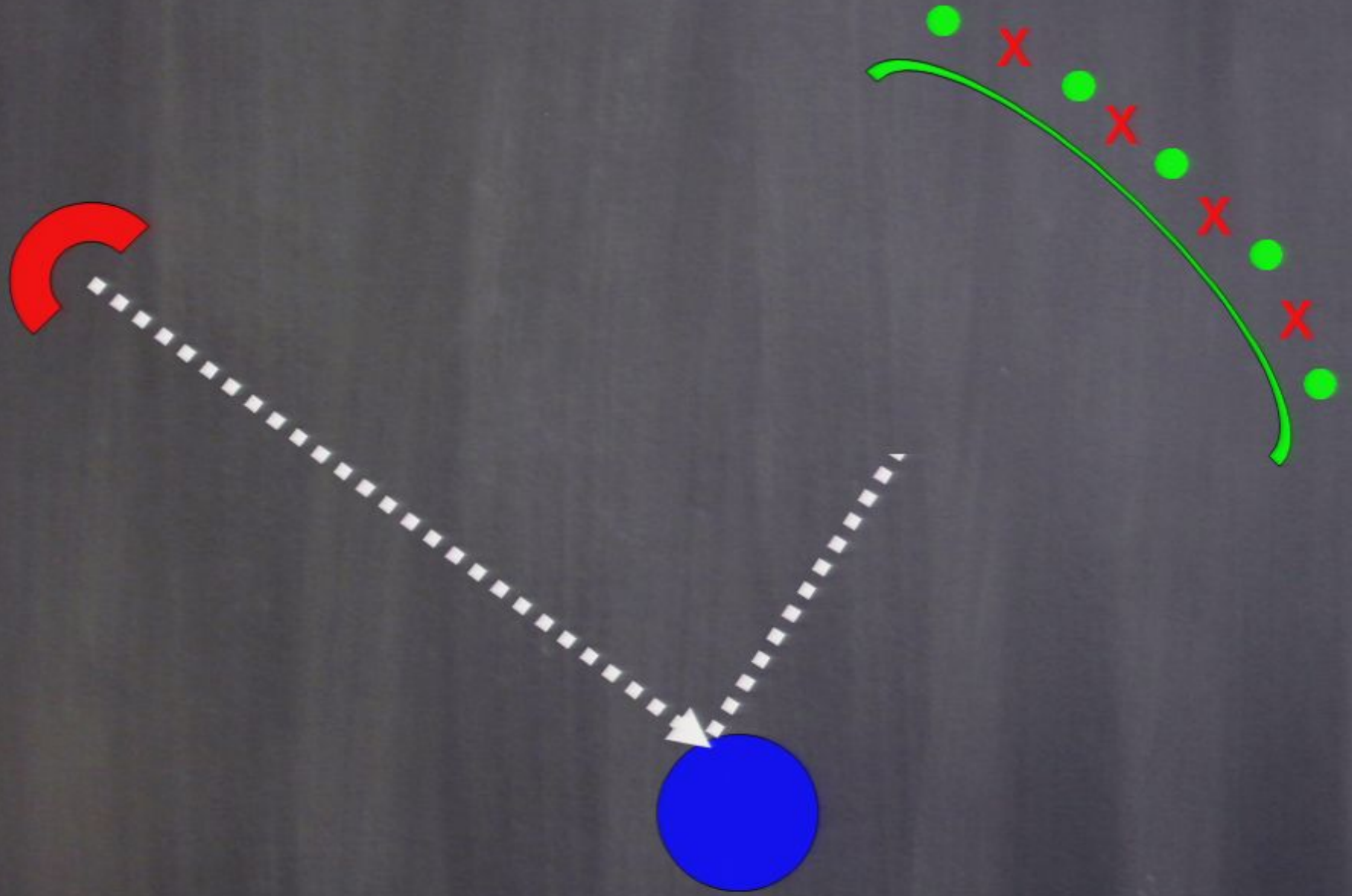

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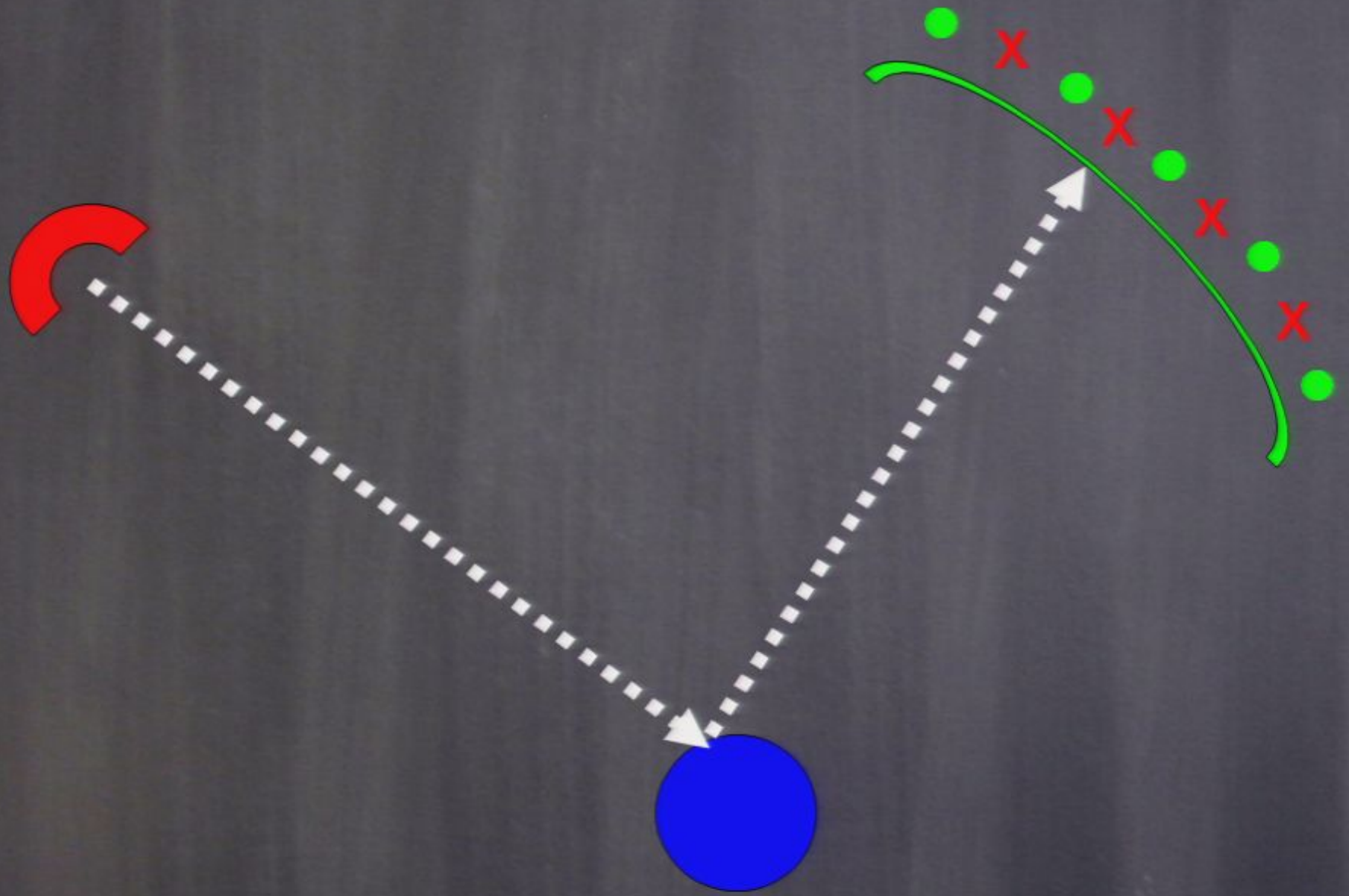

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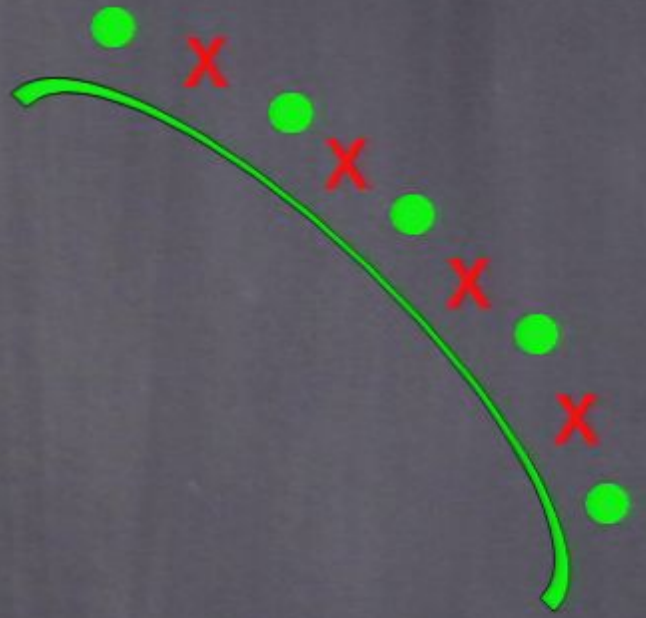

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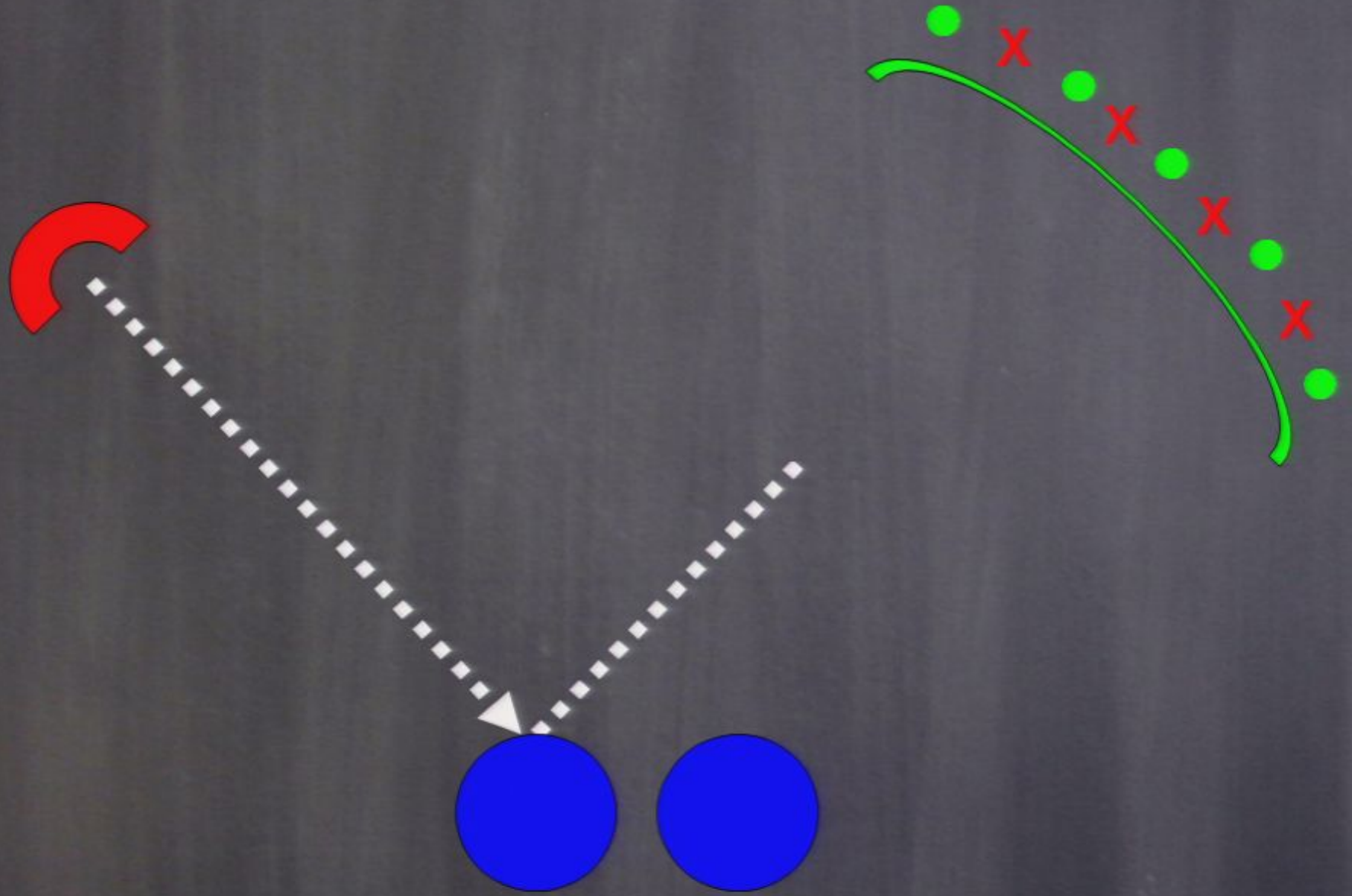

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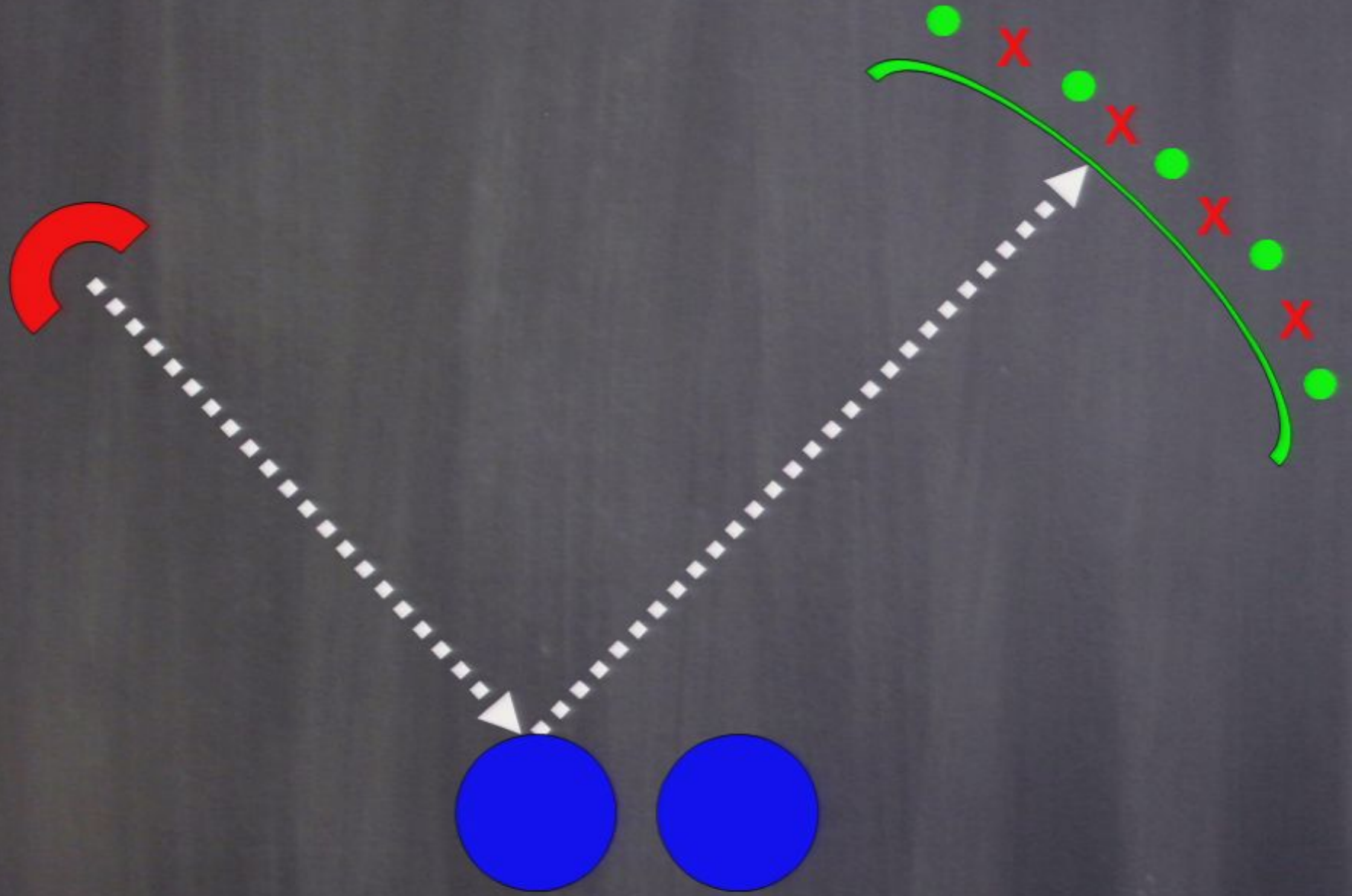
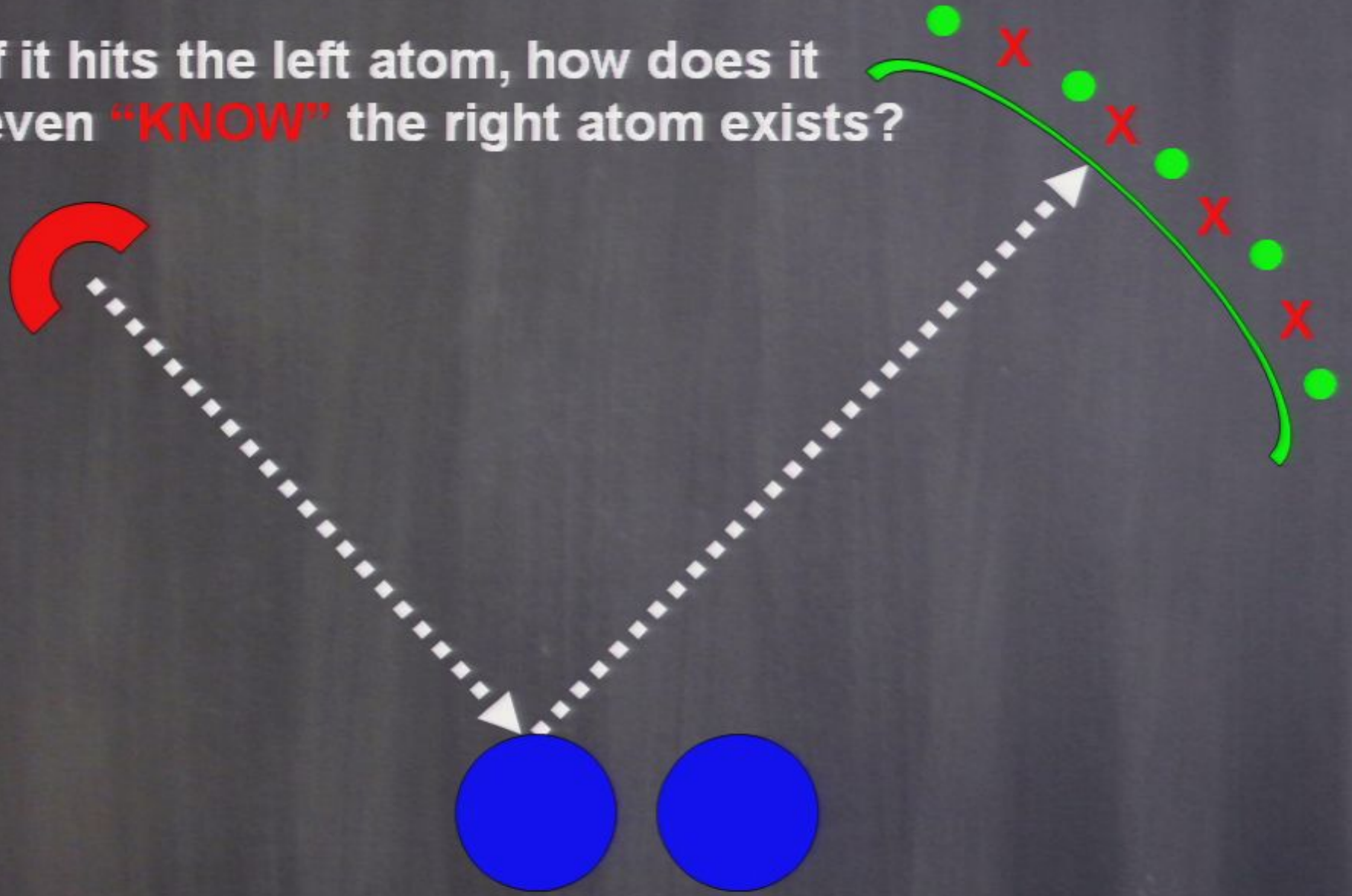


How is this POSSIBLE?

If it hits the left atom, how does it even "KNOW" the right atom exists?



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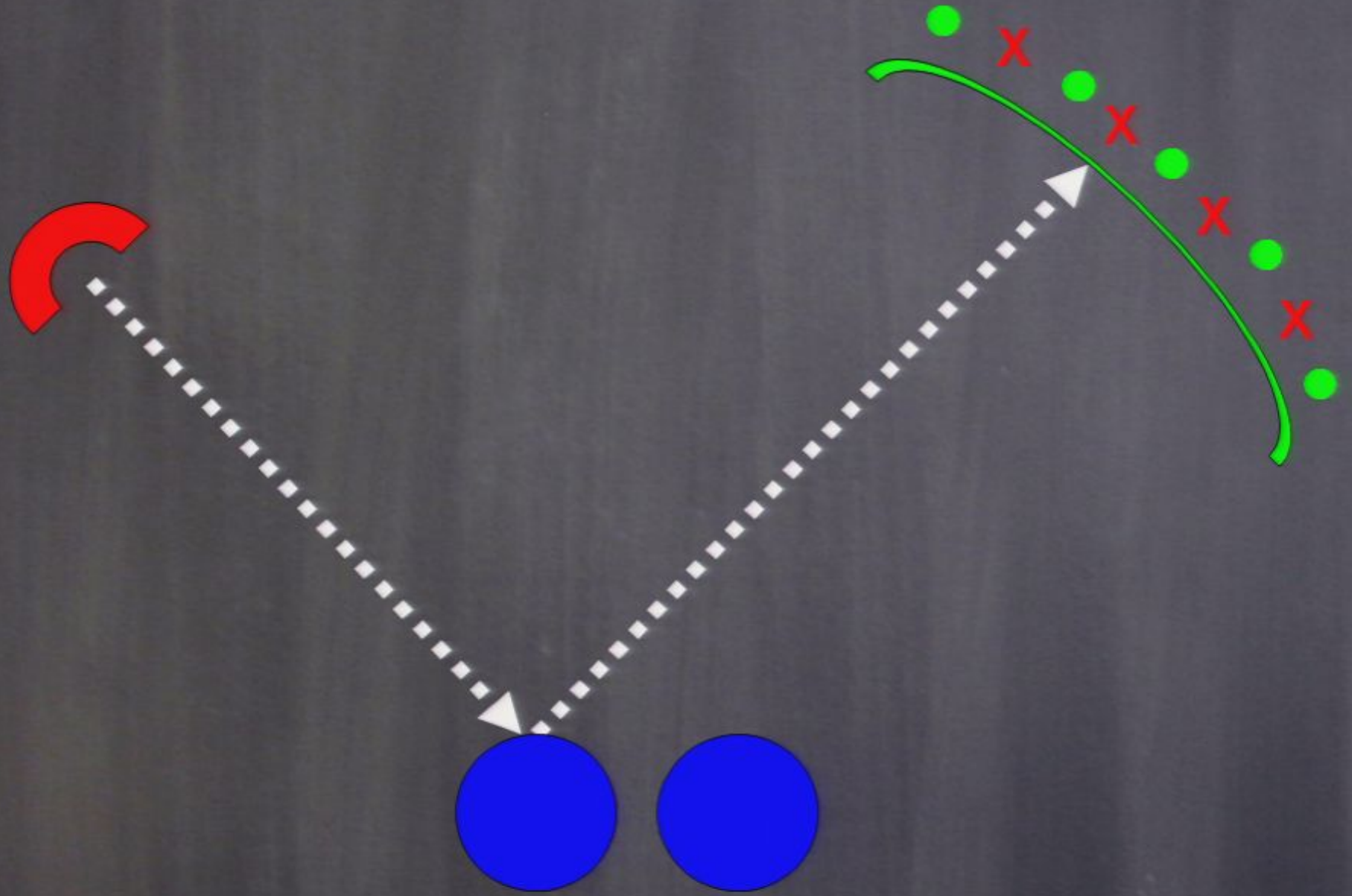

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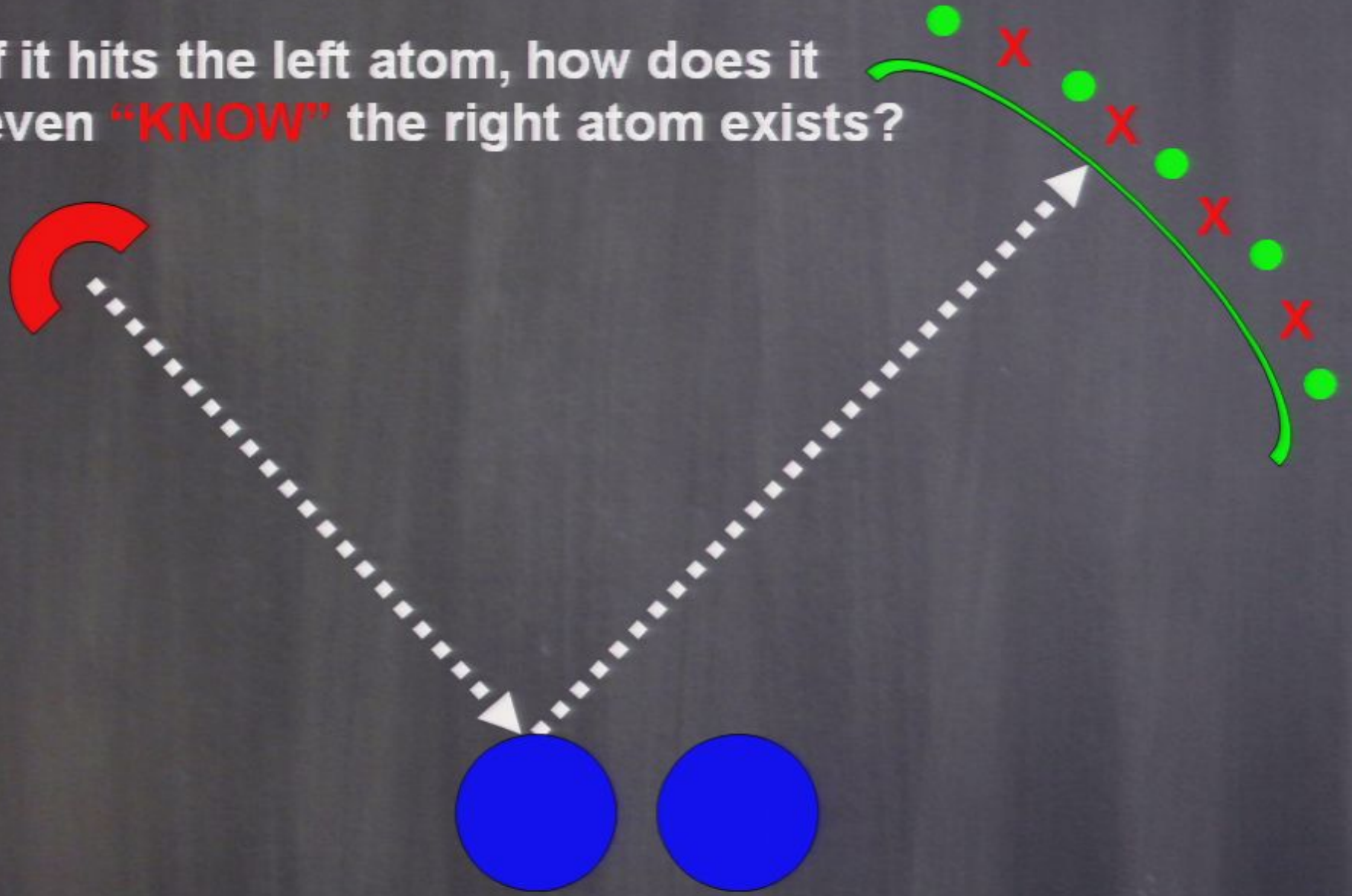
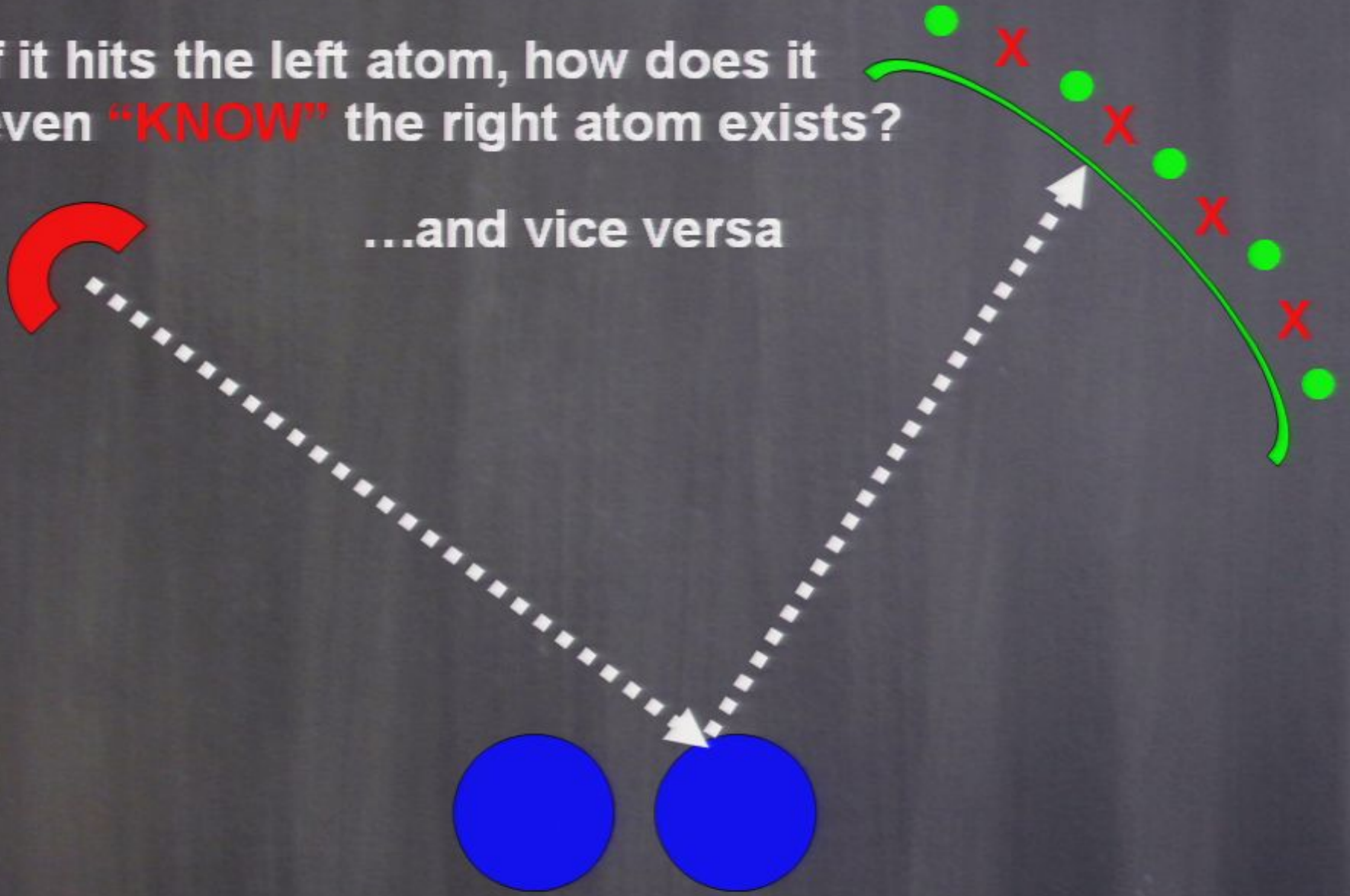


How is this POSSIBLE?

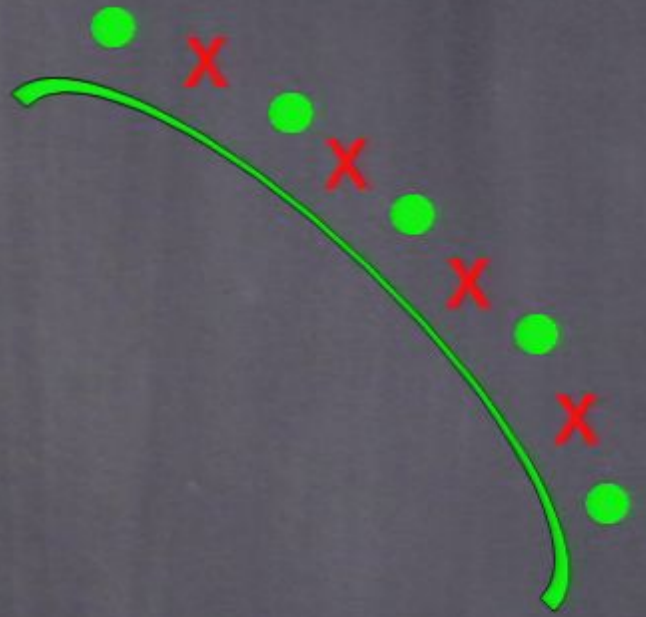
If it hits the left atom, how does it even "KNOW" the right atom exists?

…and vice versa



How is this POSSIBLE?

CLUE: Pattern depends on the difference in the two path lengths



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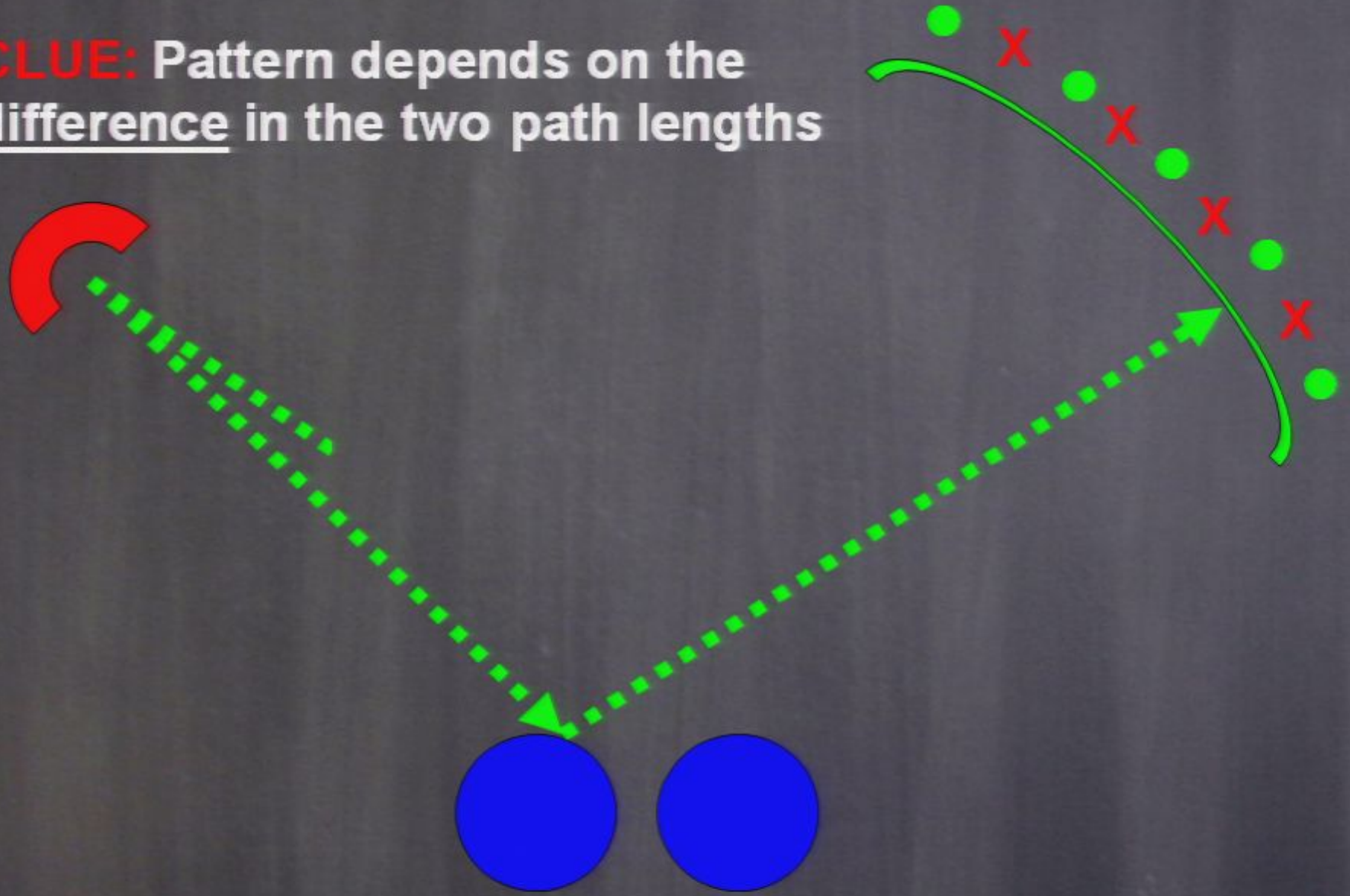

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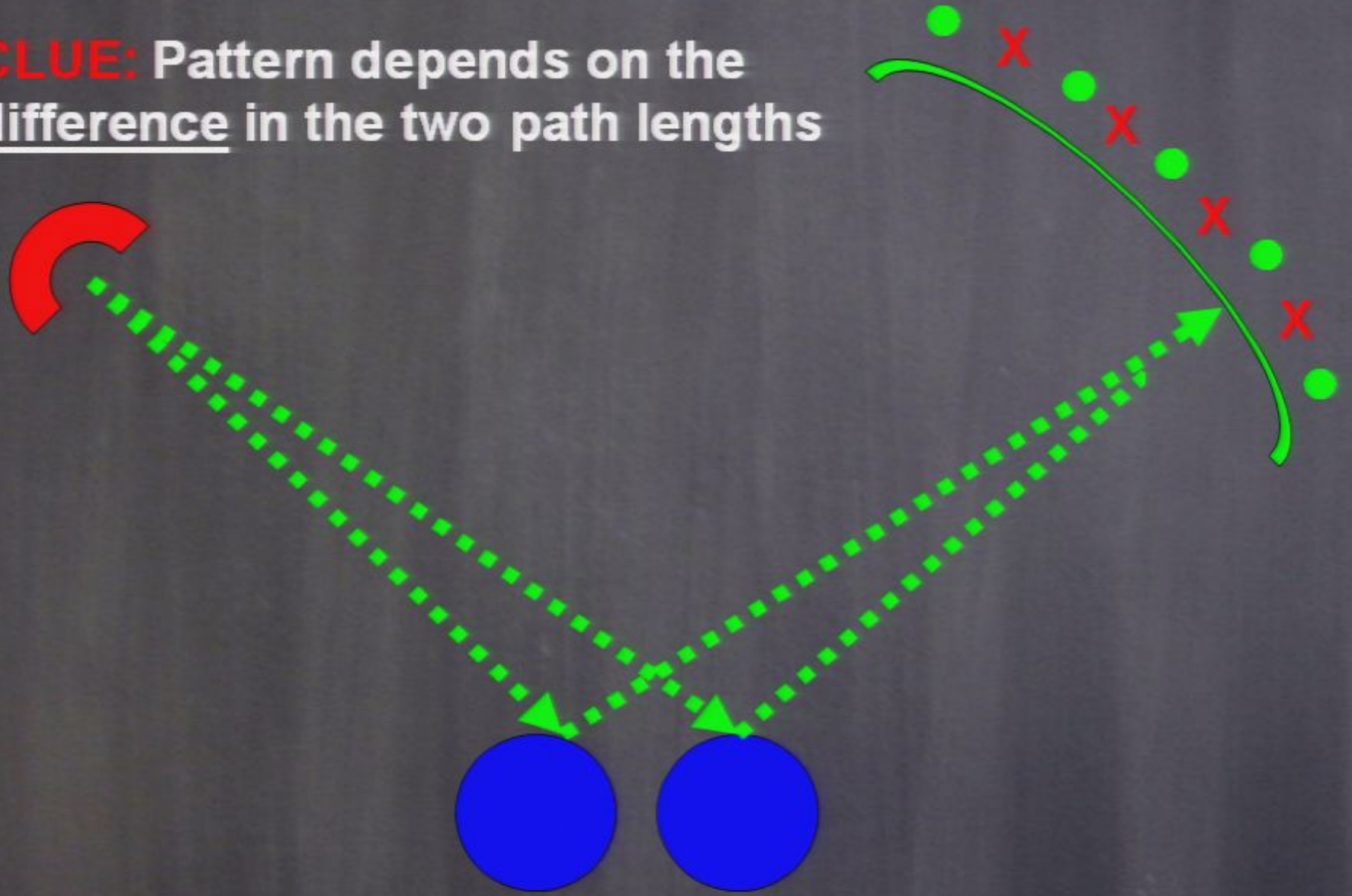
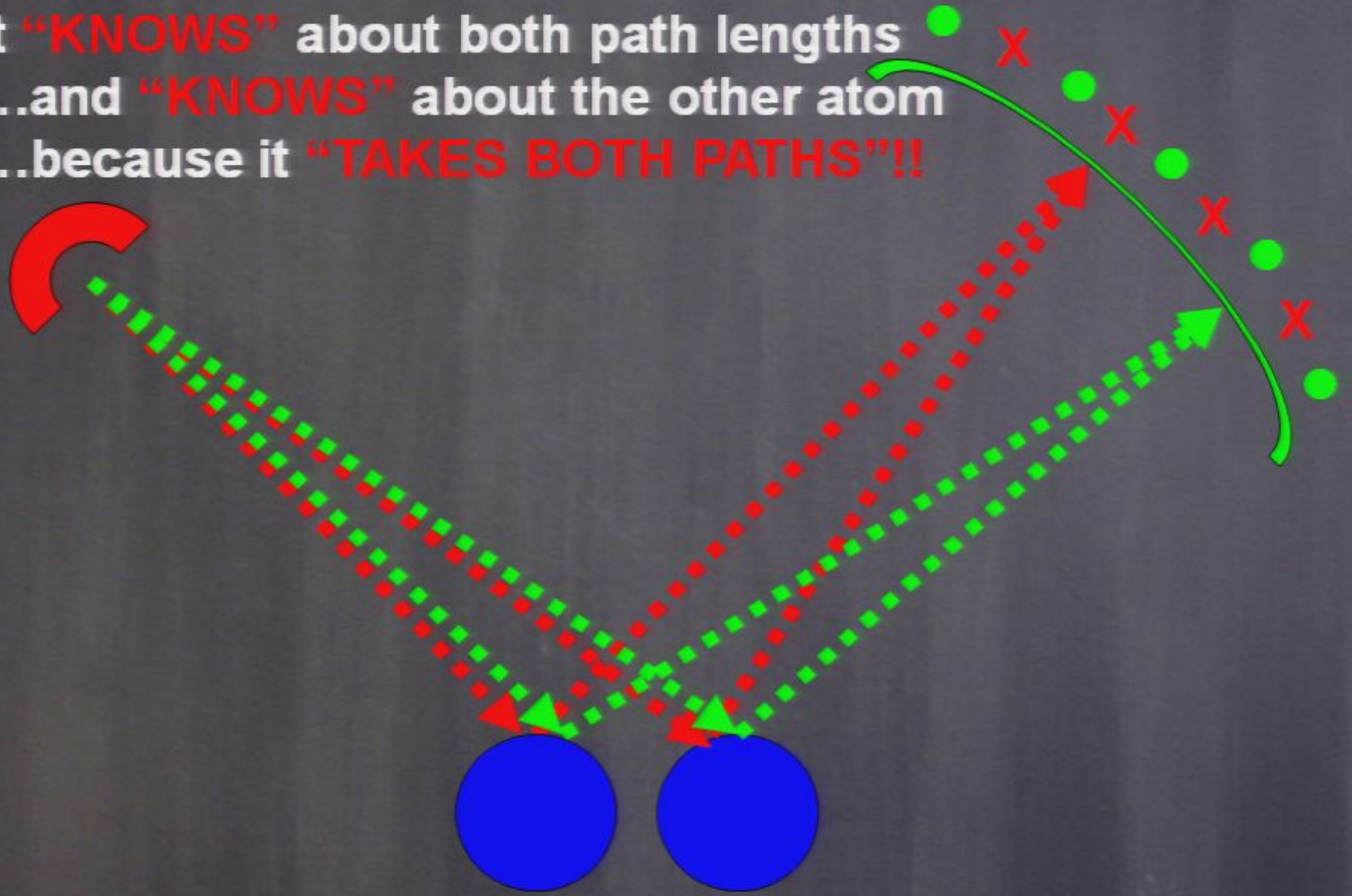


How is this POSSIBLE?

It "KNOWS" about both path lengths

…and "KNOWS" about the other atom

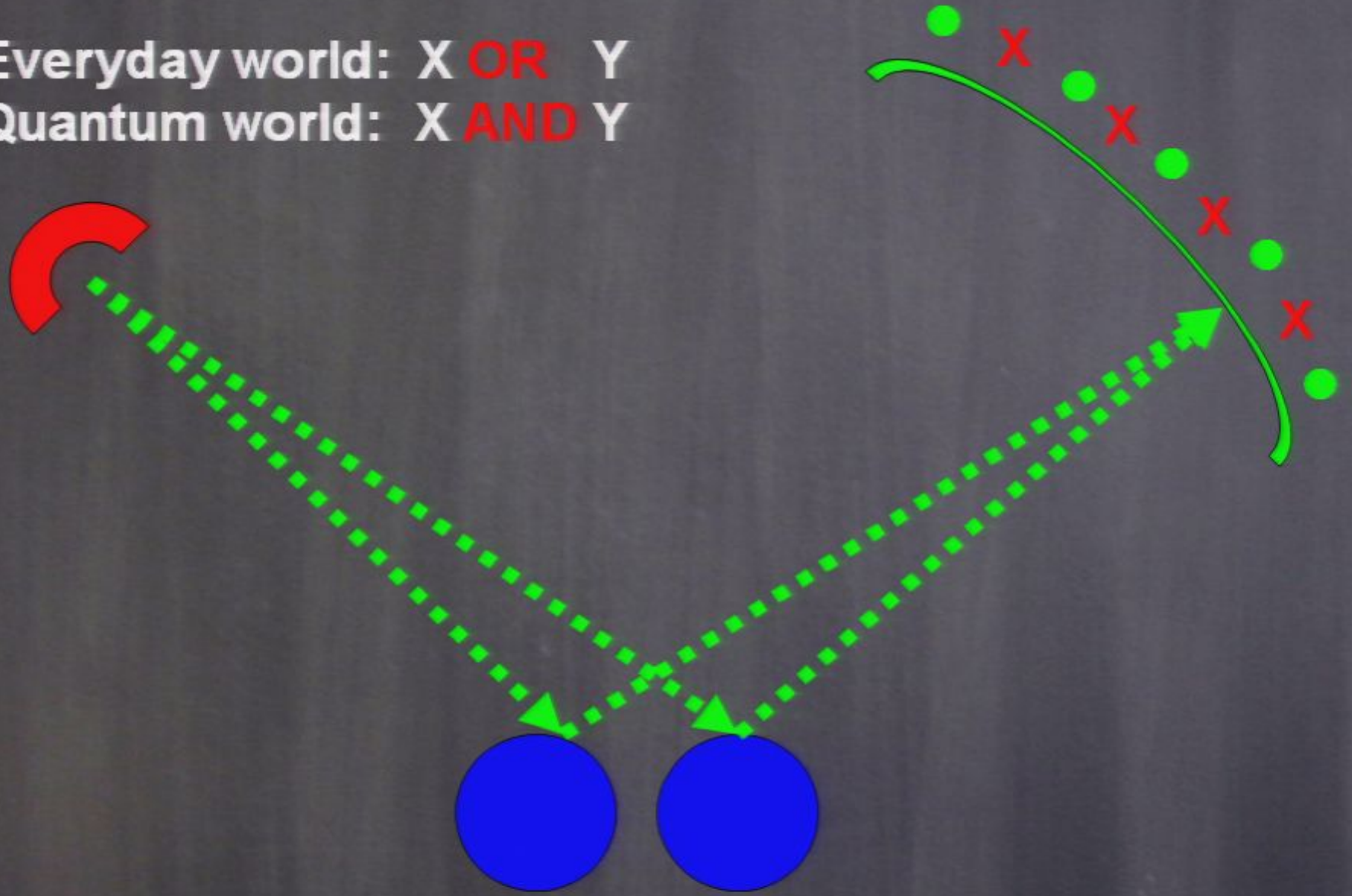
…because it "TAKES BOTH PATHS"!!



How is this POSSIBLE?

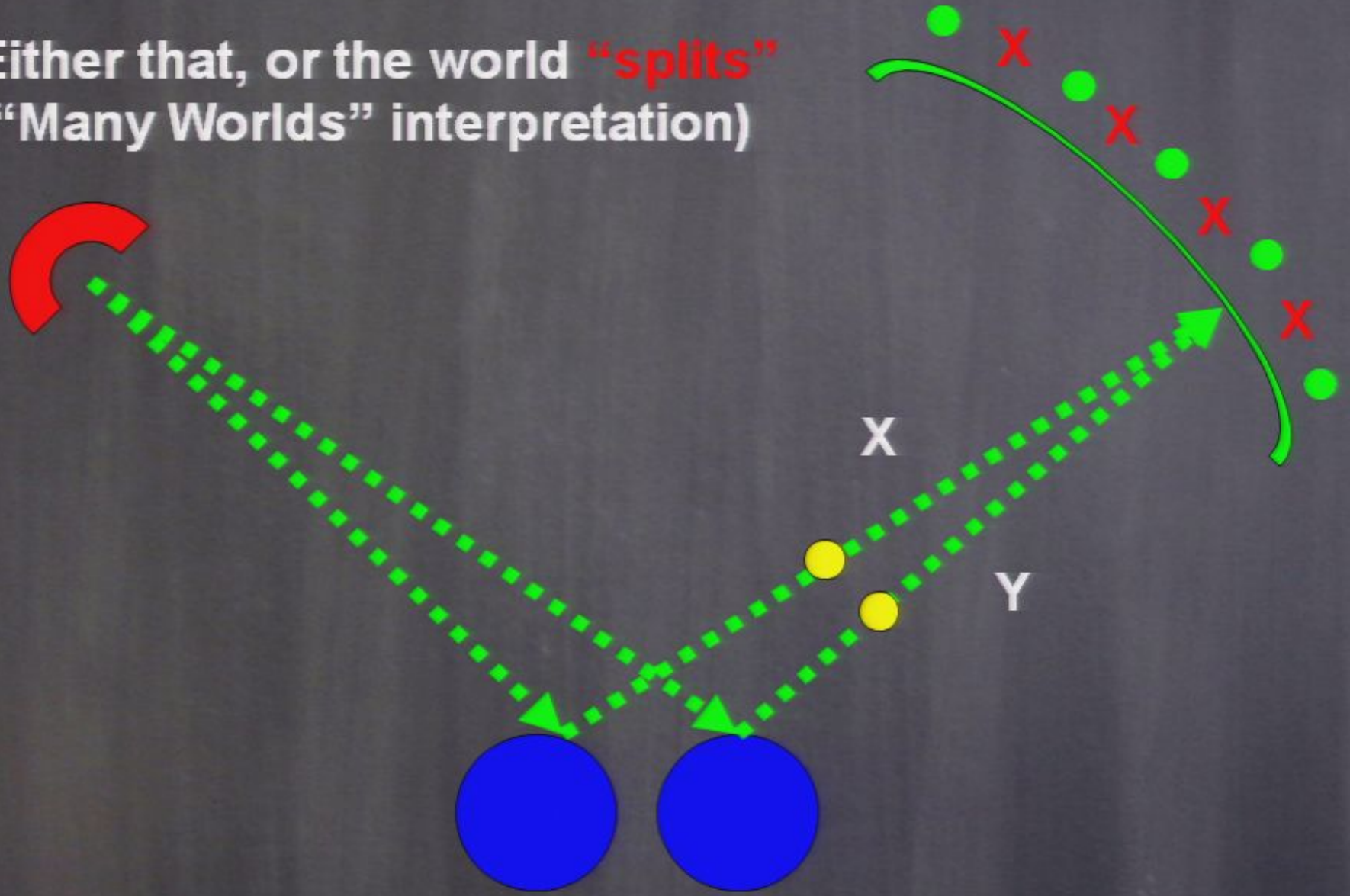
Everyday world: X OR Y

Quantum world: X AND Y



How is this POSSIBLE?

Either that, or the world "splits"
("Many Worlds" interpretation)



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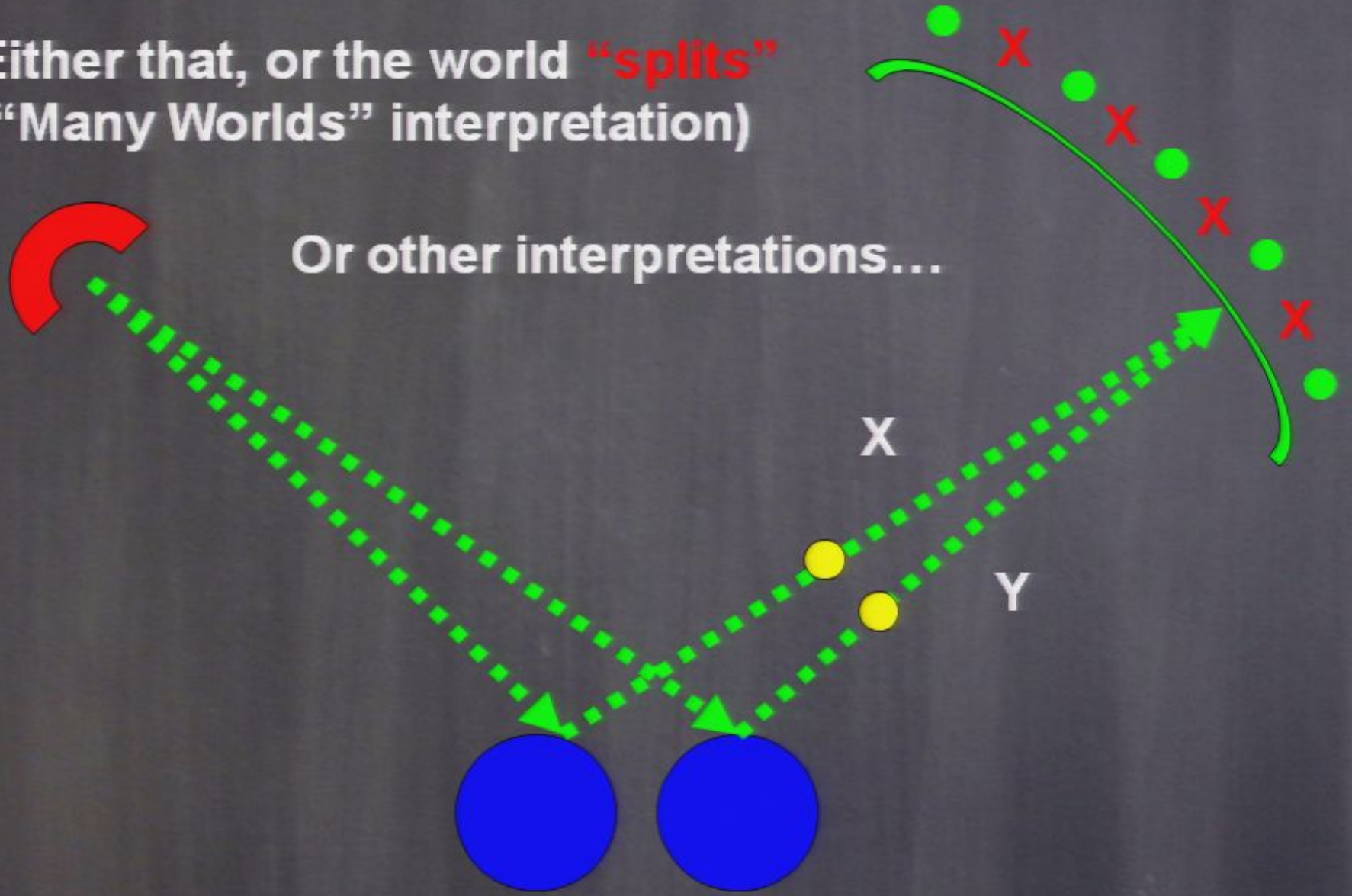
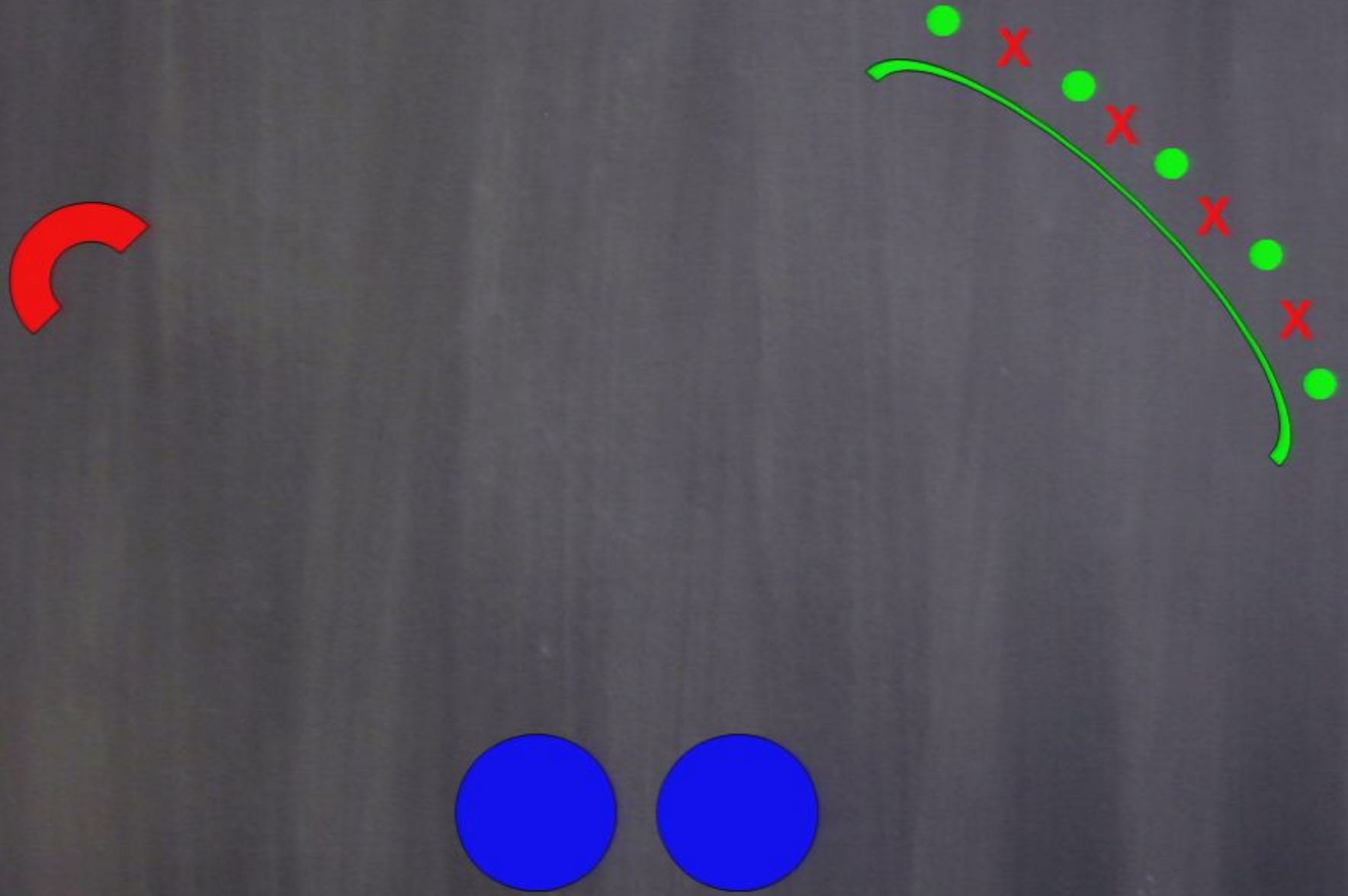


Consider ALL the Atoms



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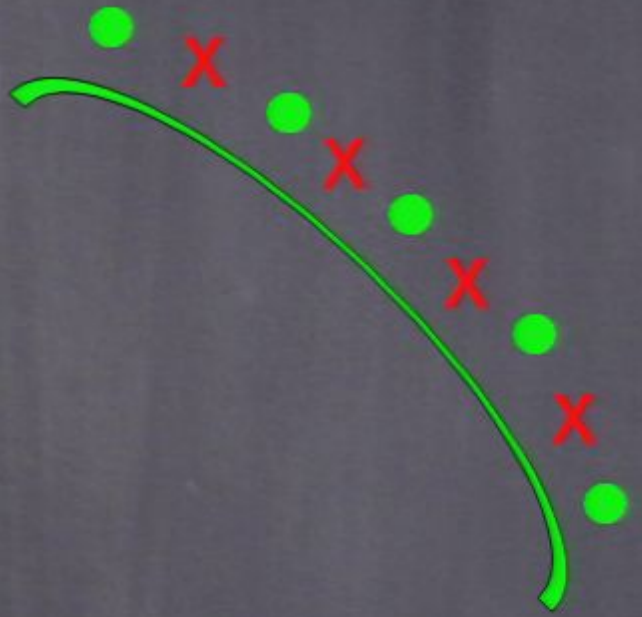
In getting from A to B, the electron exists simultaneously in all paths



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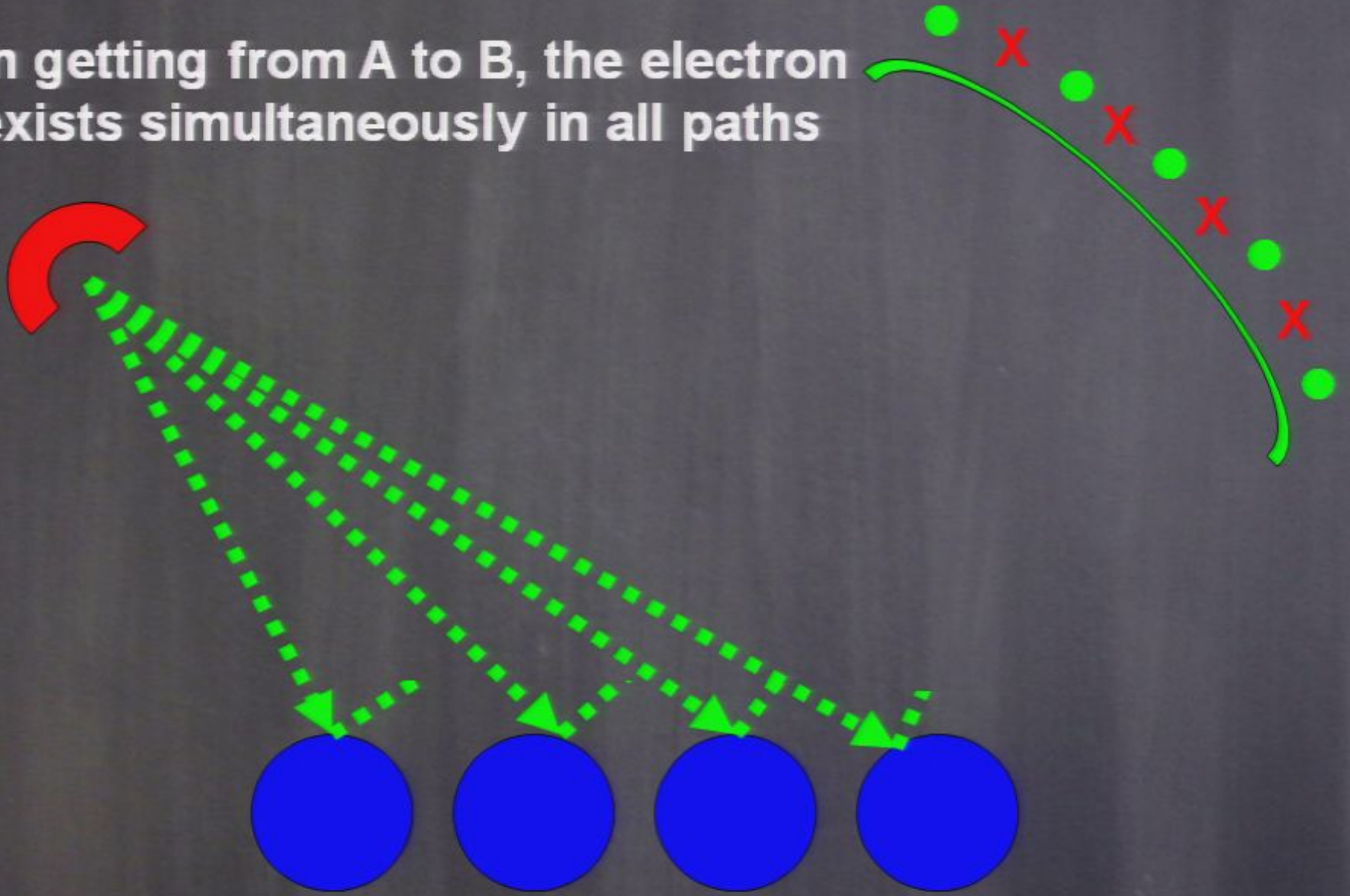

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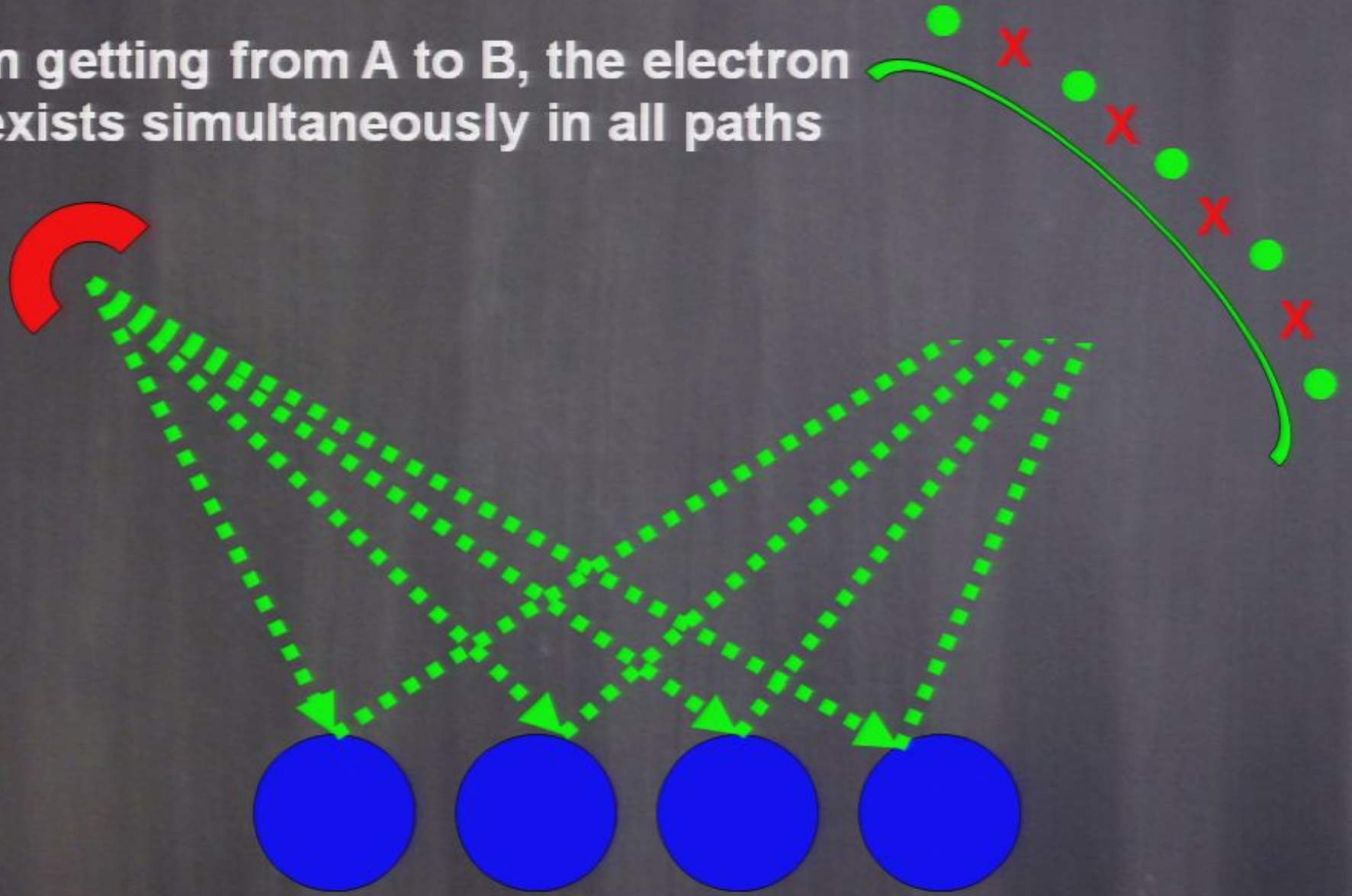

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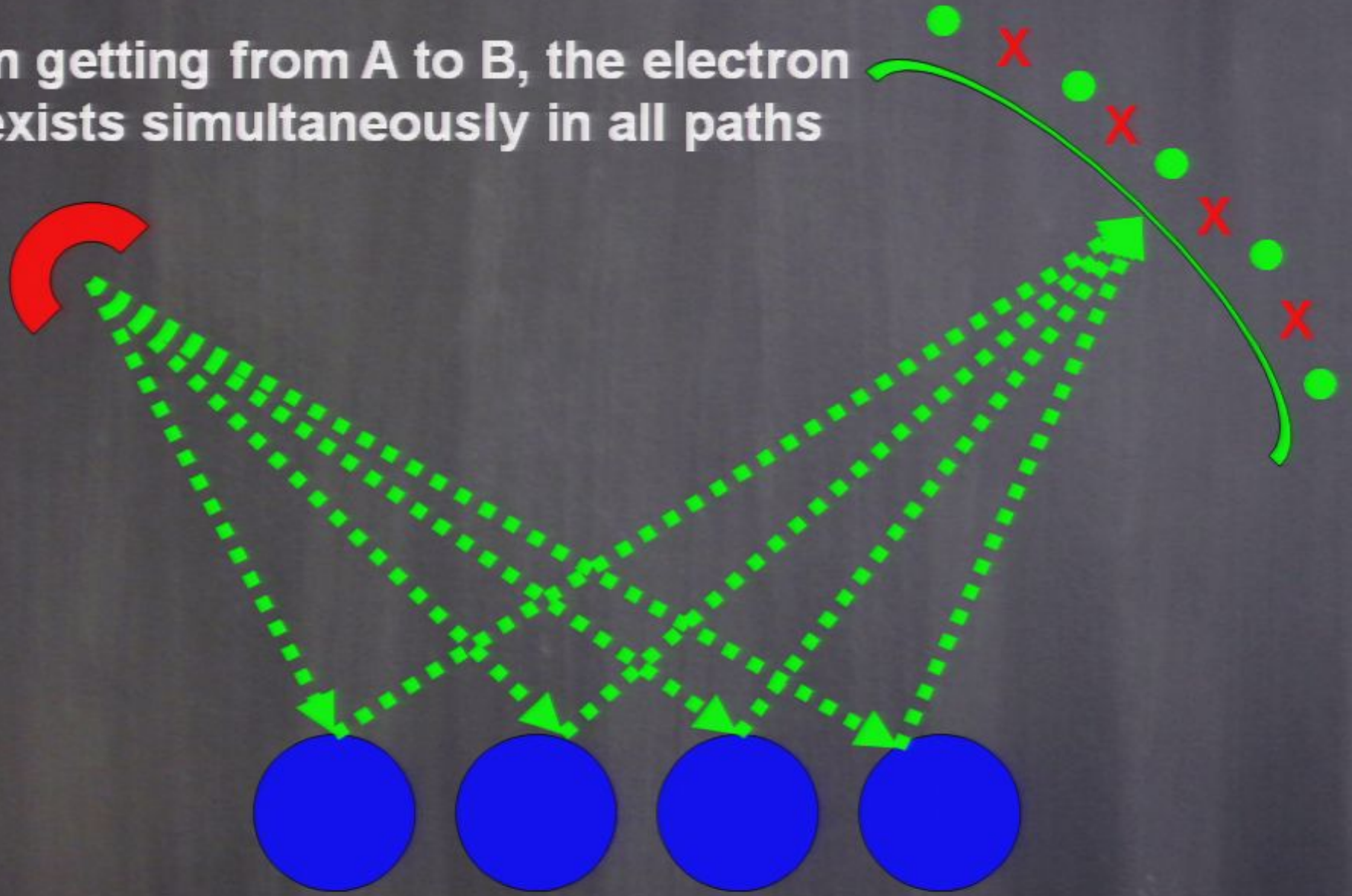
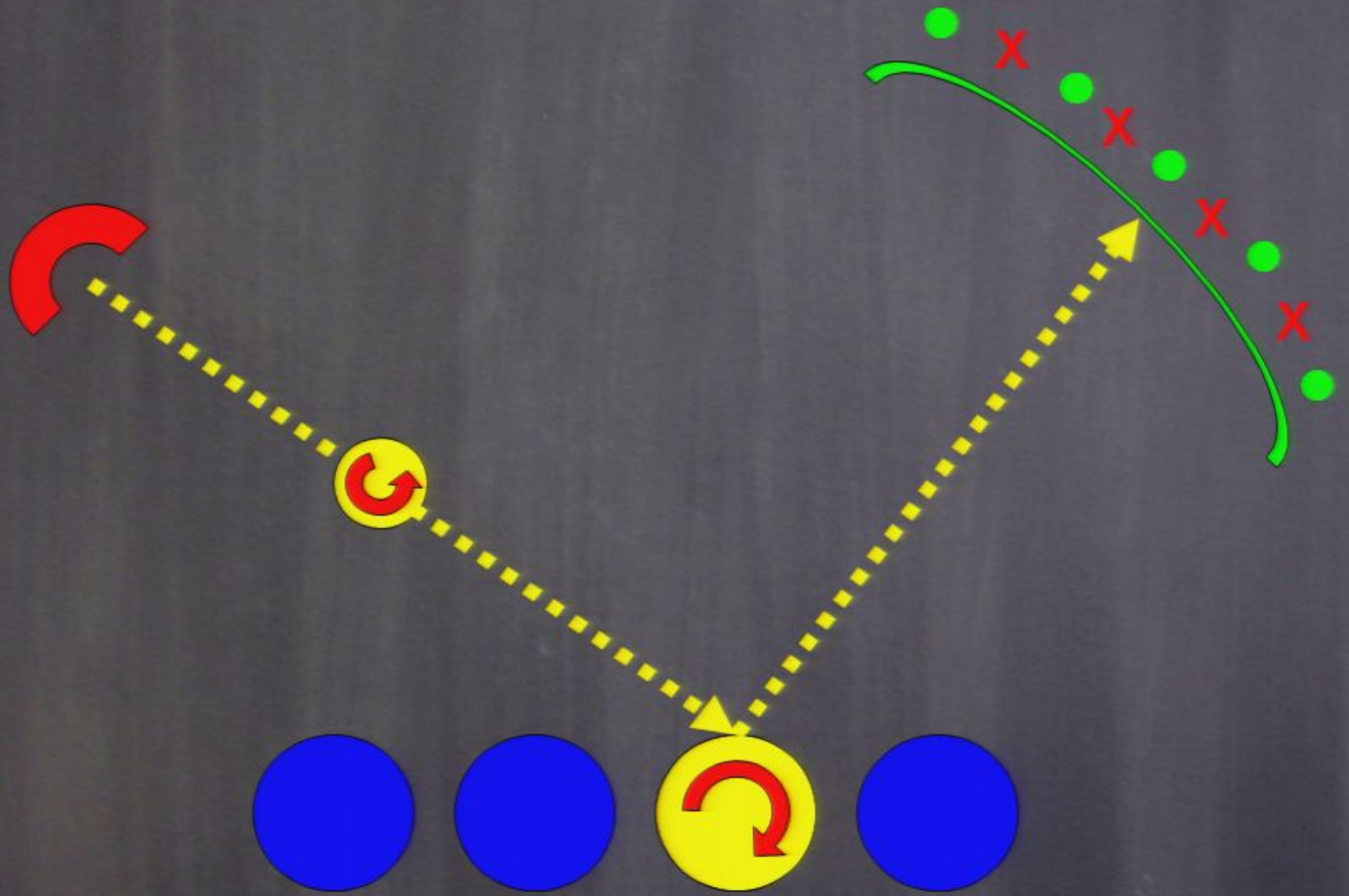
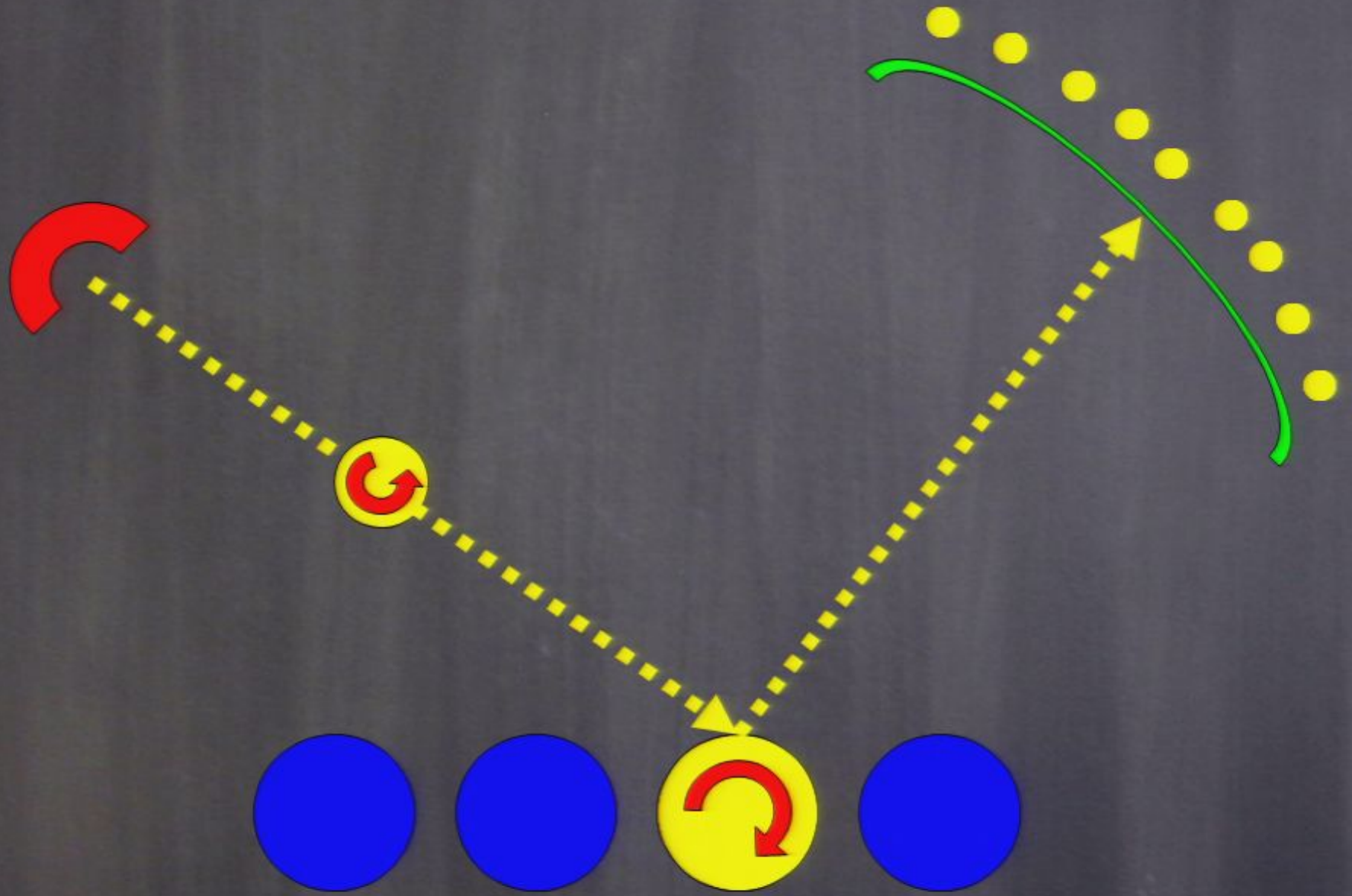


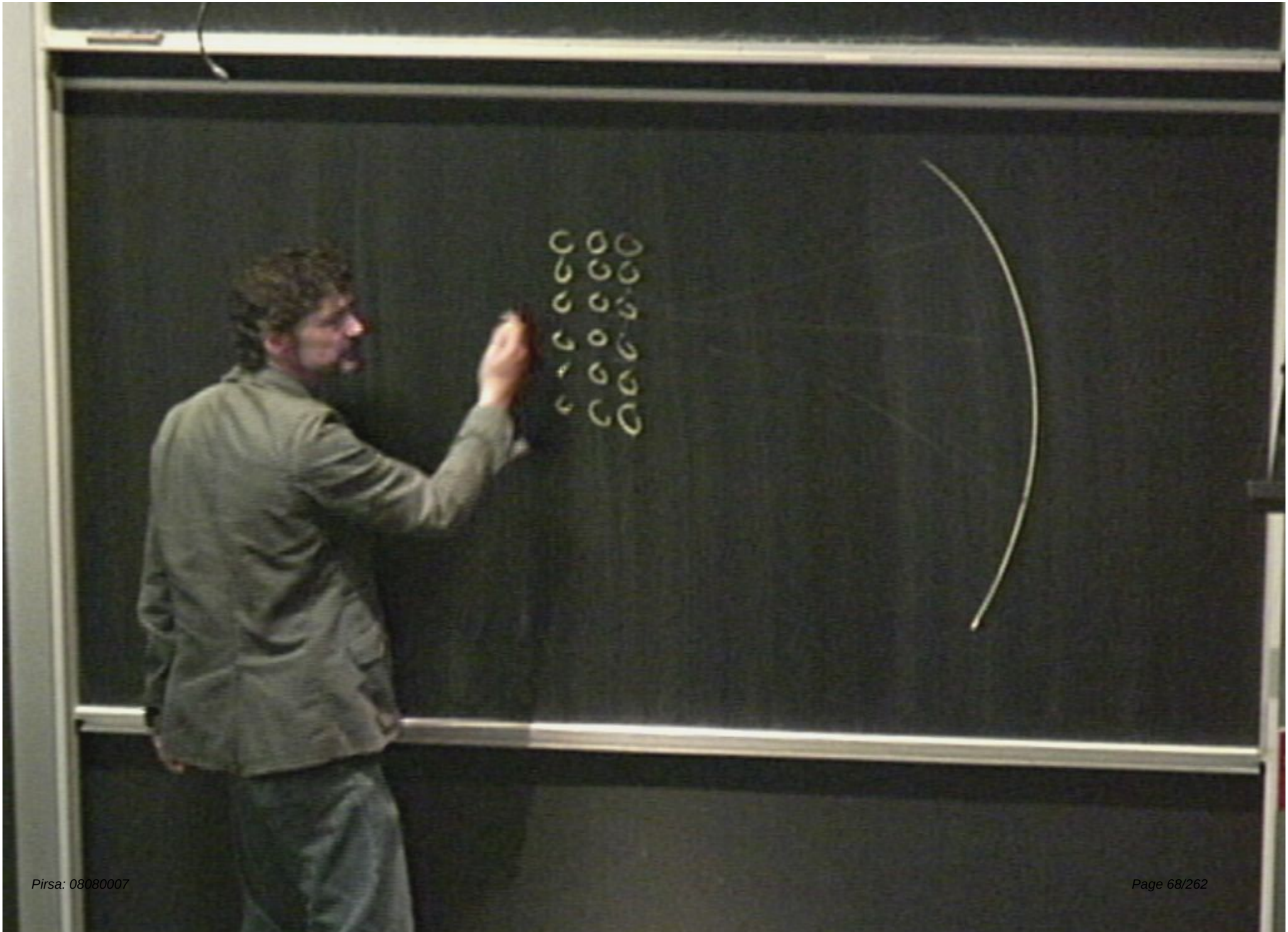
ectron a "SPIN"

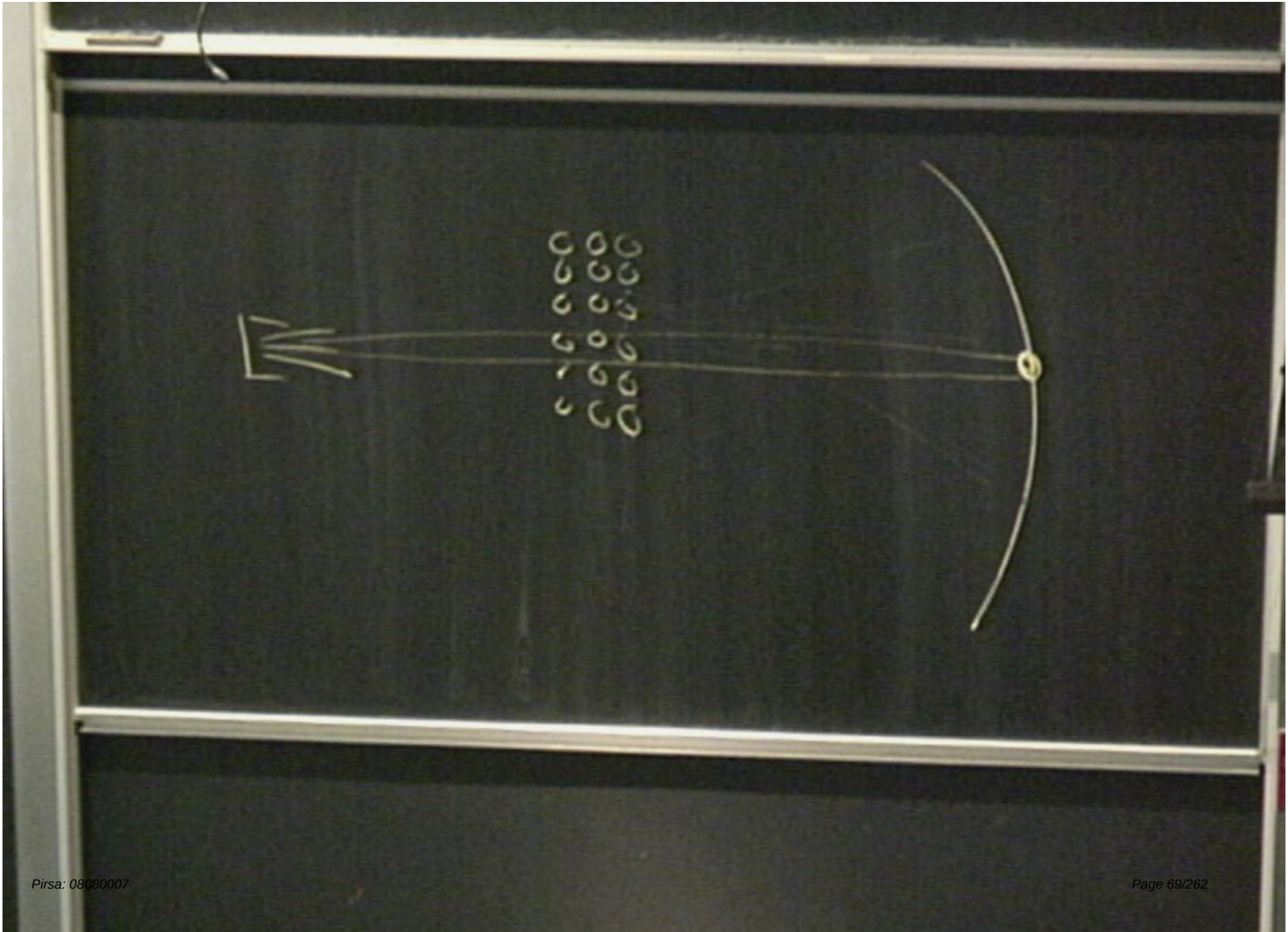
Give the Electron a "SPIN"

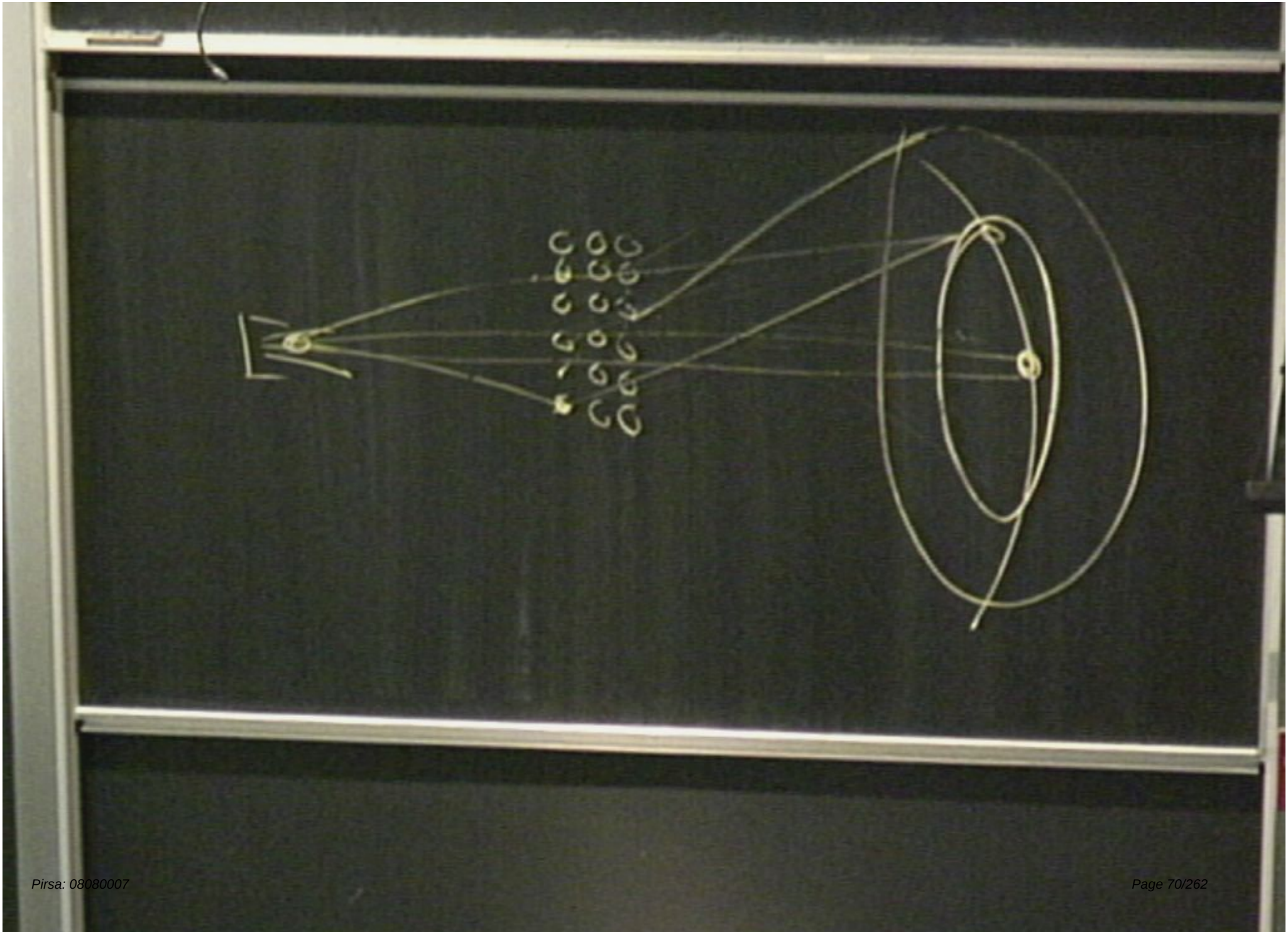


Give the Electron a "SPIN"









Quantum Entanglement 101

Quantum Entanglement 101

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Alice

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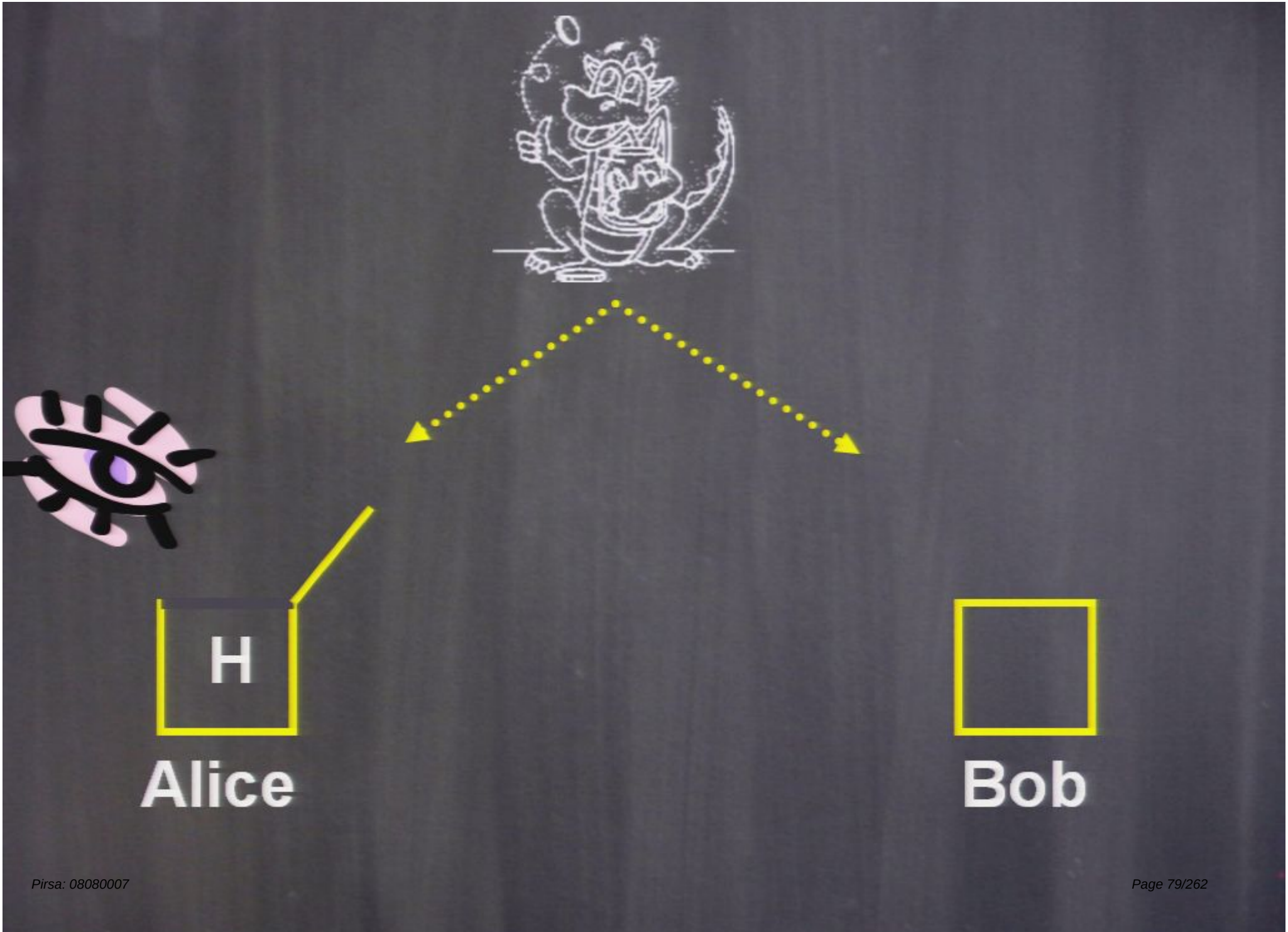
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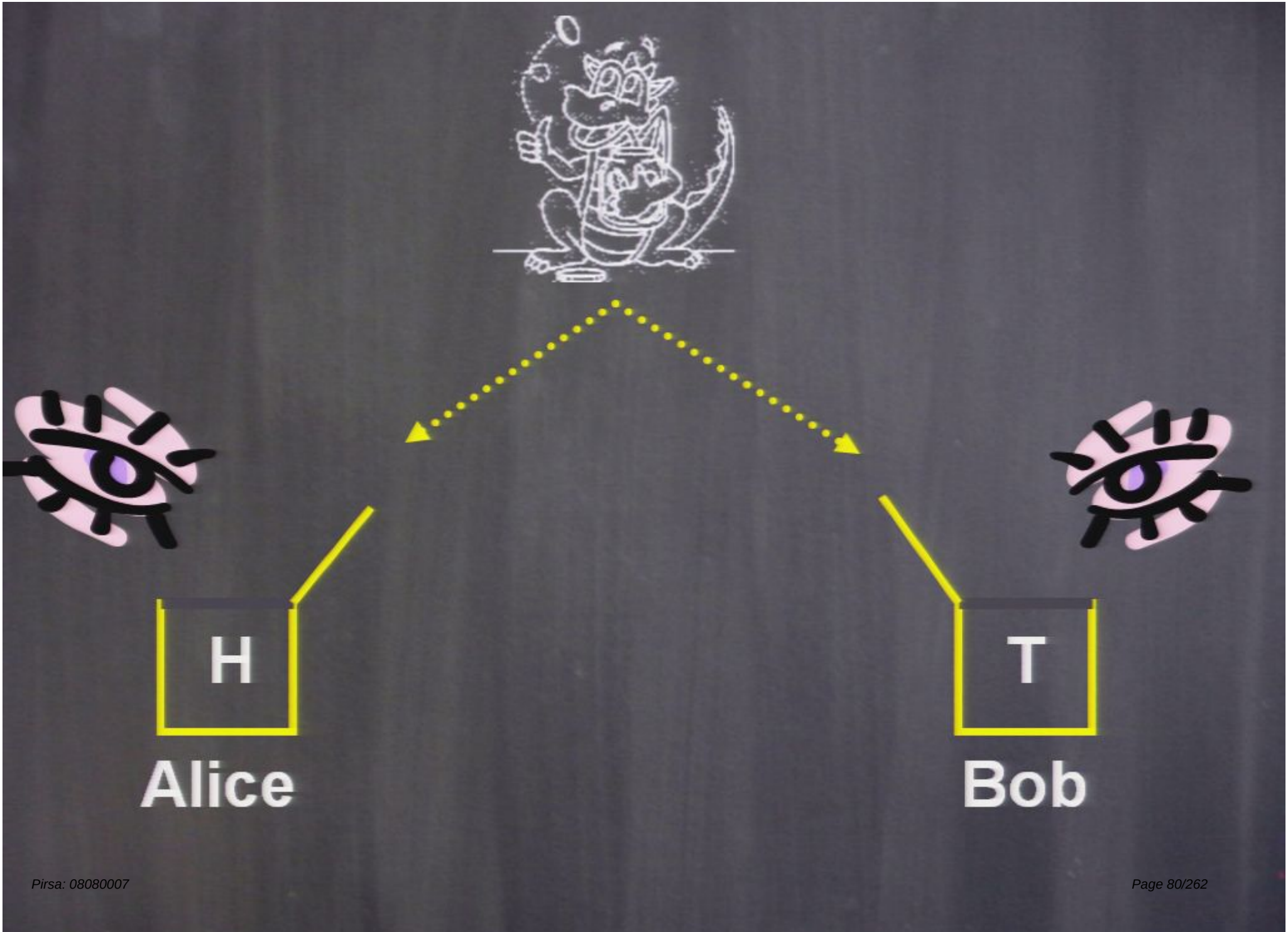
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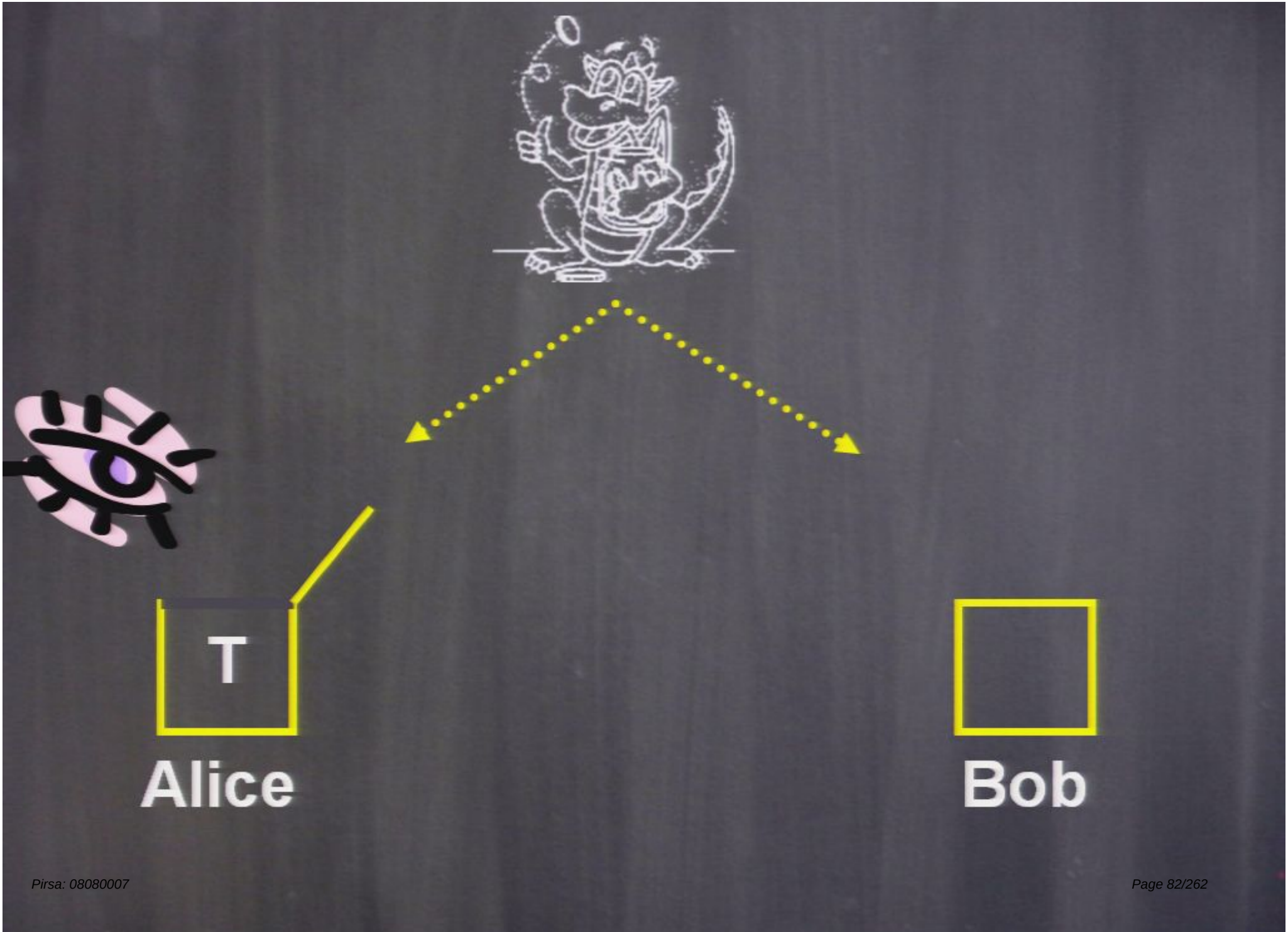
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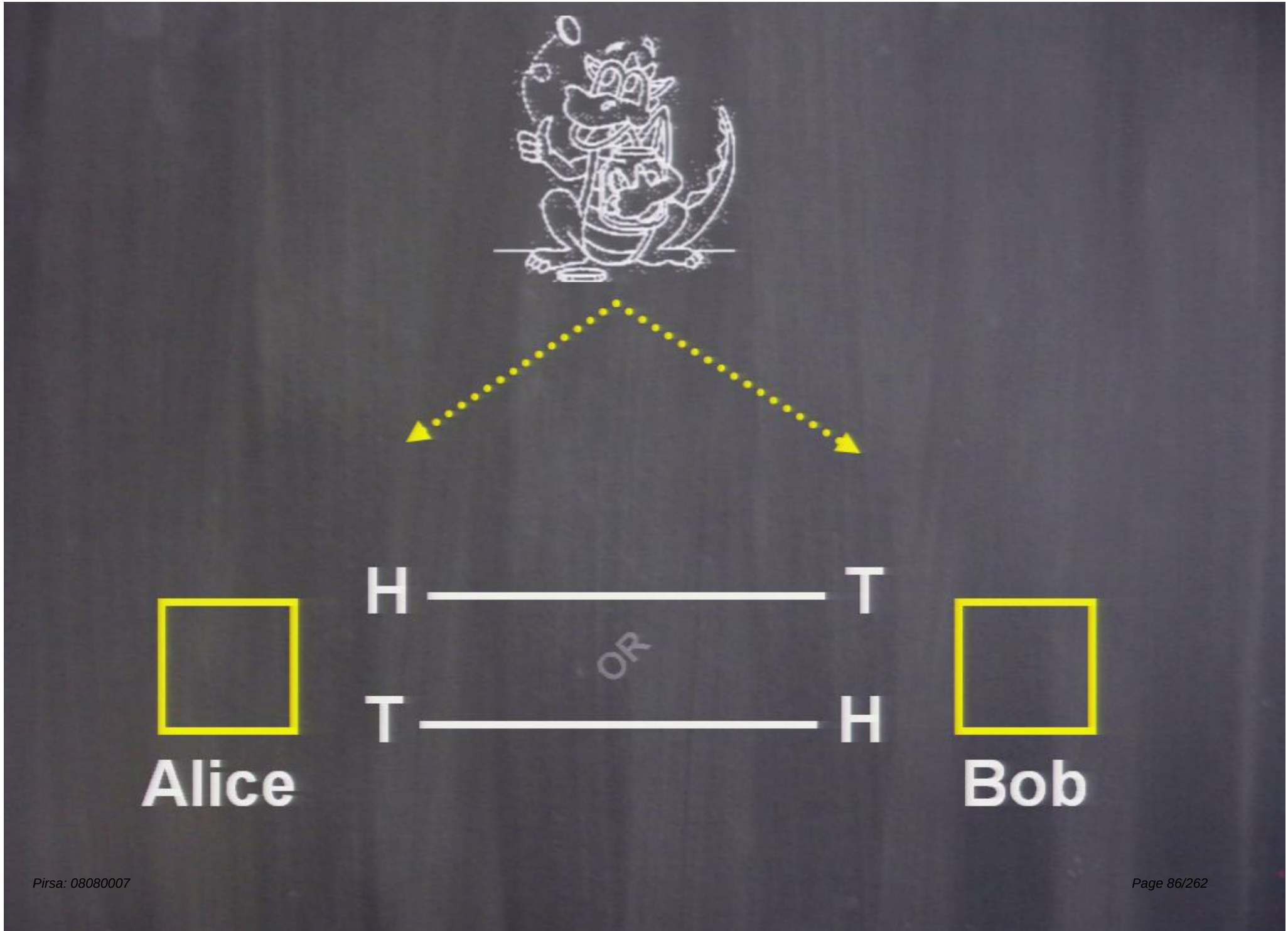
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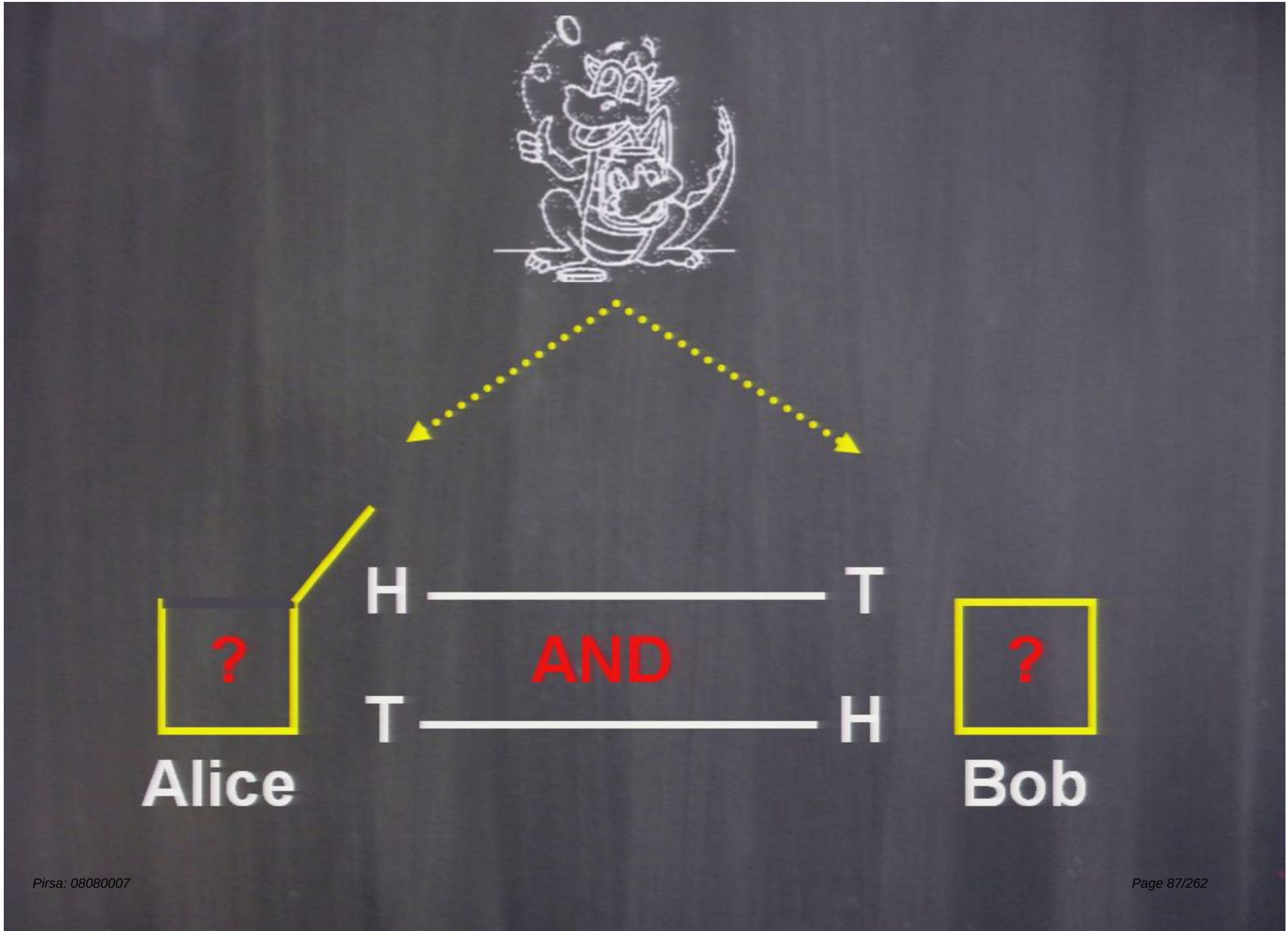
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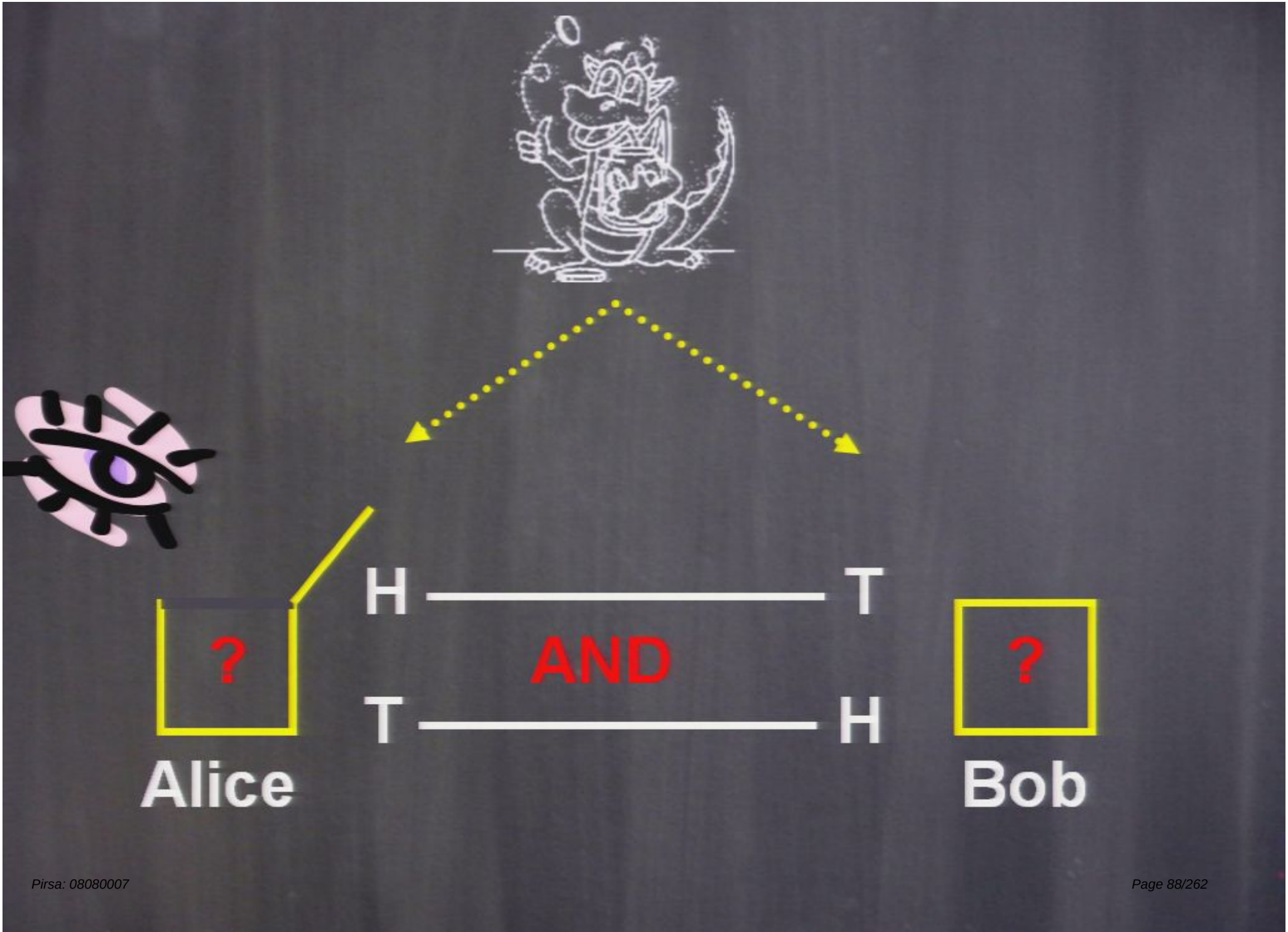
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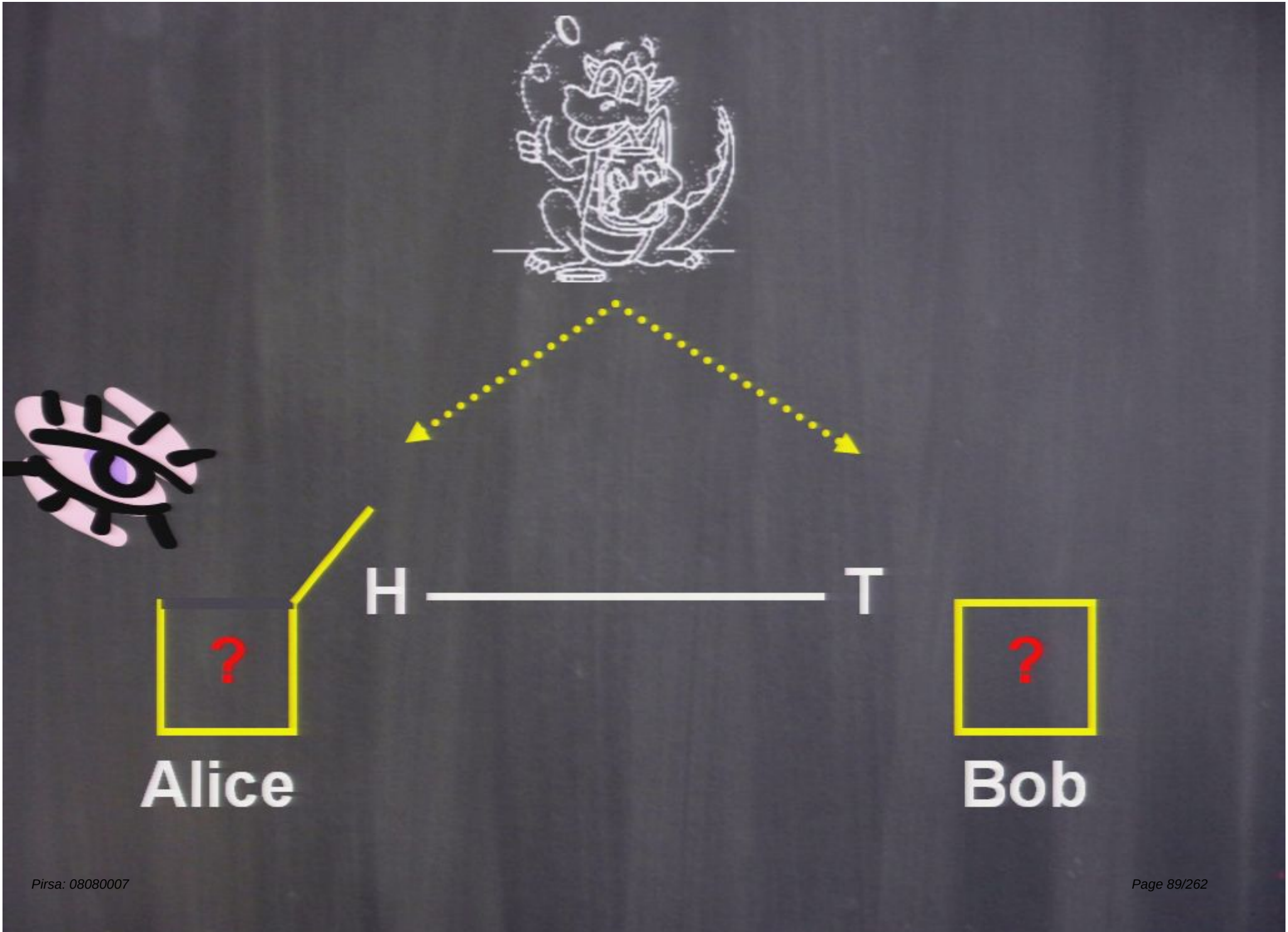
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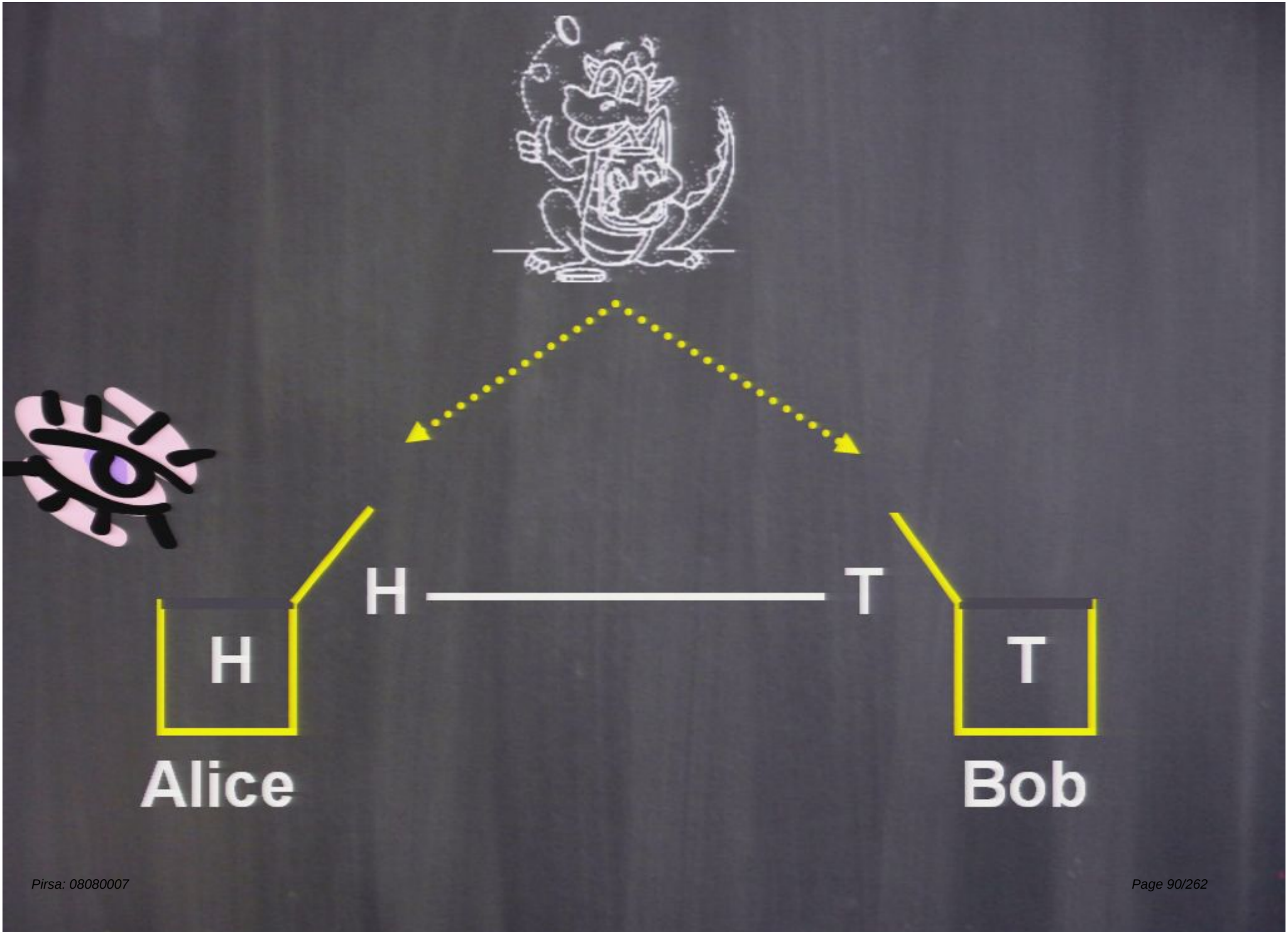
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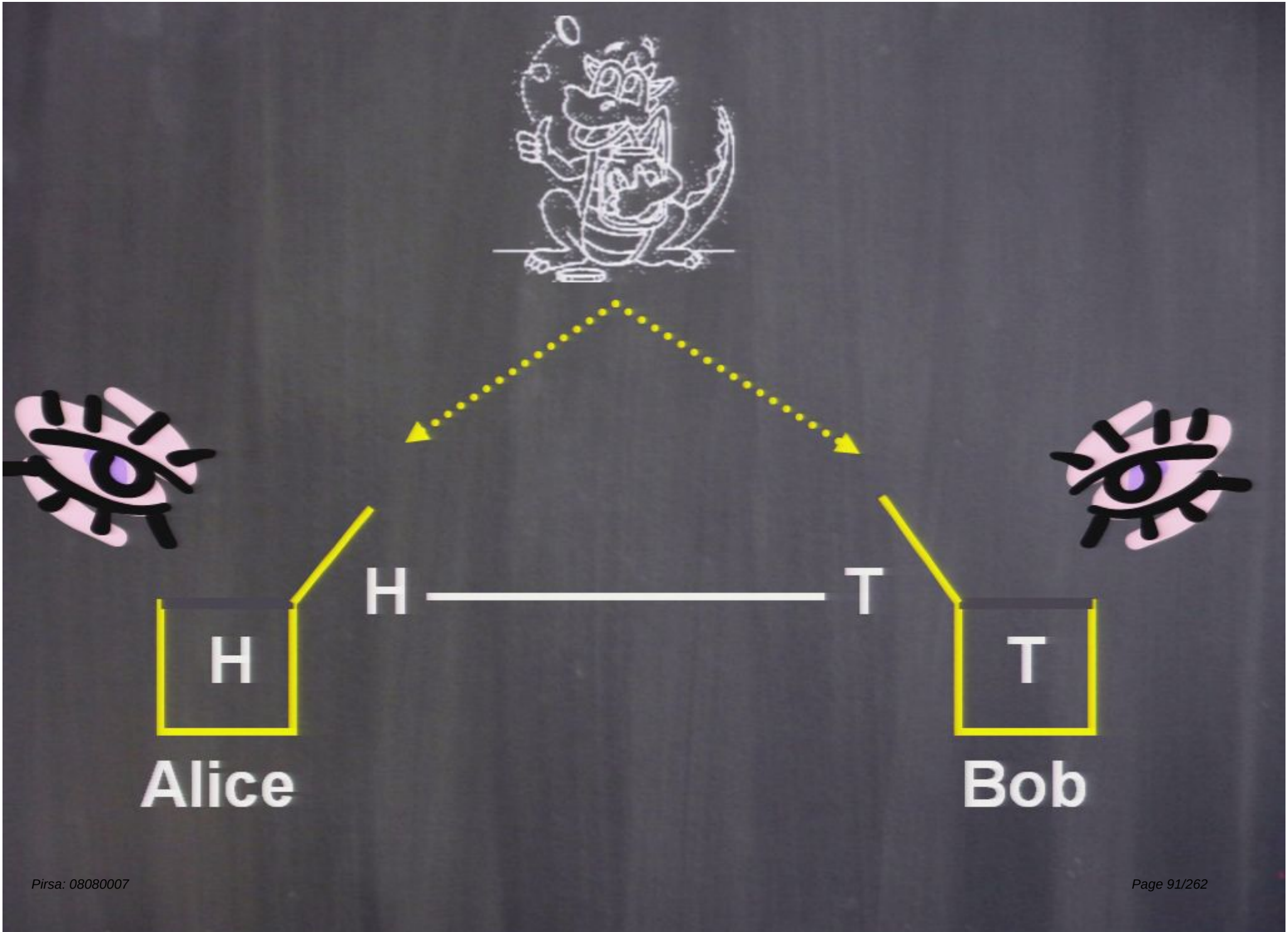
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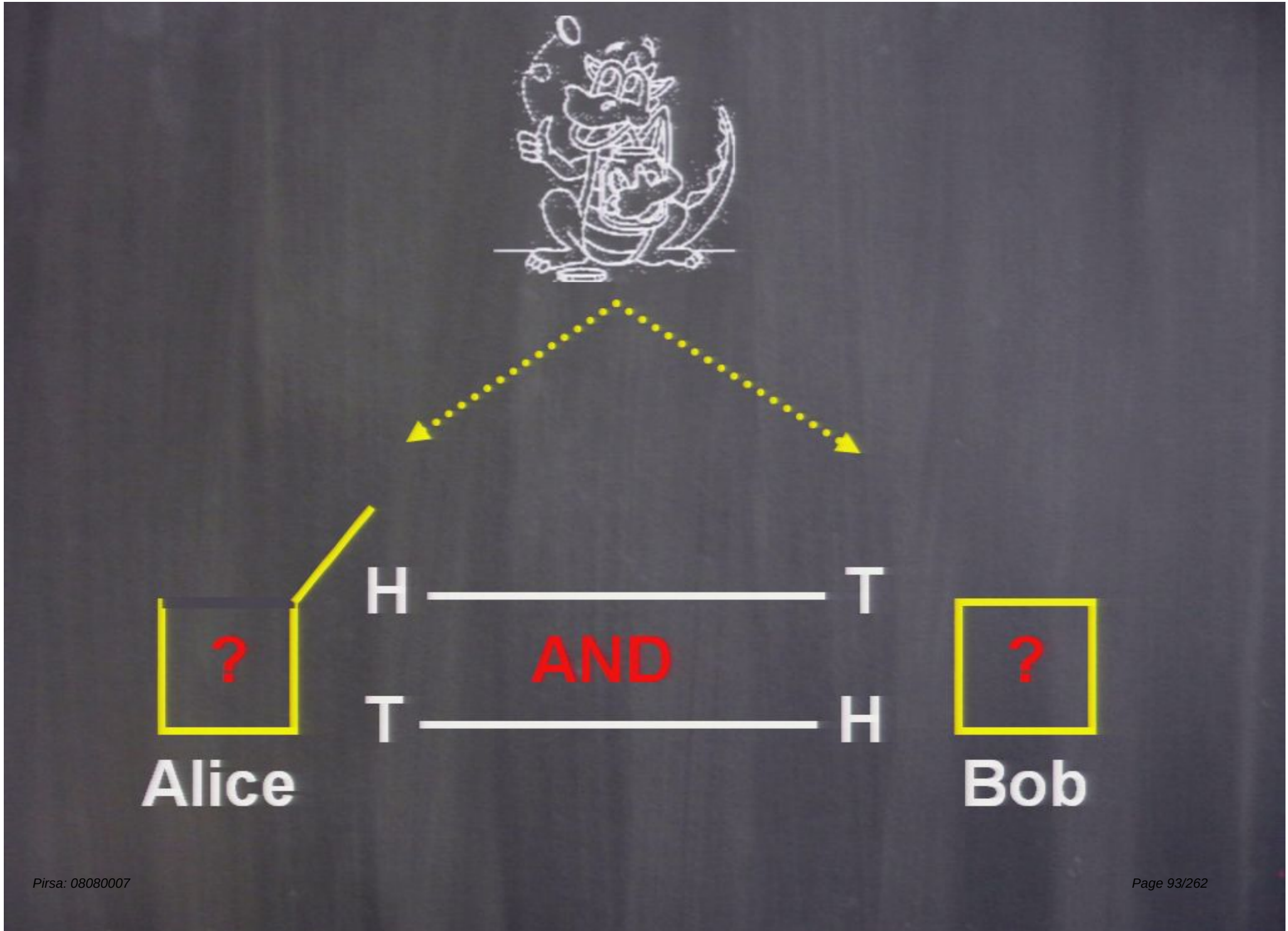
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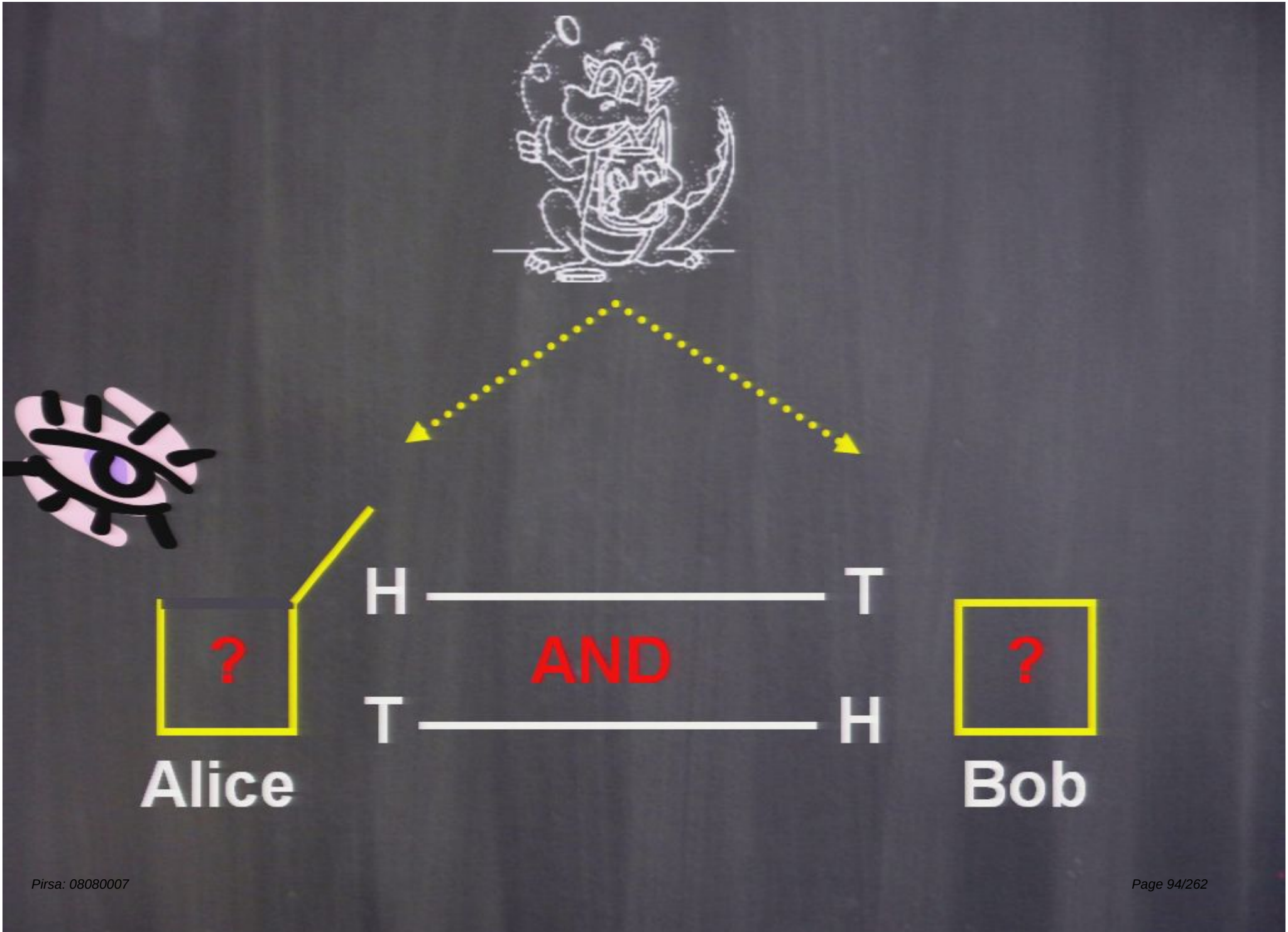
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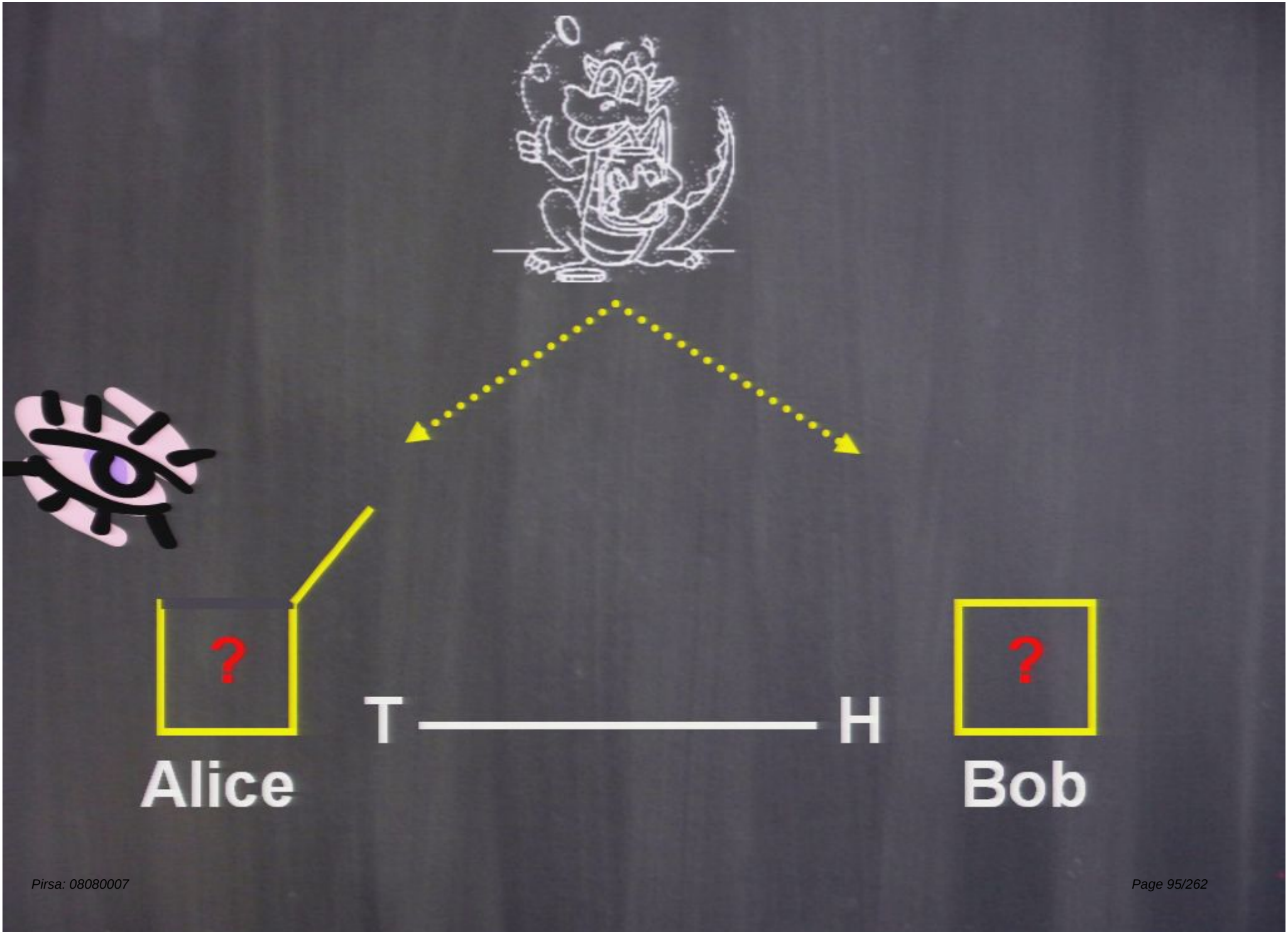
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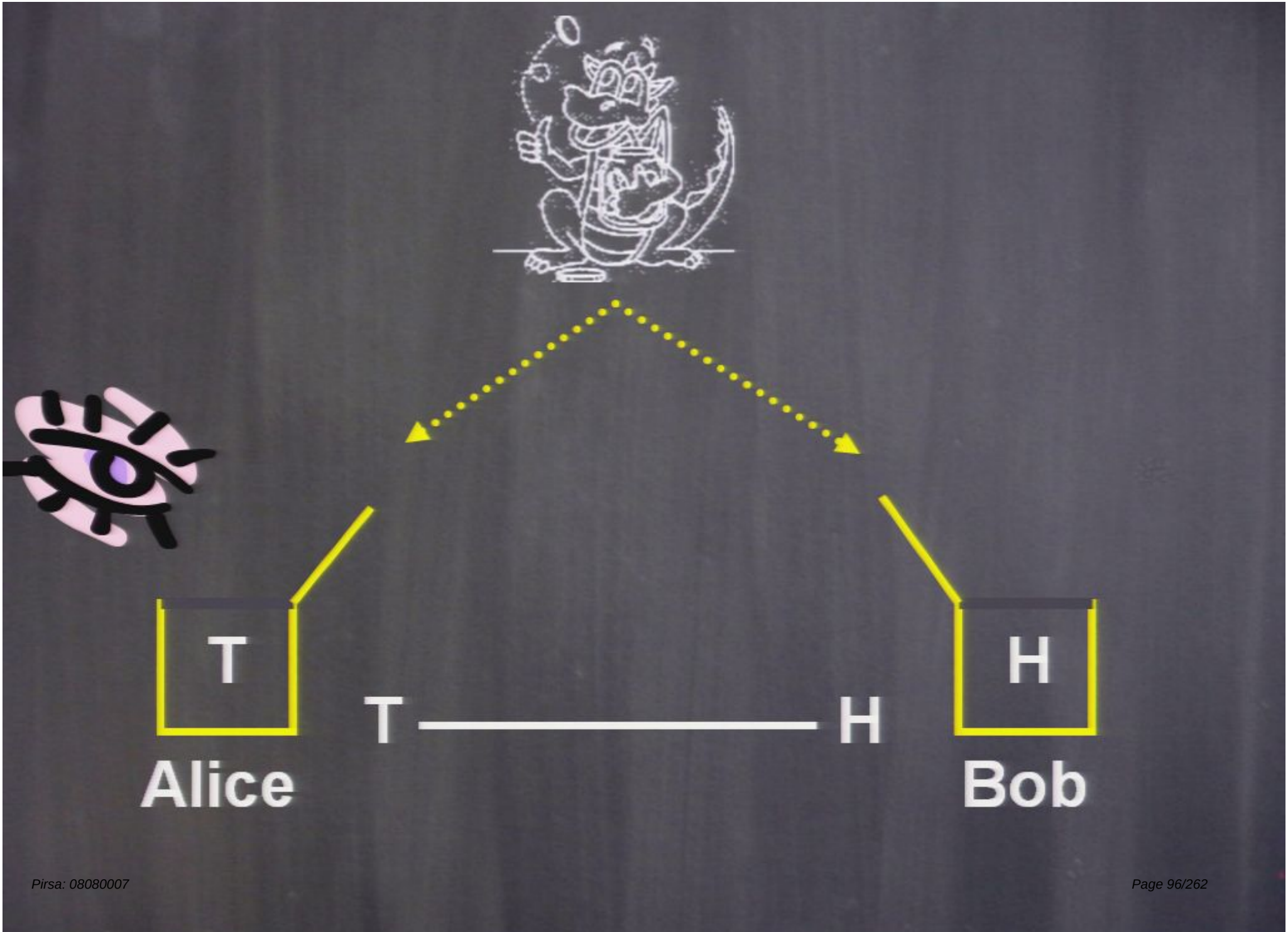
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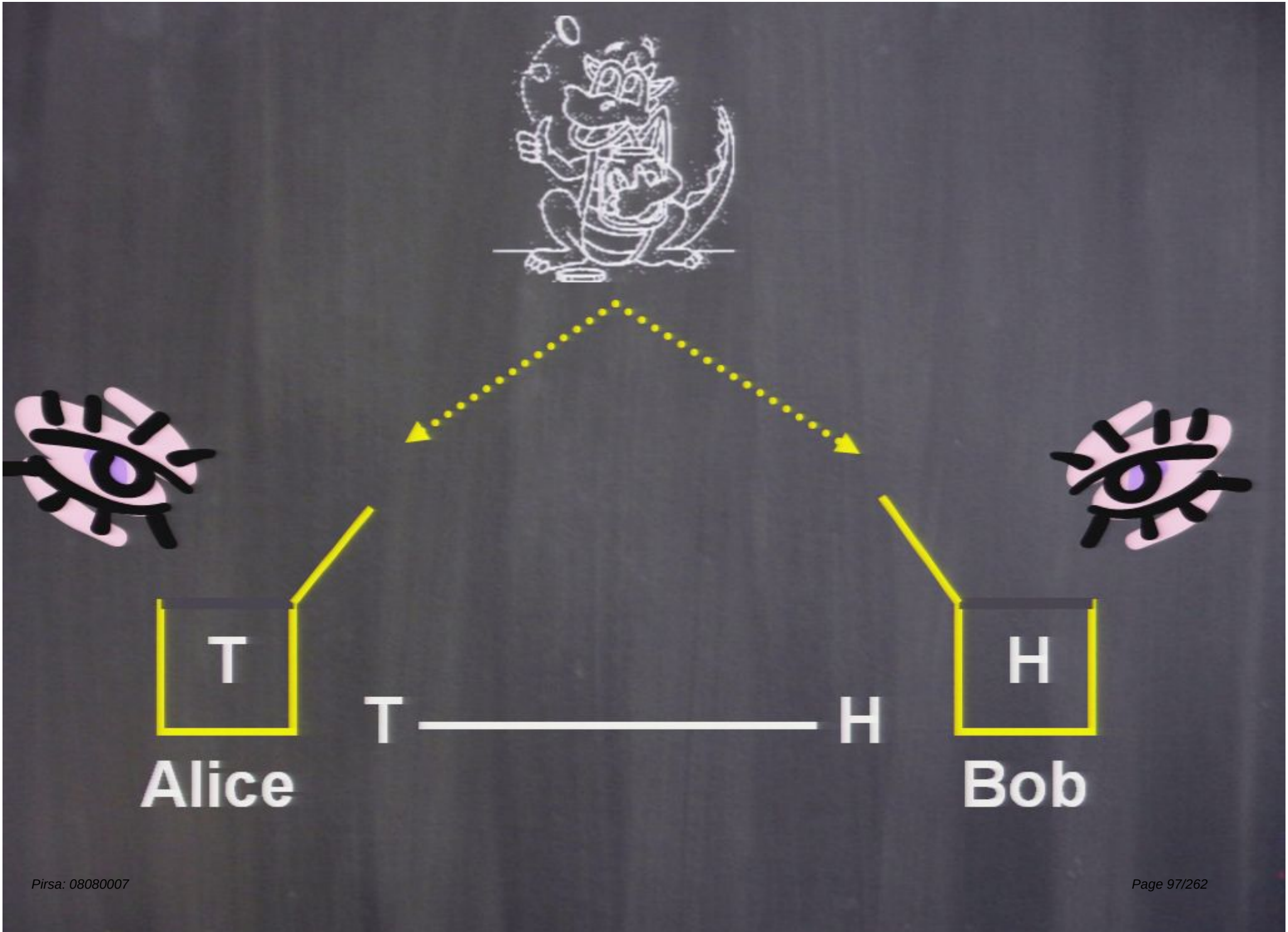
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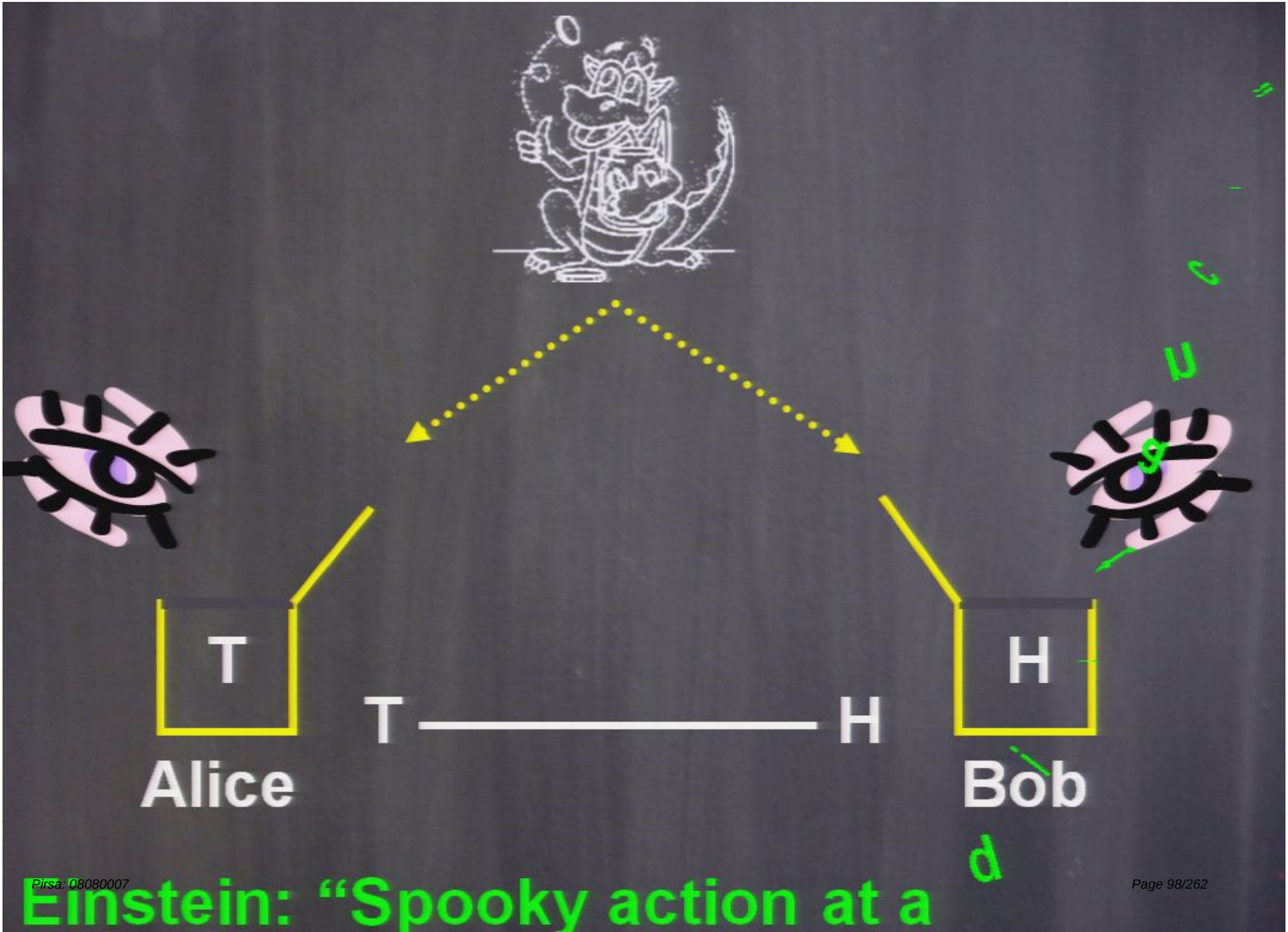
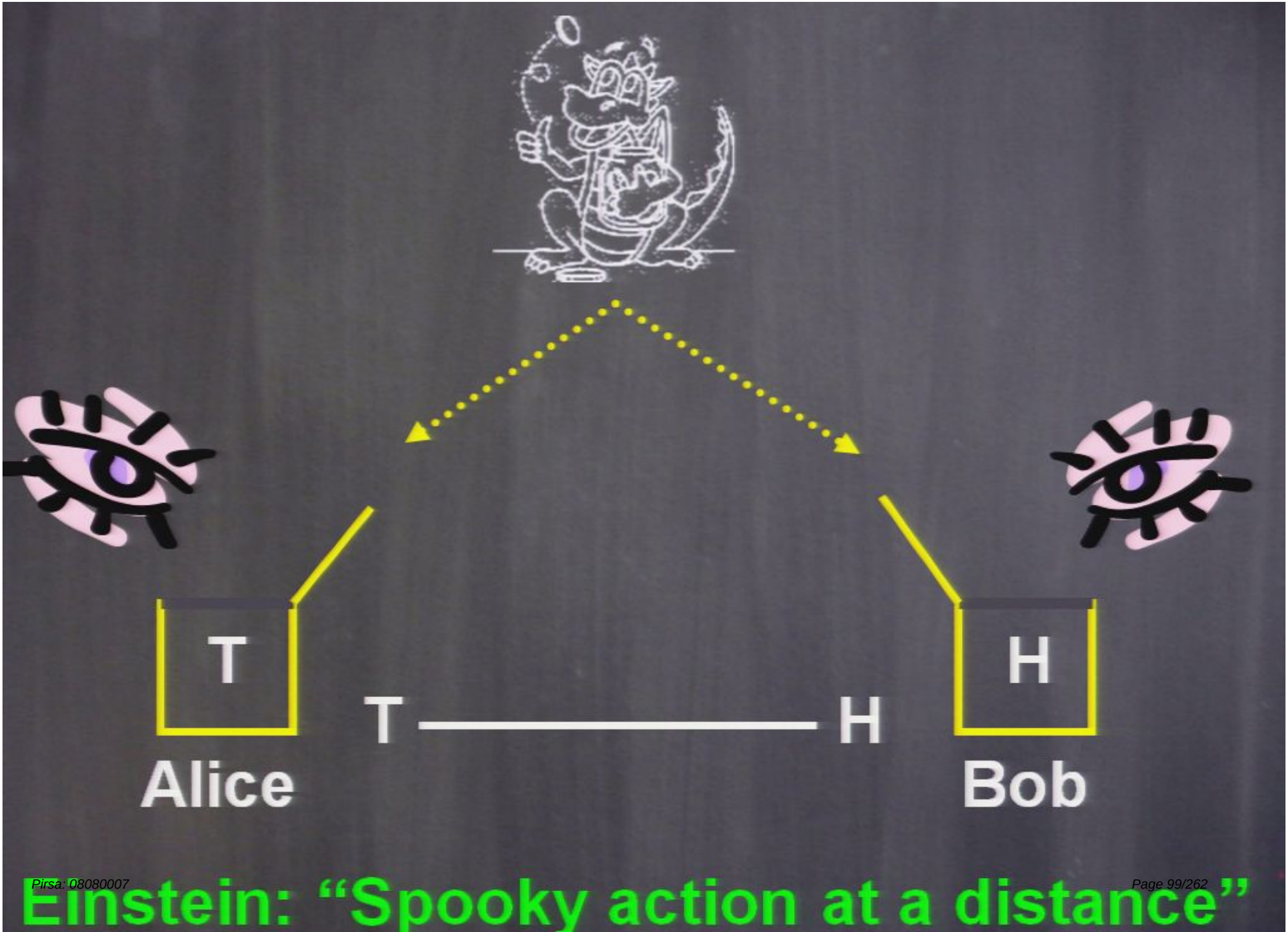
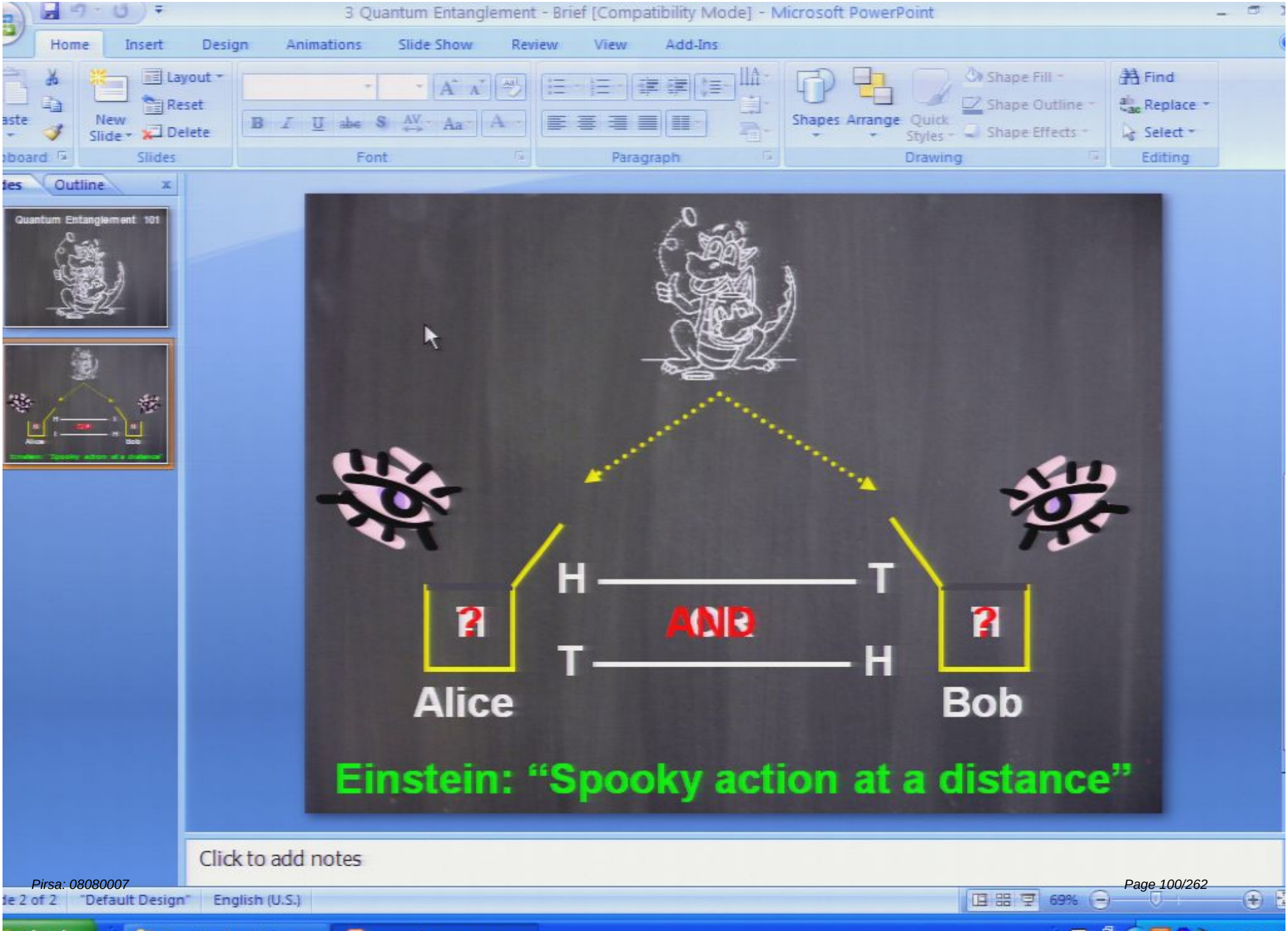


Einstein: “Spooky action at a



Einstein: “Spooky action at a distance”


3 Quantum Entanglement - Brief [Compatibility Mode] - Microsoft PowerPoint
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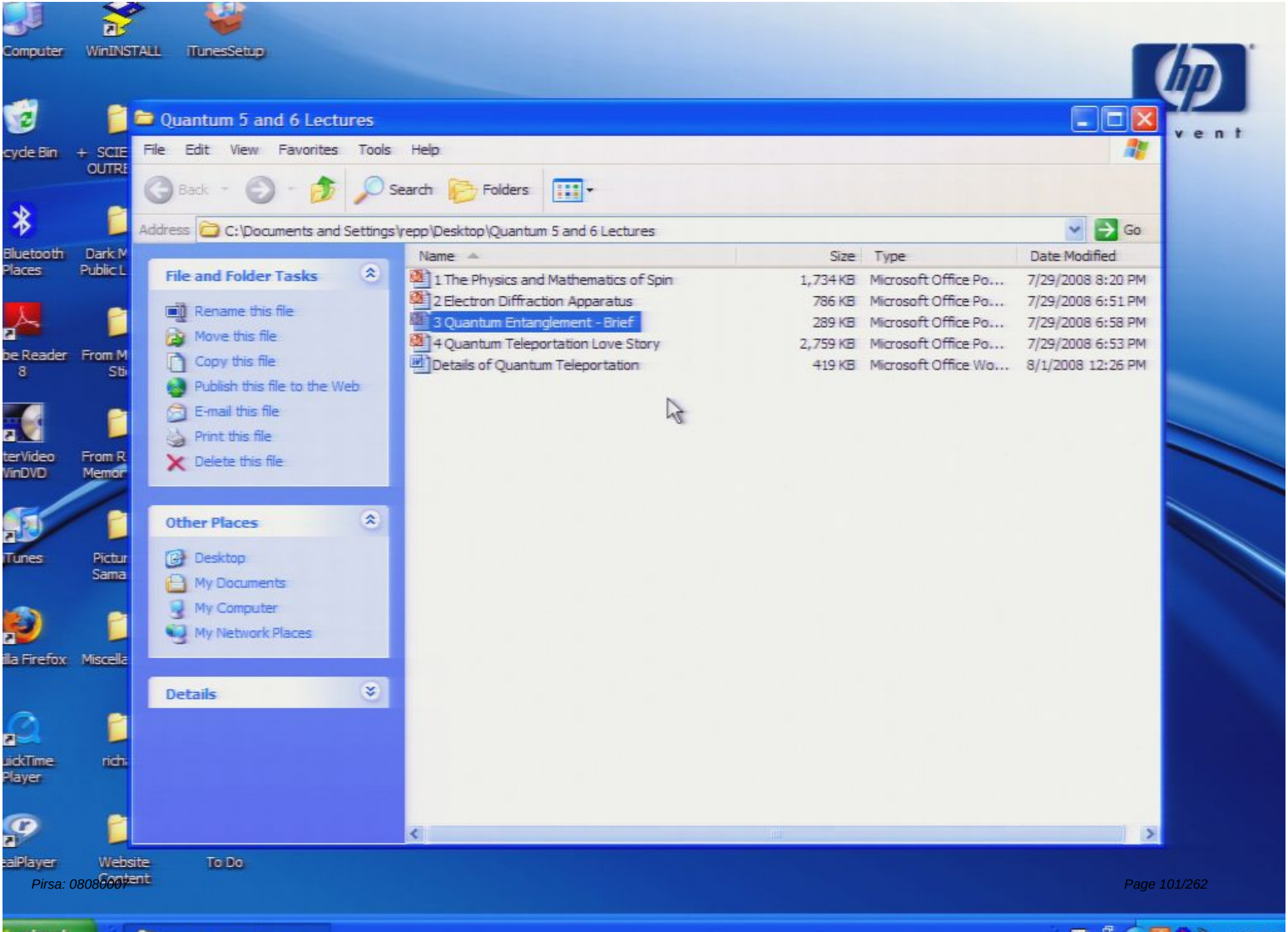
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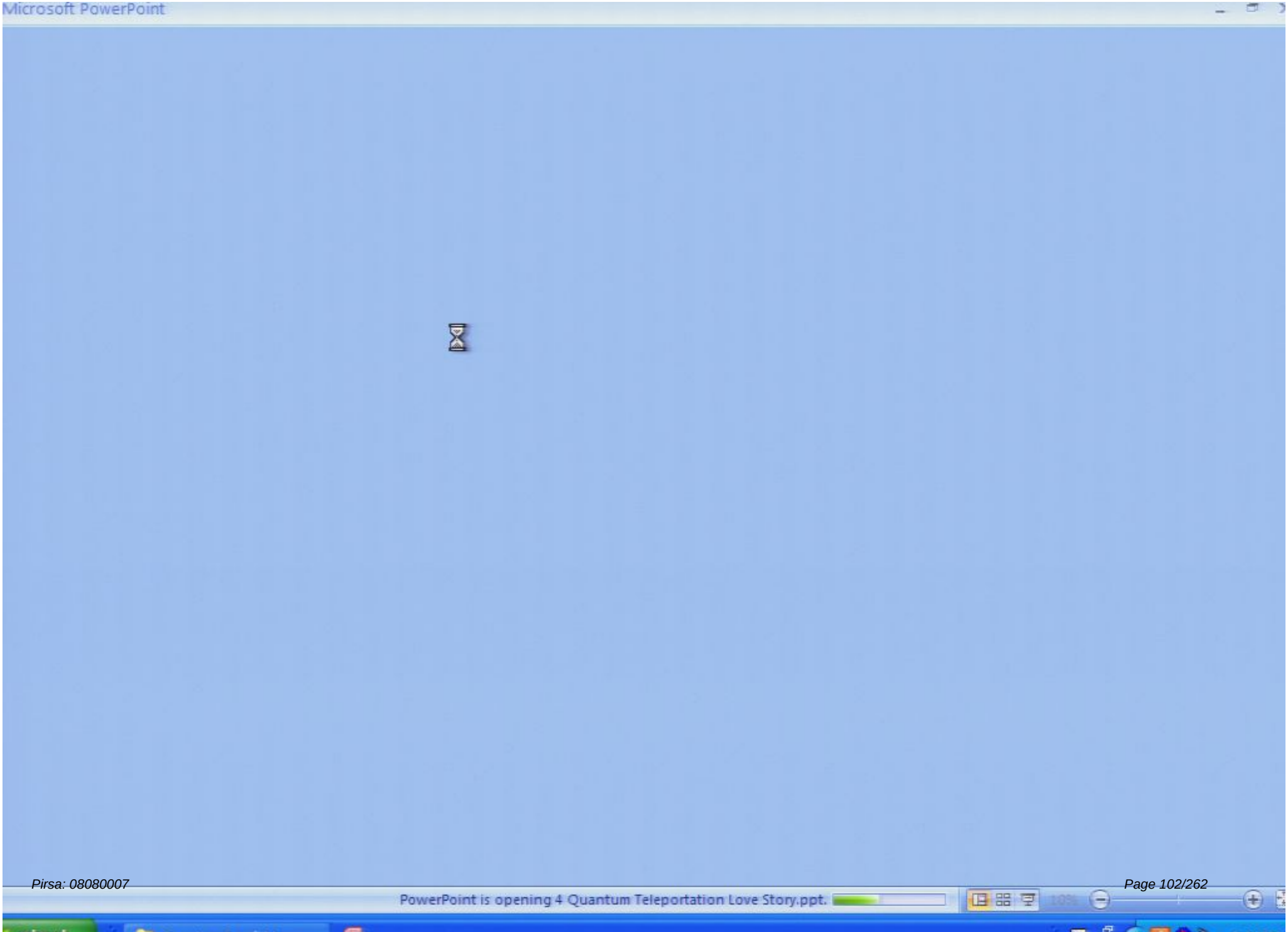
To Do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PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

Quantum Teleportation

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Quantum Teleportation

...A Lo

PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

Quantum Teleportation

...A Love Story

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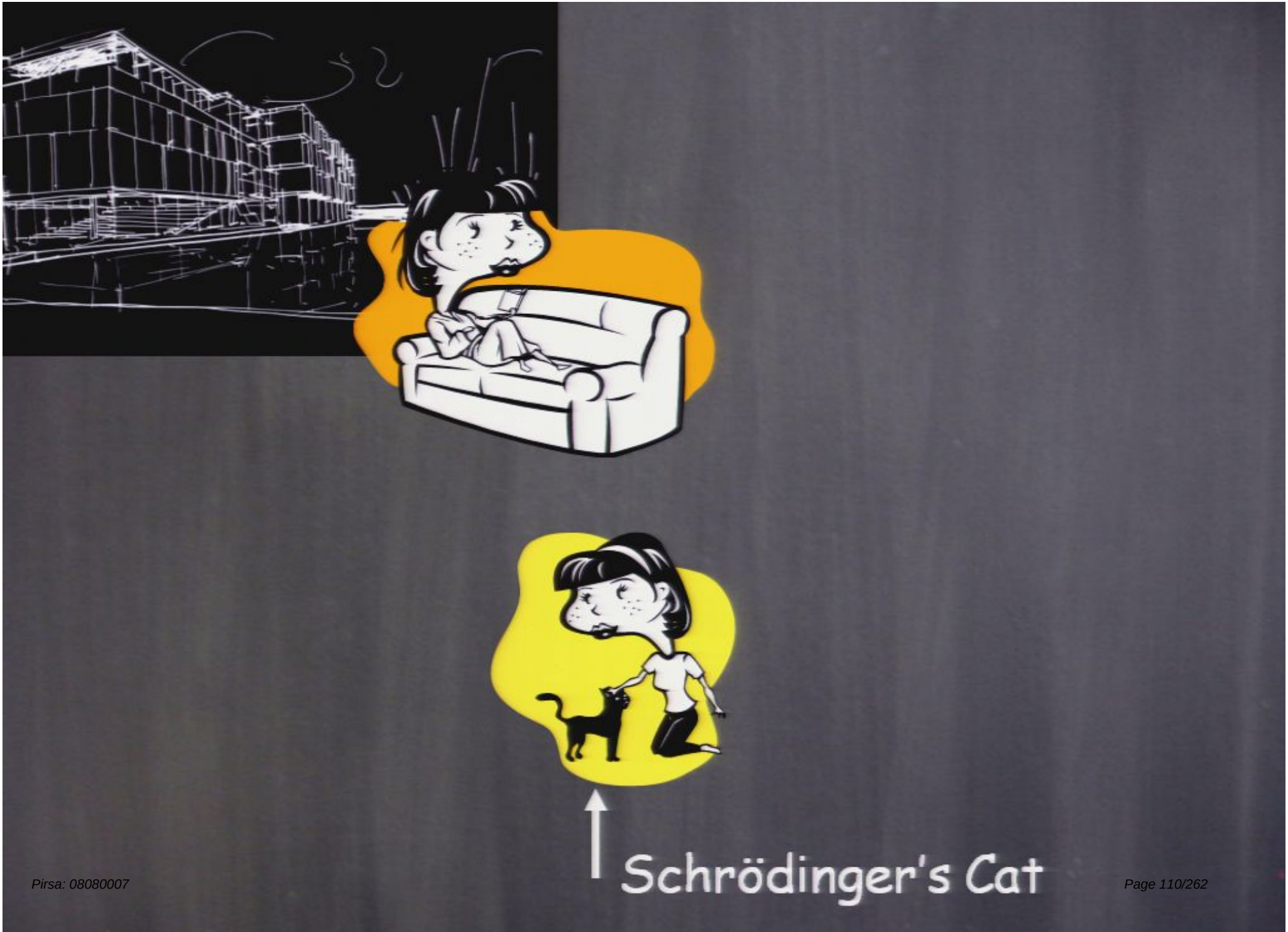
Schrödinger's Cat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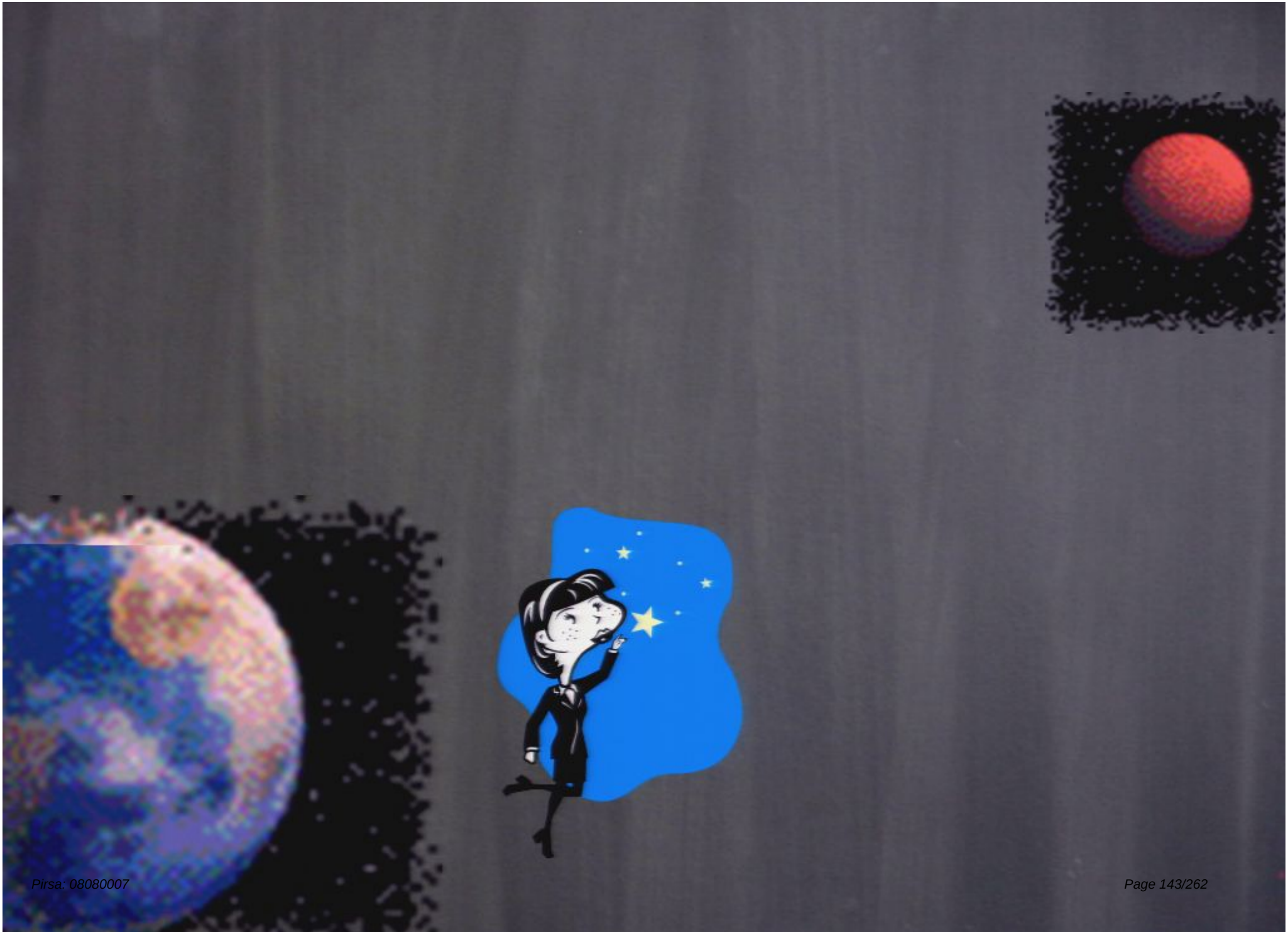

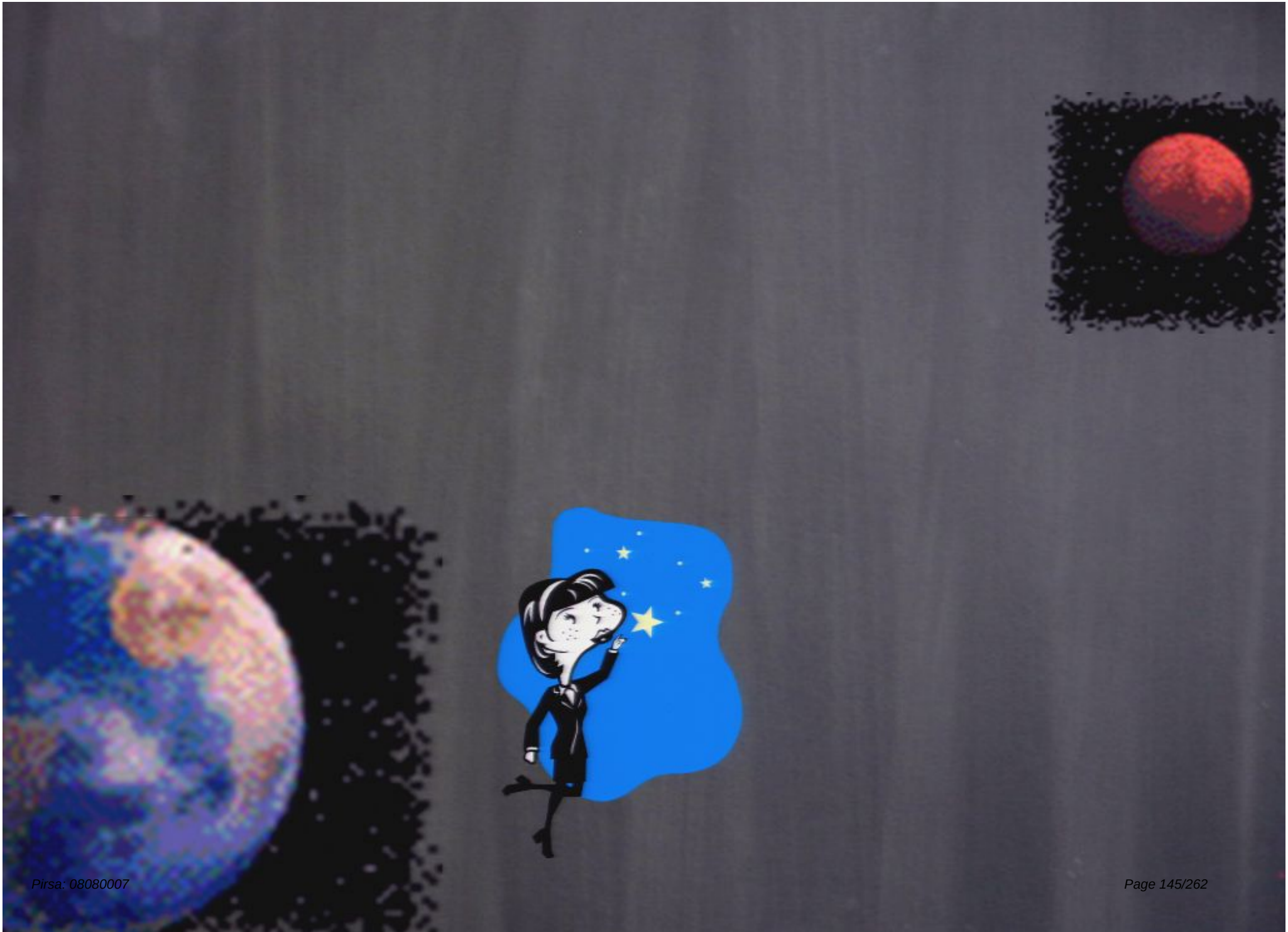

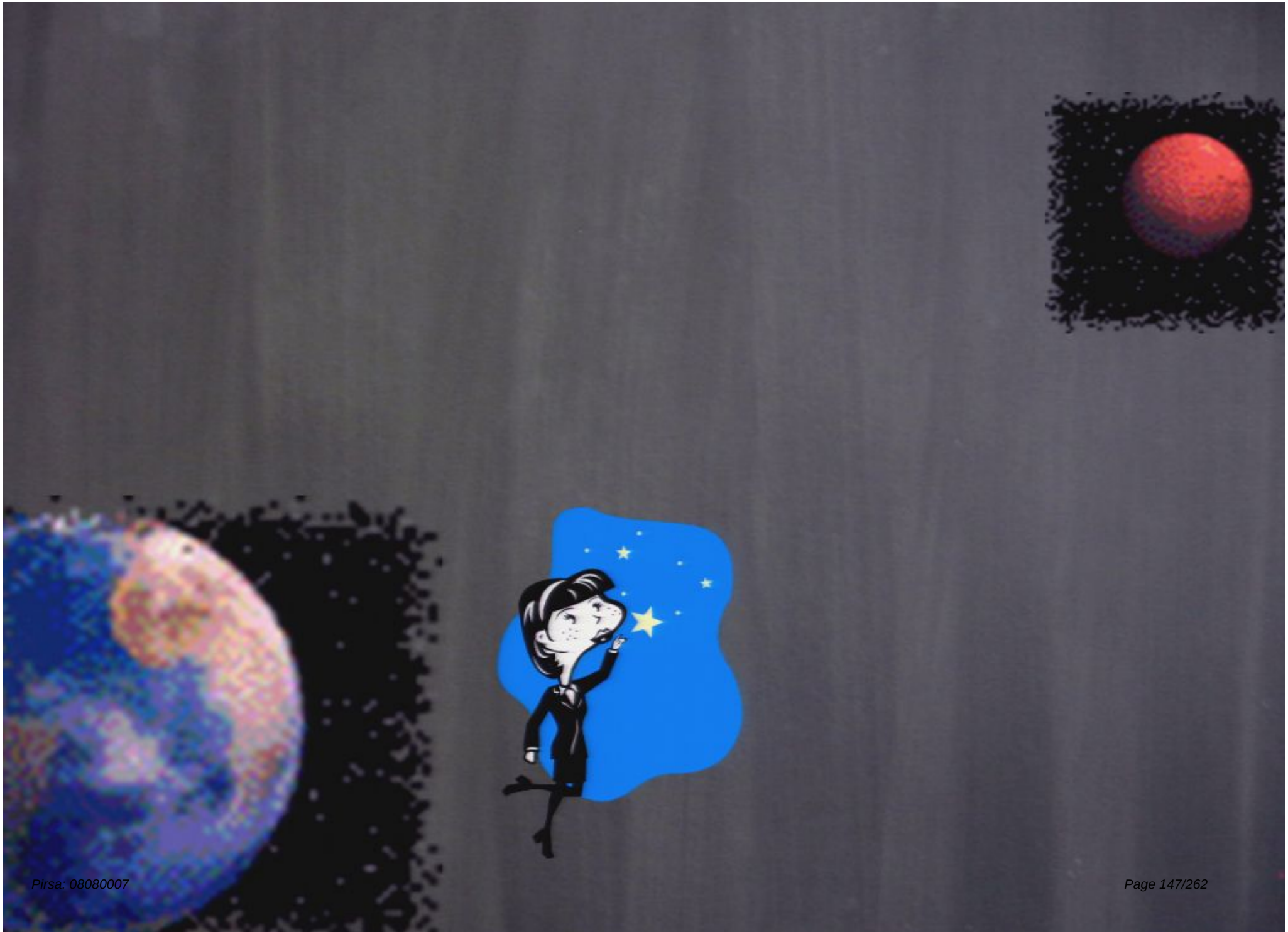

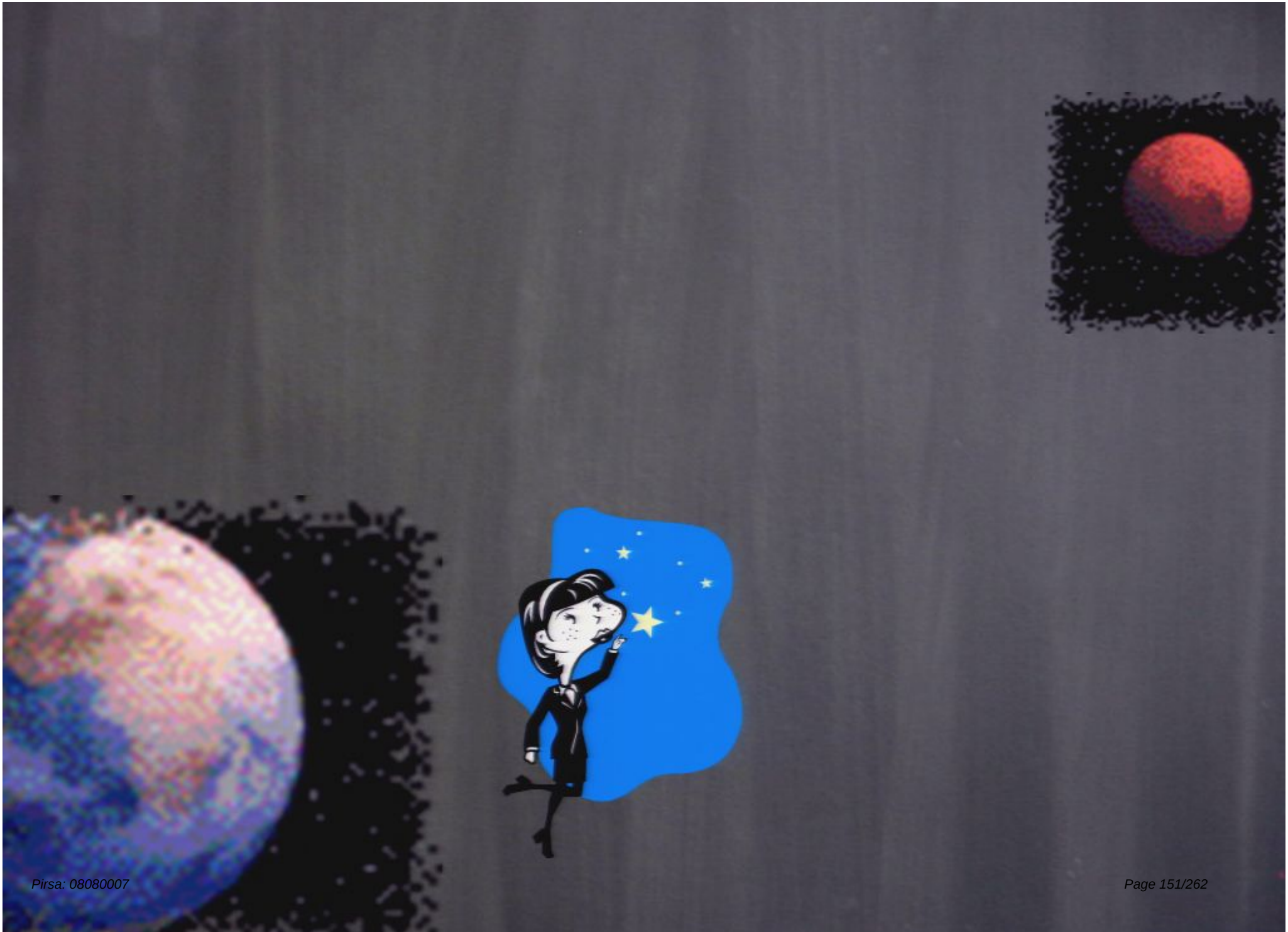

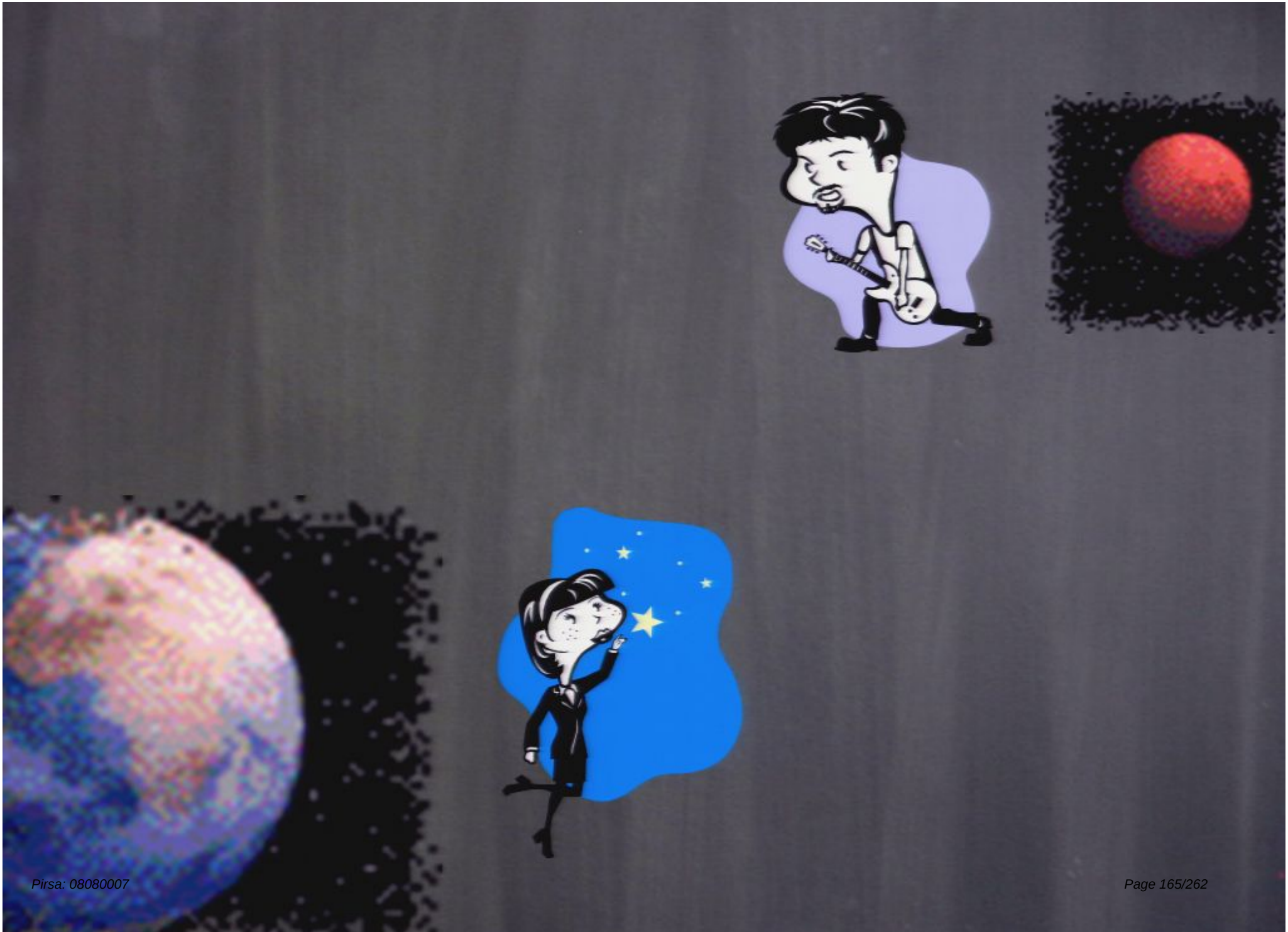

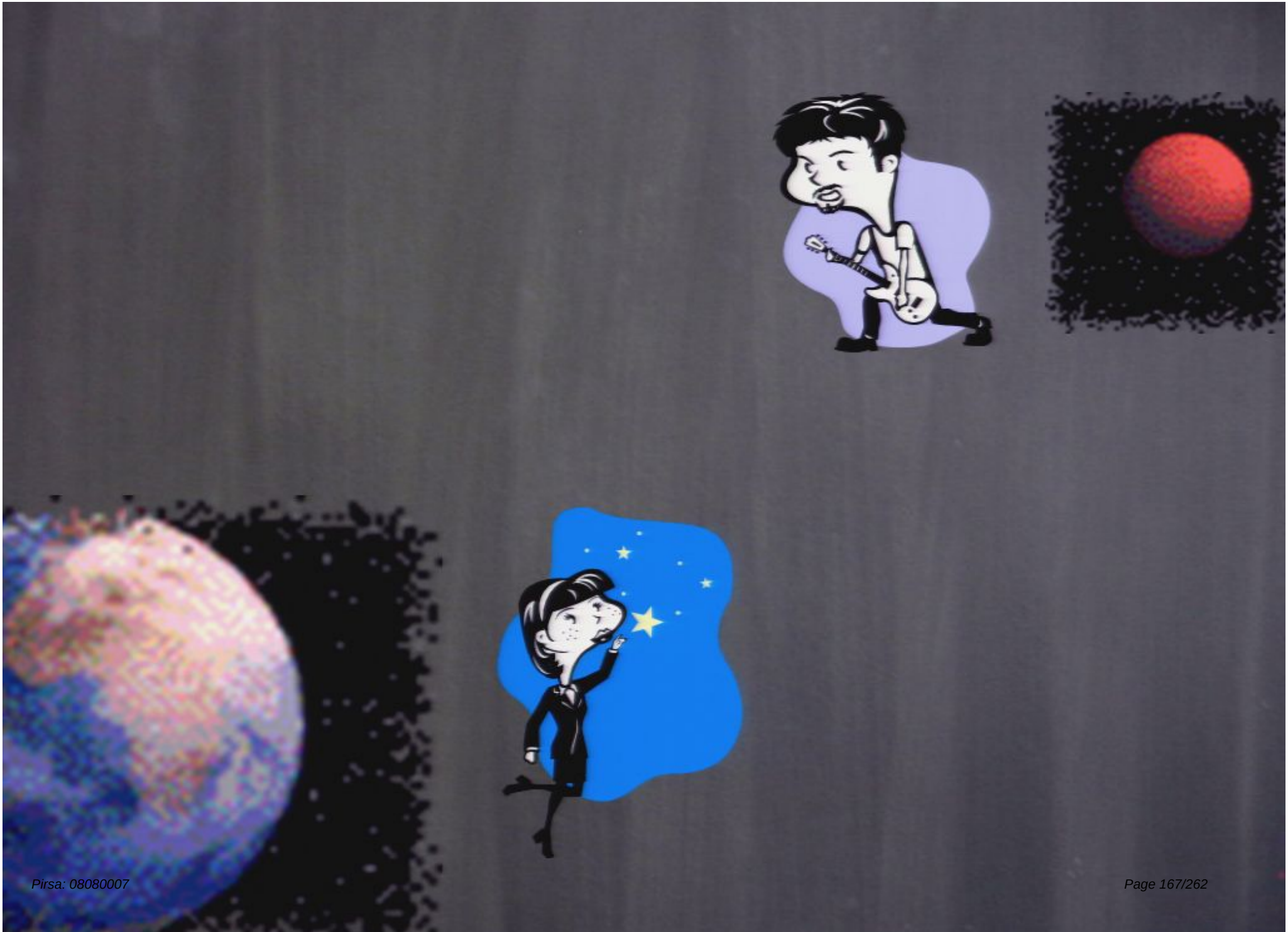

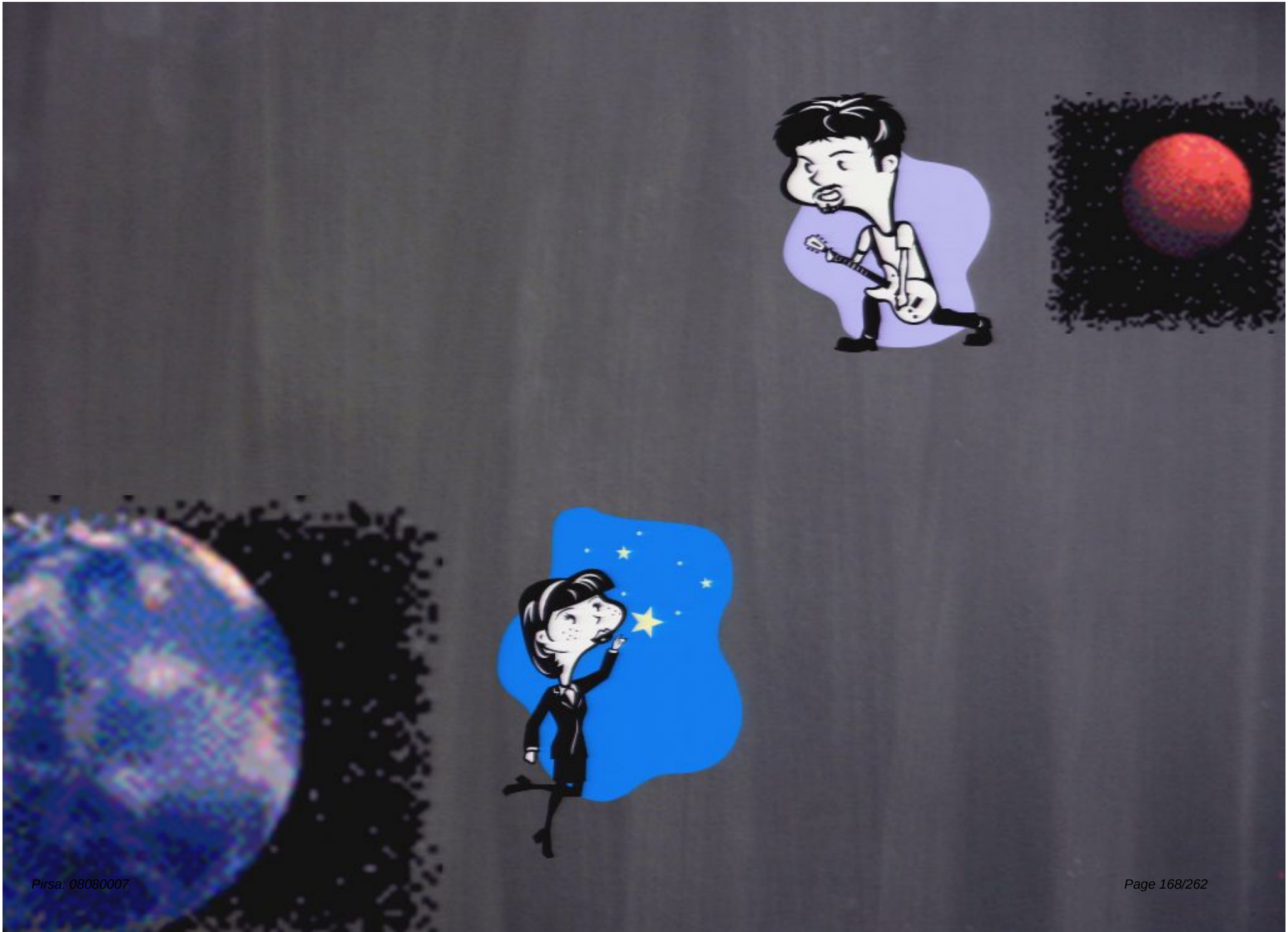

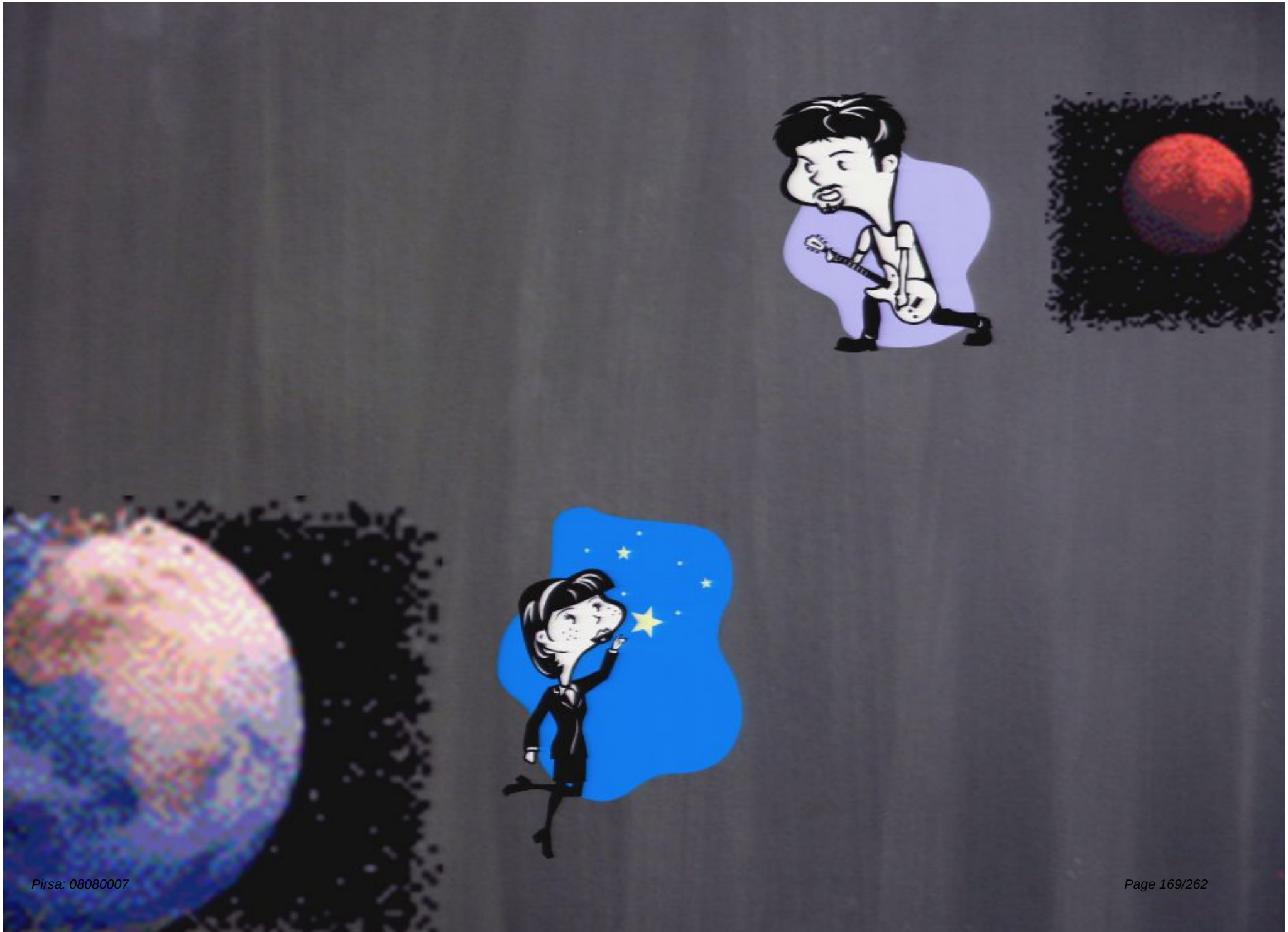

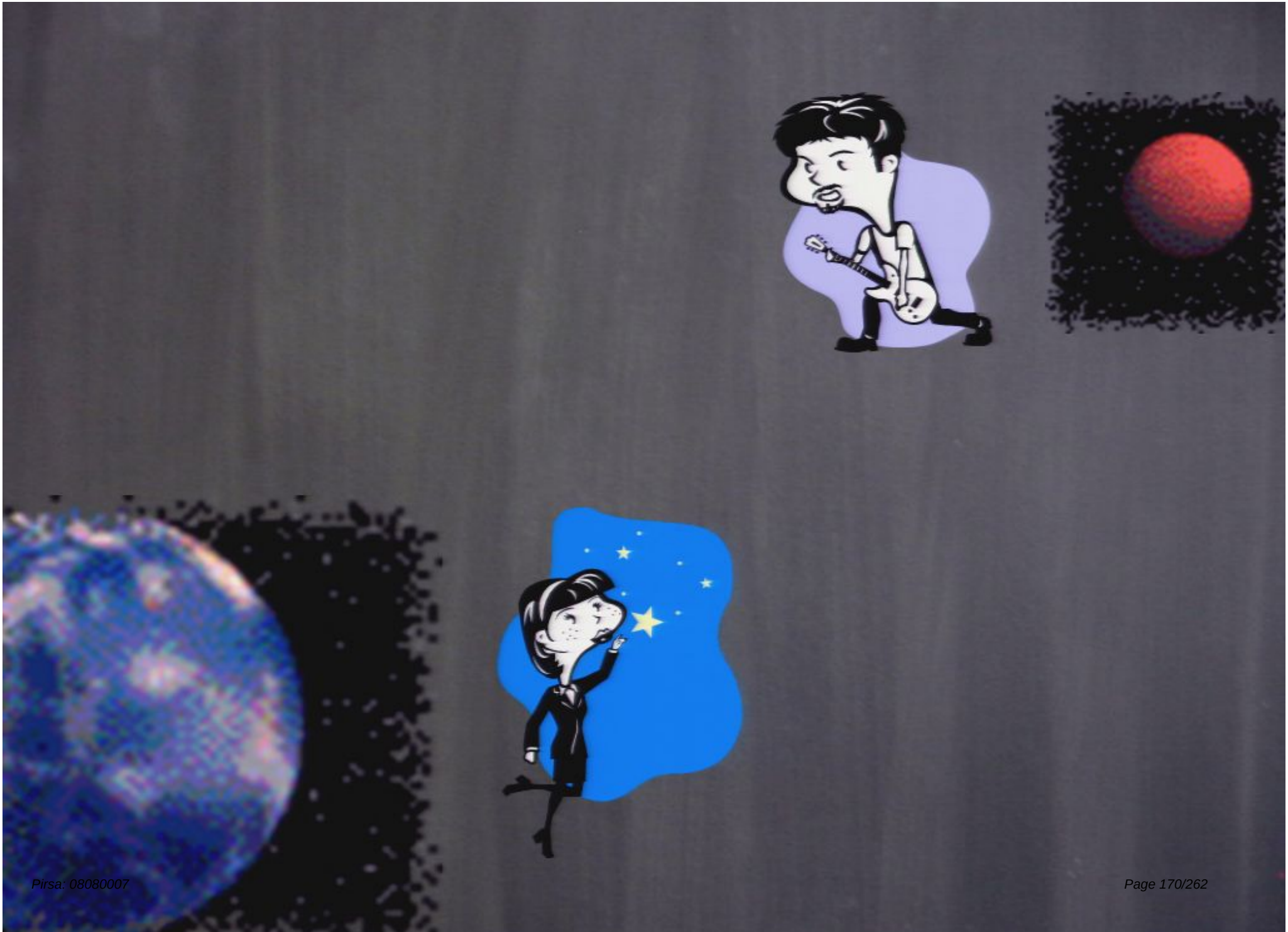

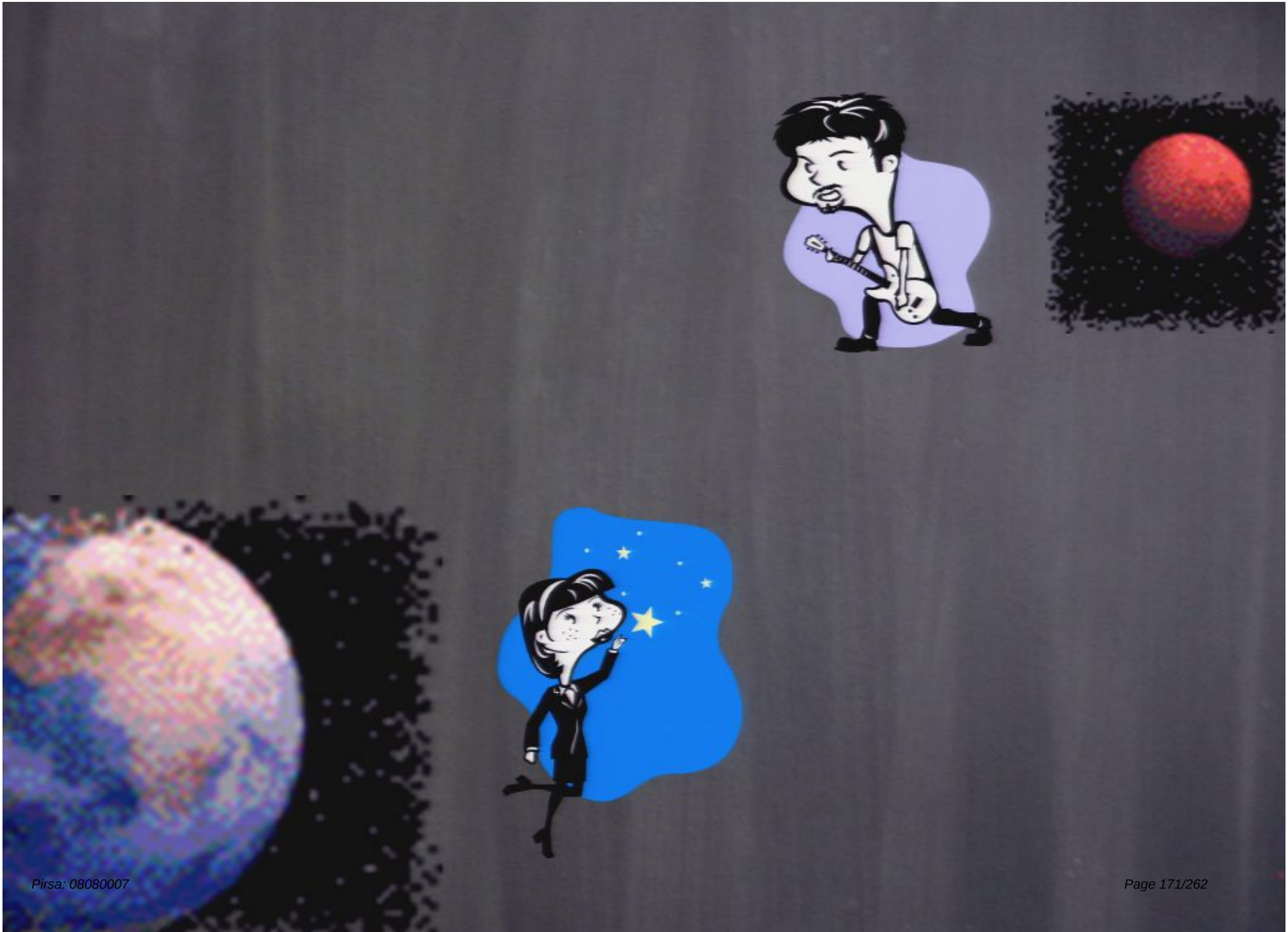

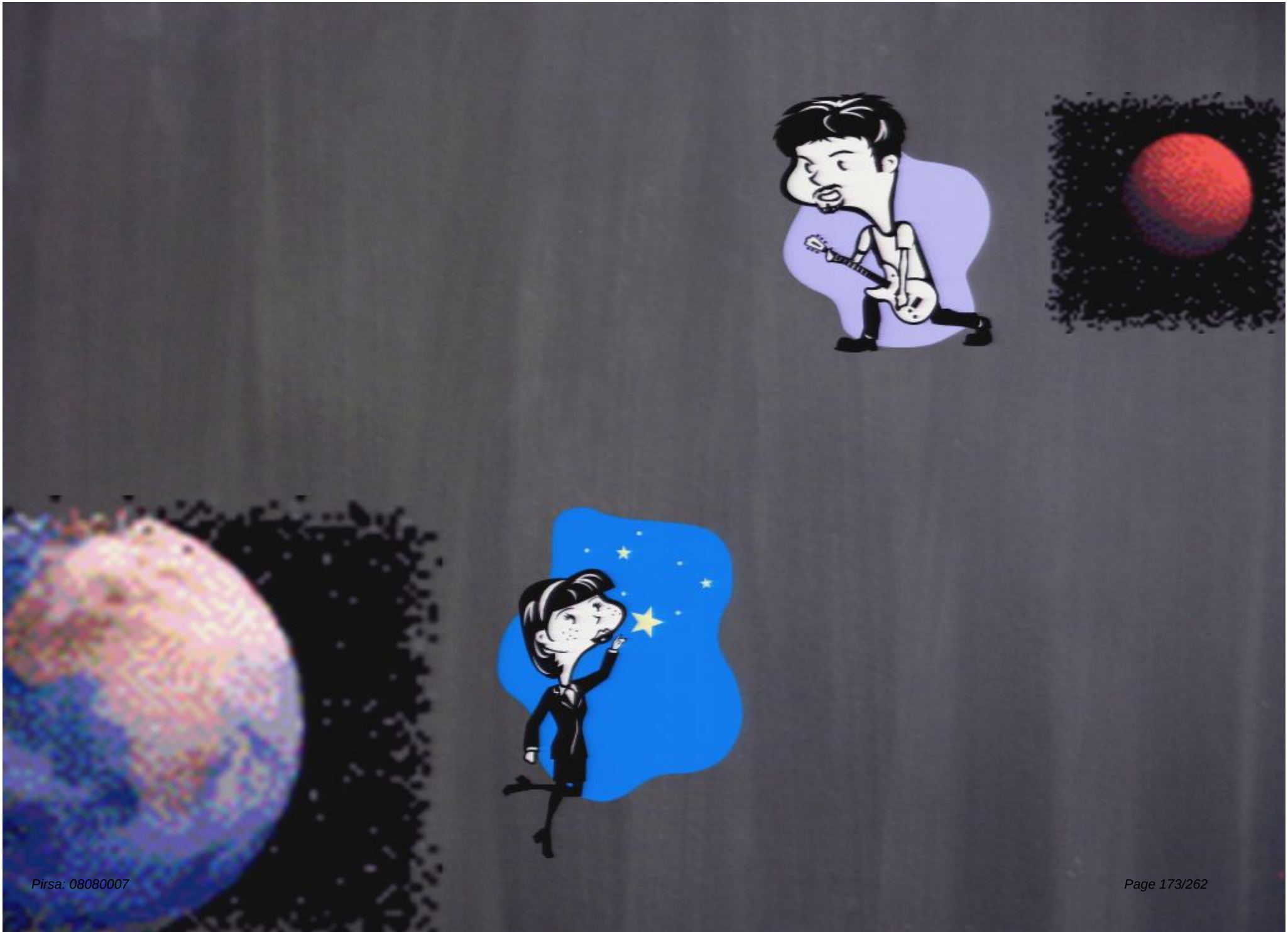

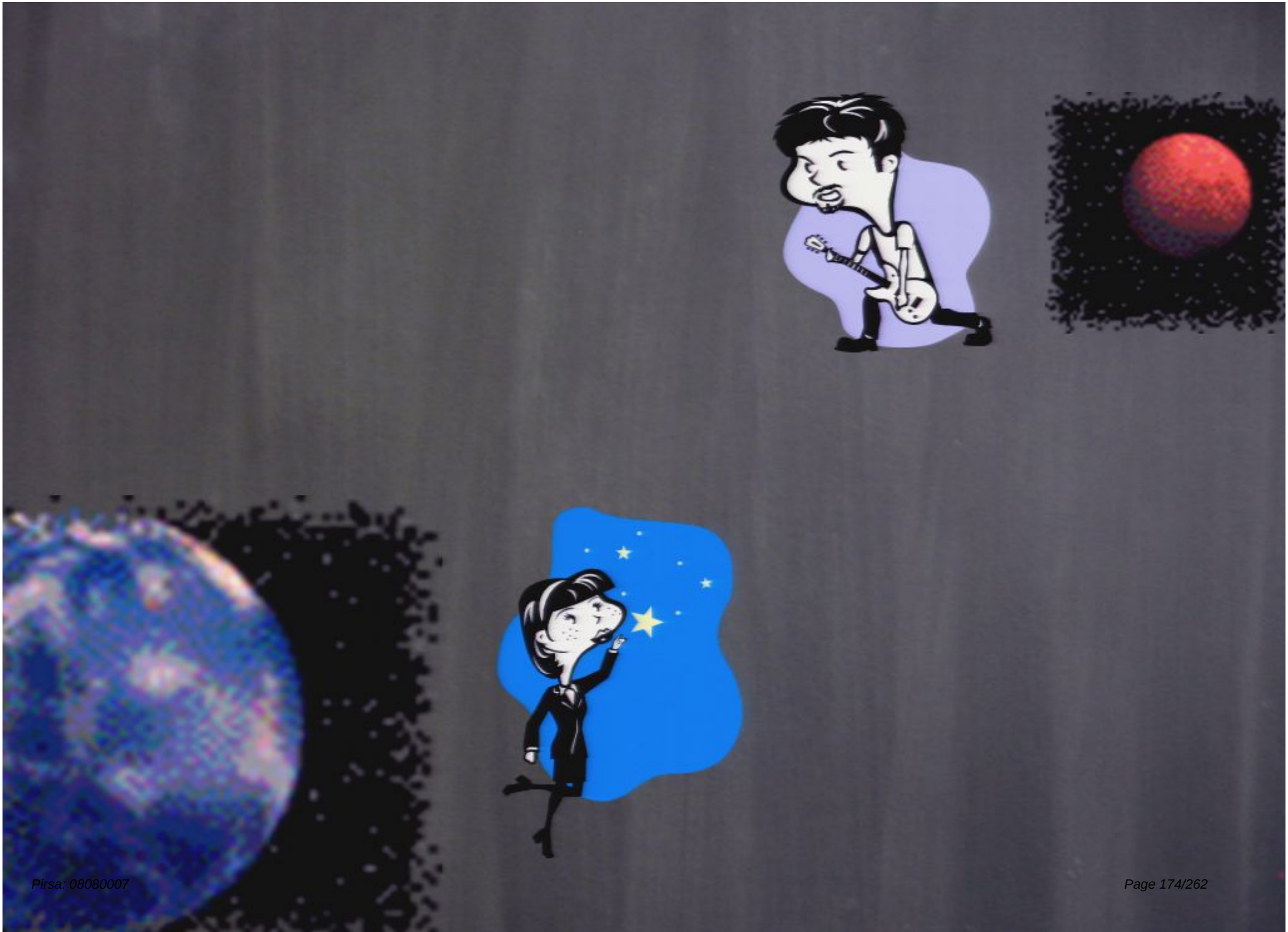

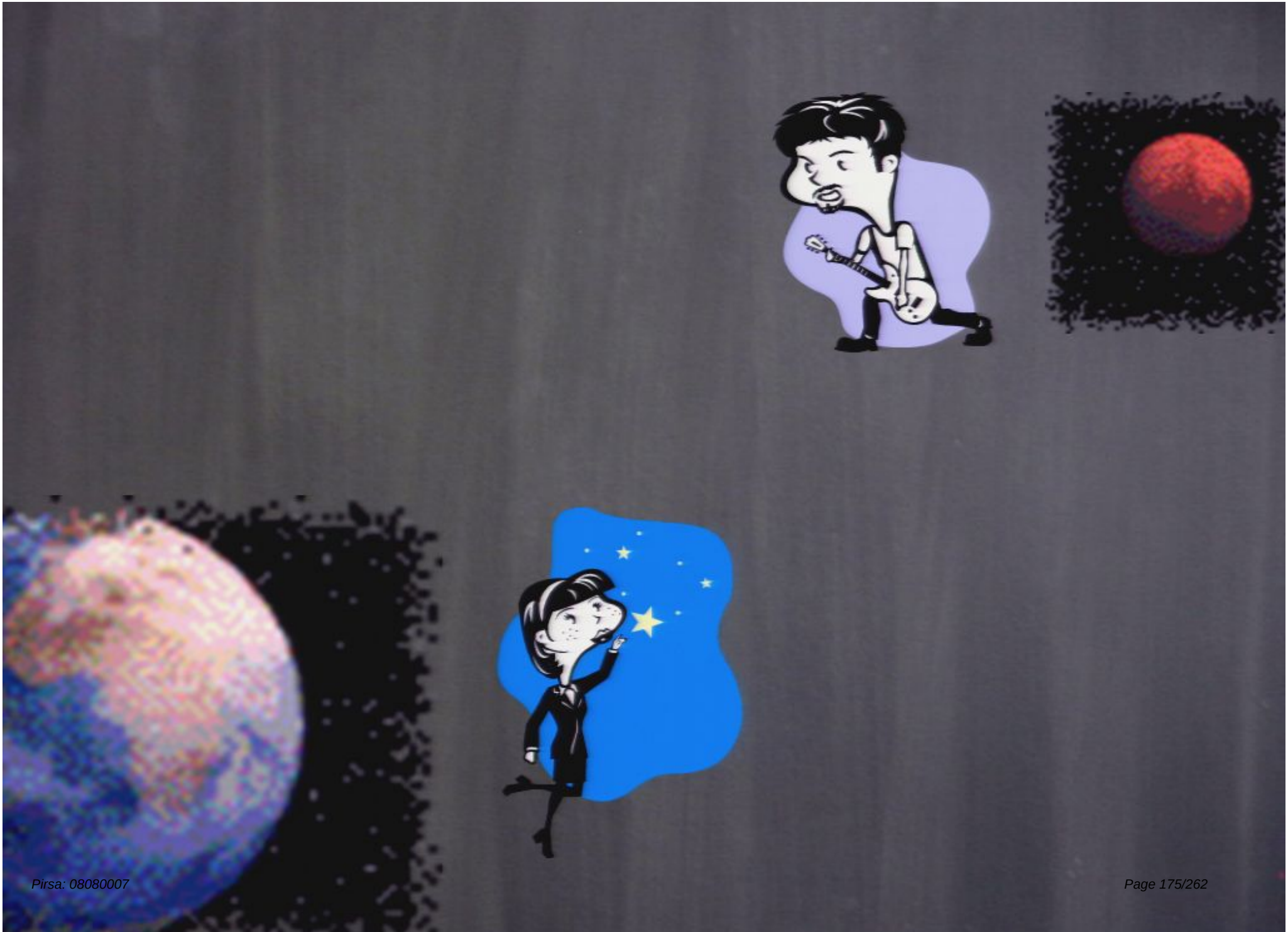

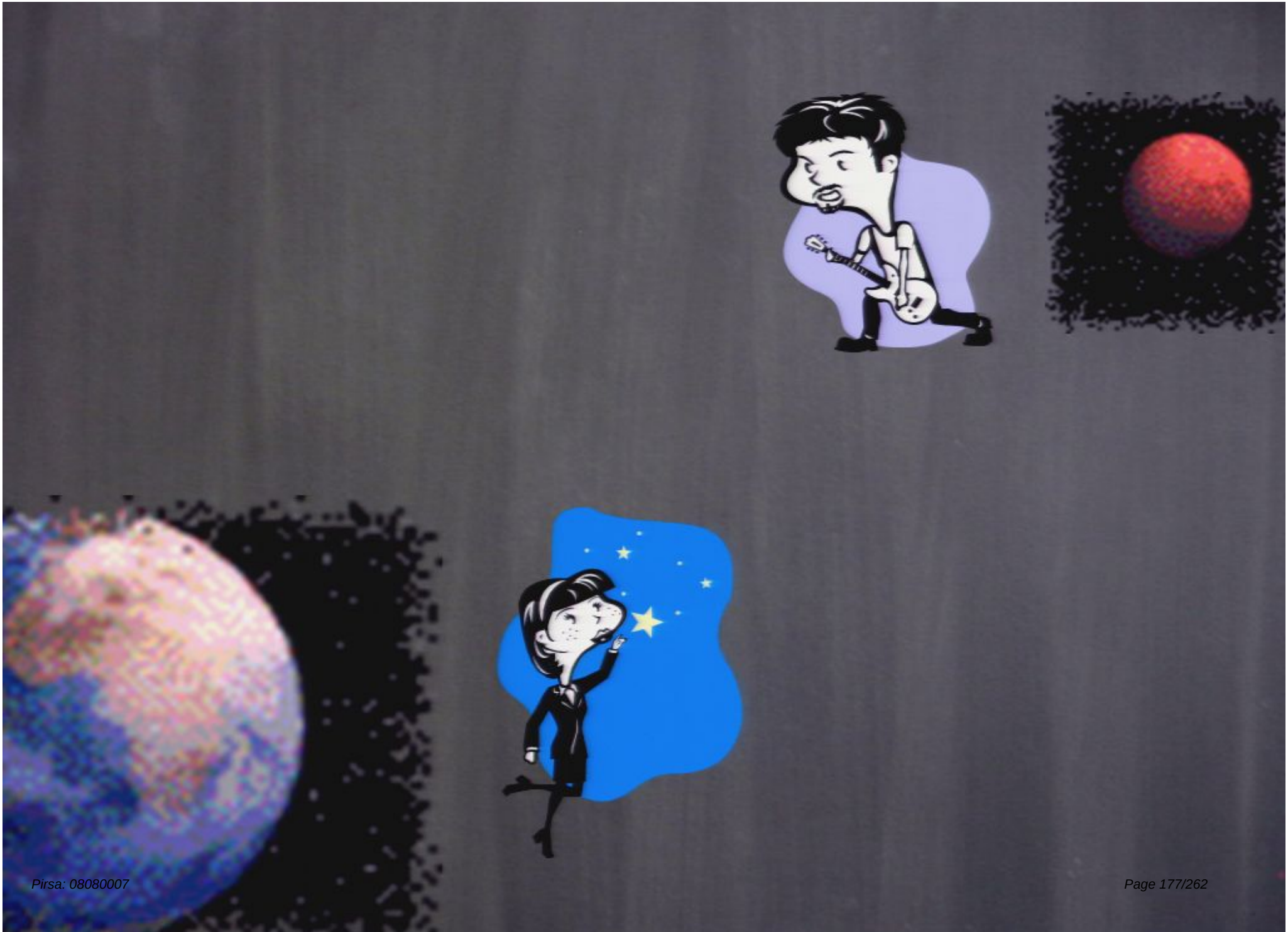

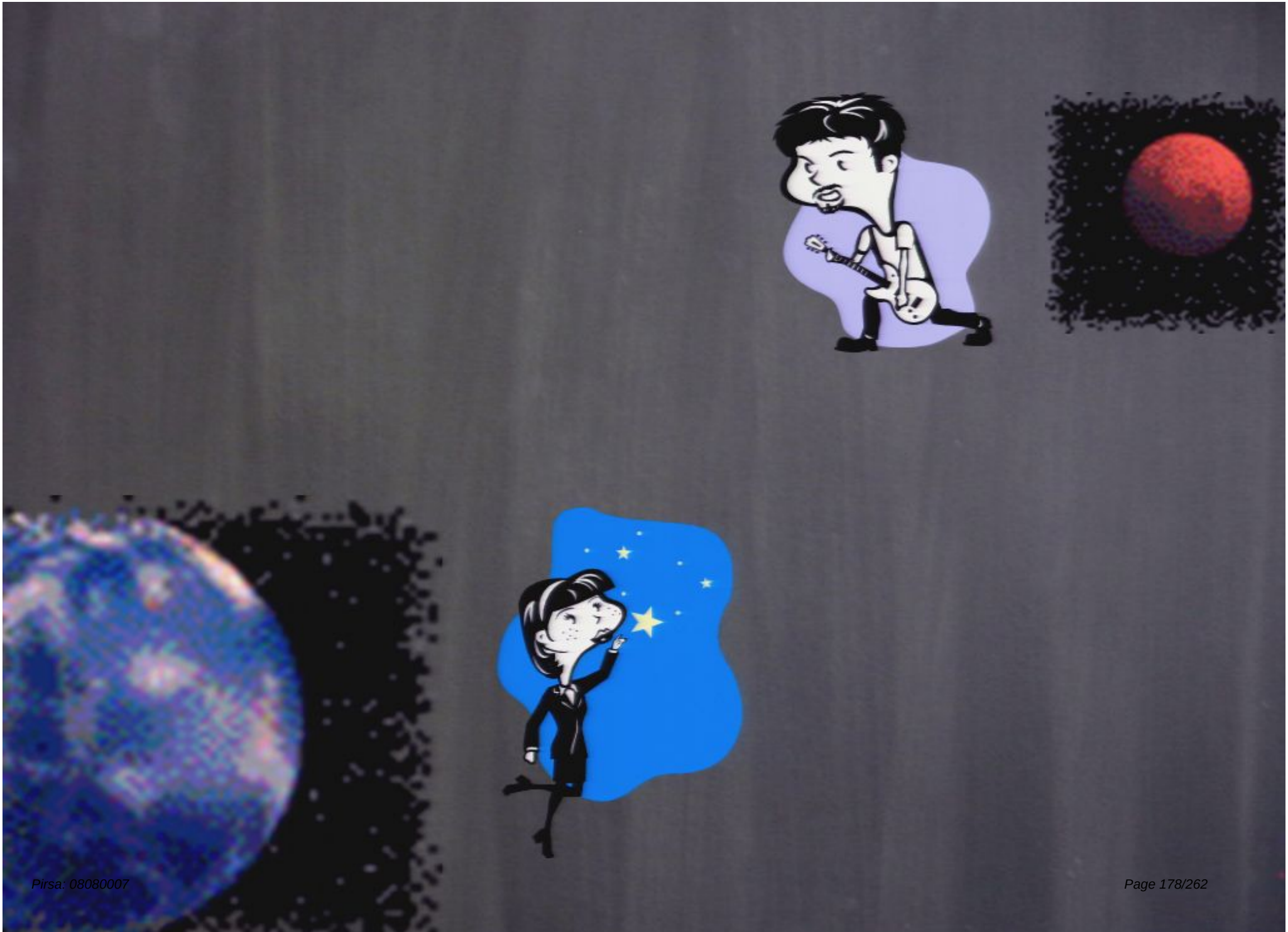

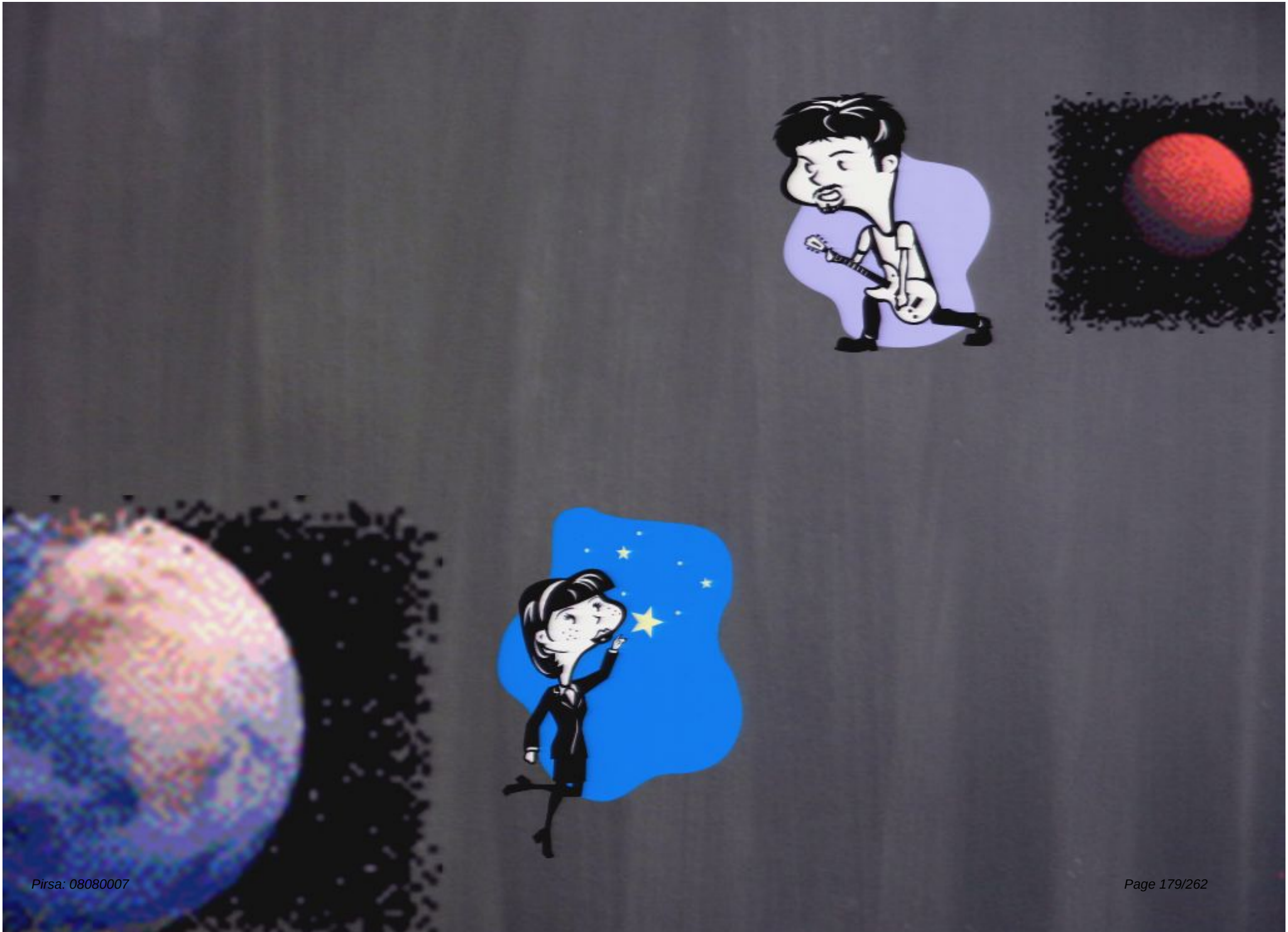

What do we mean by "teleportation"?

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What do we mean by "teleportation"?

Disappear Here

What do we mean by "teleportation"?

What do we mean by "teleportation"?

Reappear There

What do we mean by "teleportation"?

- ✓ Must be a time delay (< speed of light)

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Disassemble into individual atoms...

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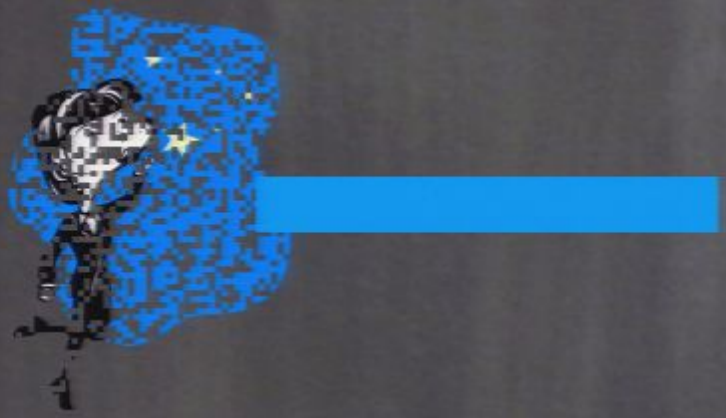

Disassemble into individual atoms...

...beam the physical atoms

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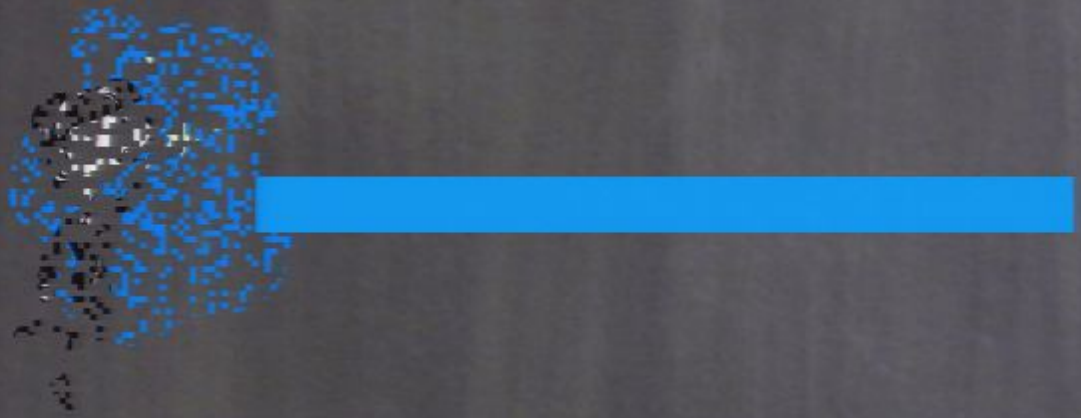

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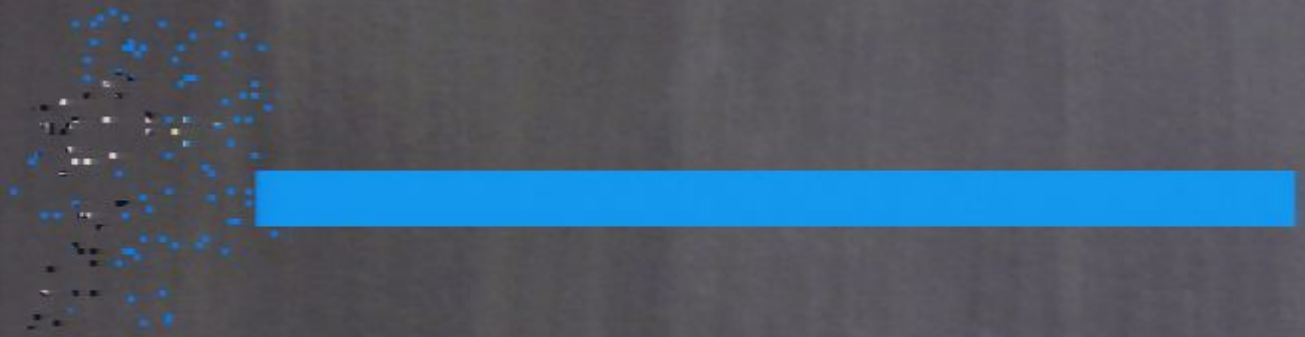

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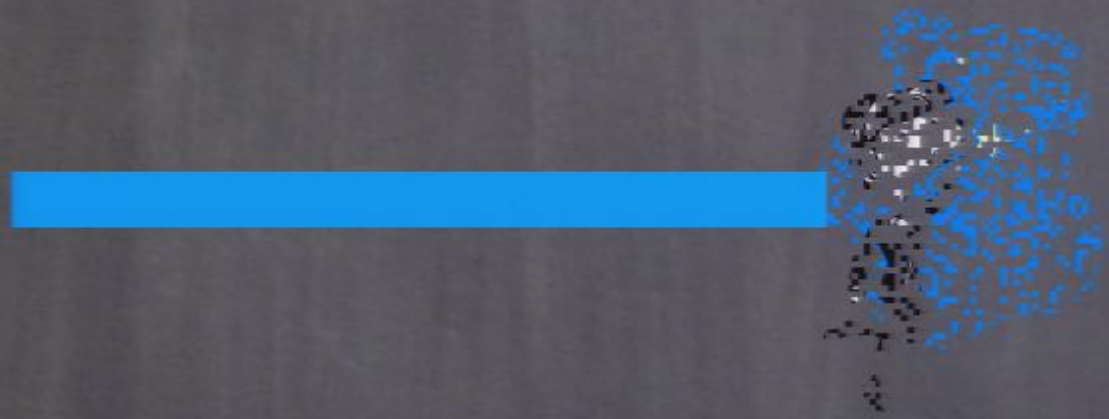

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Reassemble like giant jigsaw puzzle?

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Unnecessarily complicated!

Quantum Fact: All atoms of same type are *truly identical*

Need only send the information, not the atoms

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- ✓ Send only information; reassemble using atoms on Mars

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Problem: Won't we end up with two copies of Alice?

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Reassembling Machine

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Measure information

beam information

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...beam information

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Measure information

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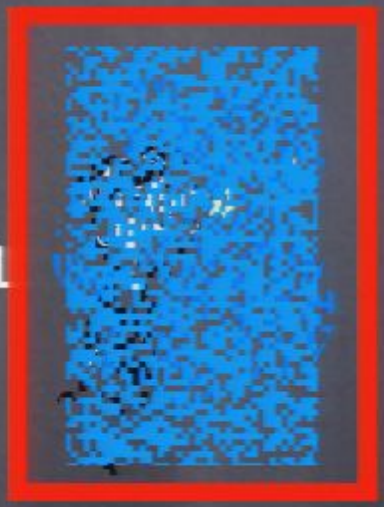
...beam information



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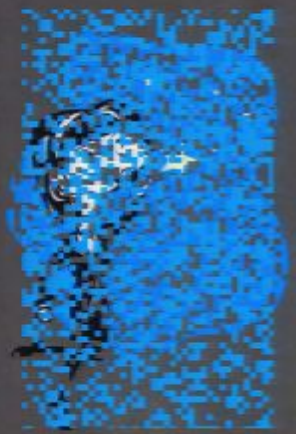

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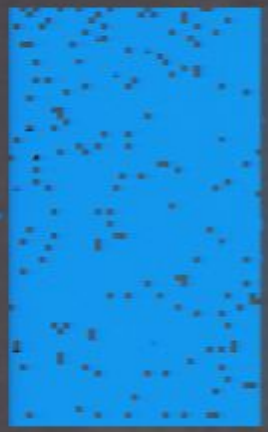

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There can be only one Alice →

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Question: How do we measure the "quantum information" in Alice's atoms?

Answer: We *can't!*

Quantum Facts: *Heisenberg Uncertainty limits the amount of information that can be extracted*

Worse: Certain quantum information cannot be measured at all!

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can't even *measure* the information we wish to send,
't this mean quantum teleportation is *impossible*?

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If we can't even *measure* the information we wish to send, doesn't this mean quantum teleportation is *impossible*?

NO: In 1993 Charles Bennett *et al* discovered that quantum *entanglement* could be used to *send* the information without actually *measuring* it!

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- ✓ Quantum teleportation is possible using entanglement

Quantum Teleportation

Here's how it works:

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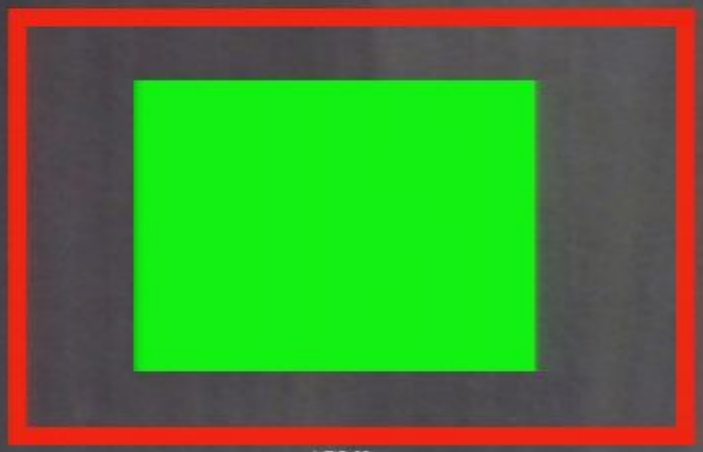

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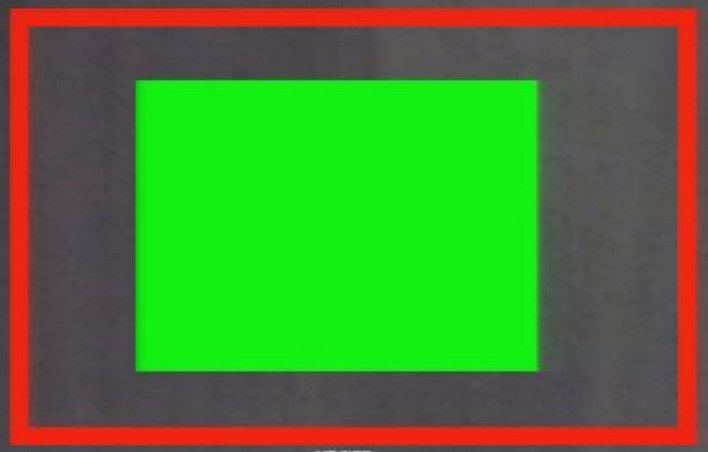

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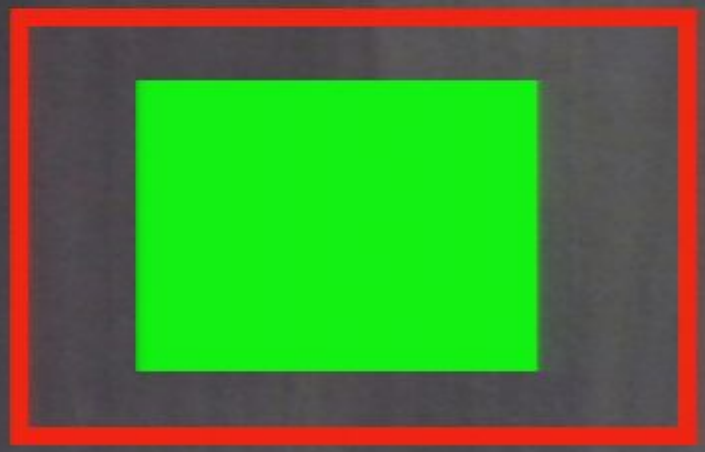

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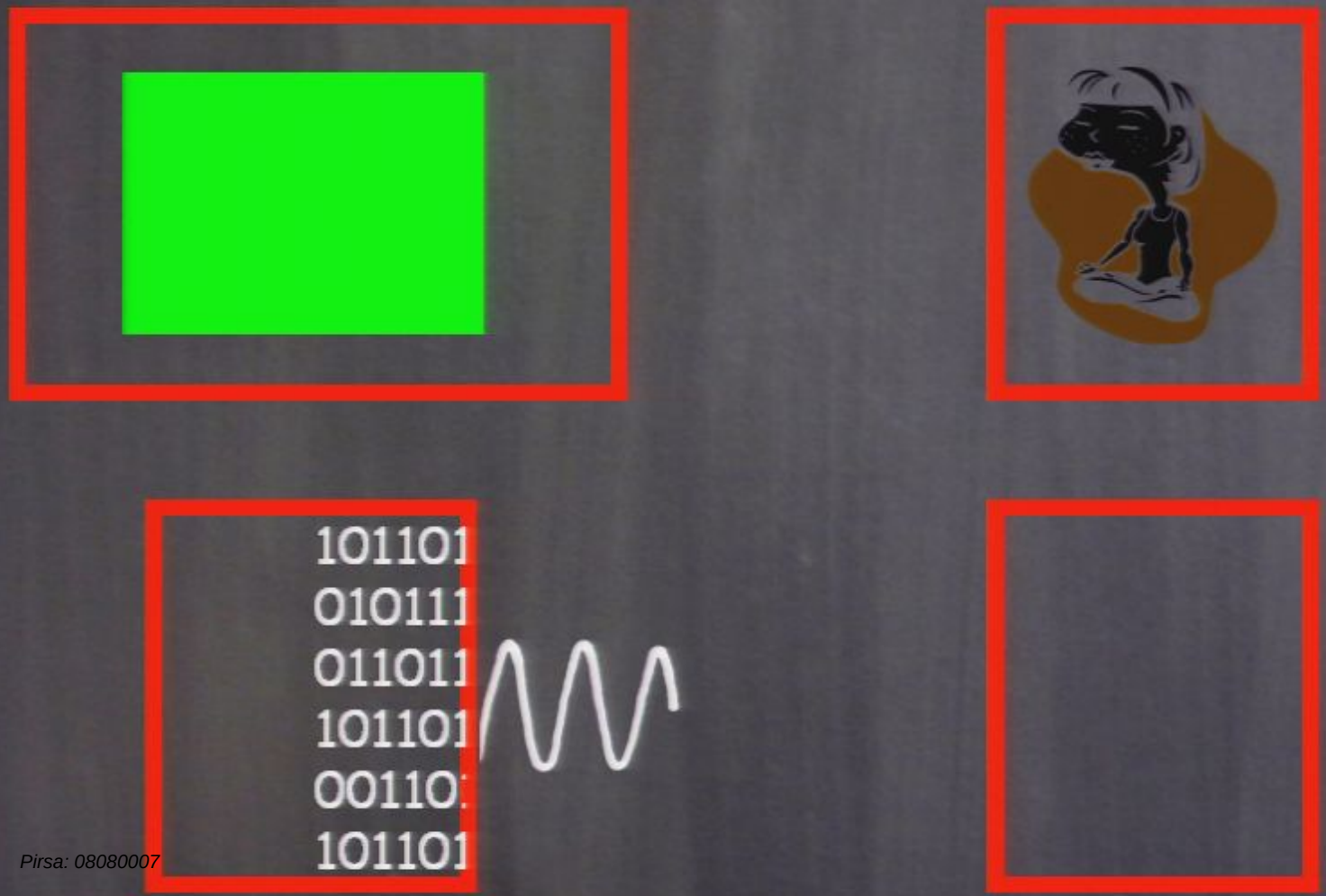

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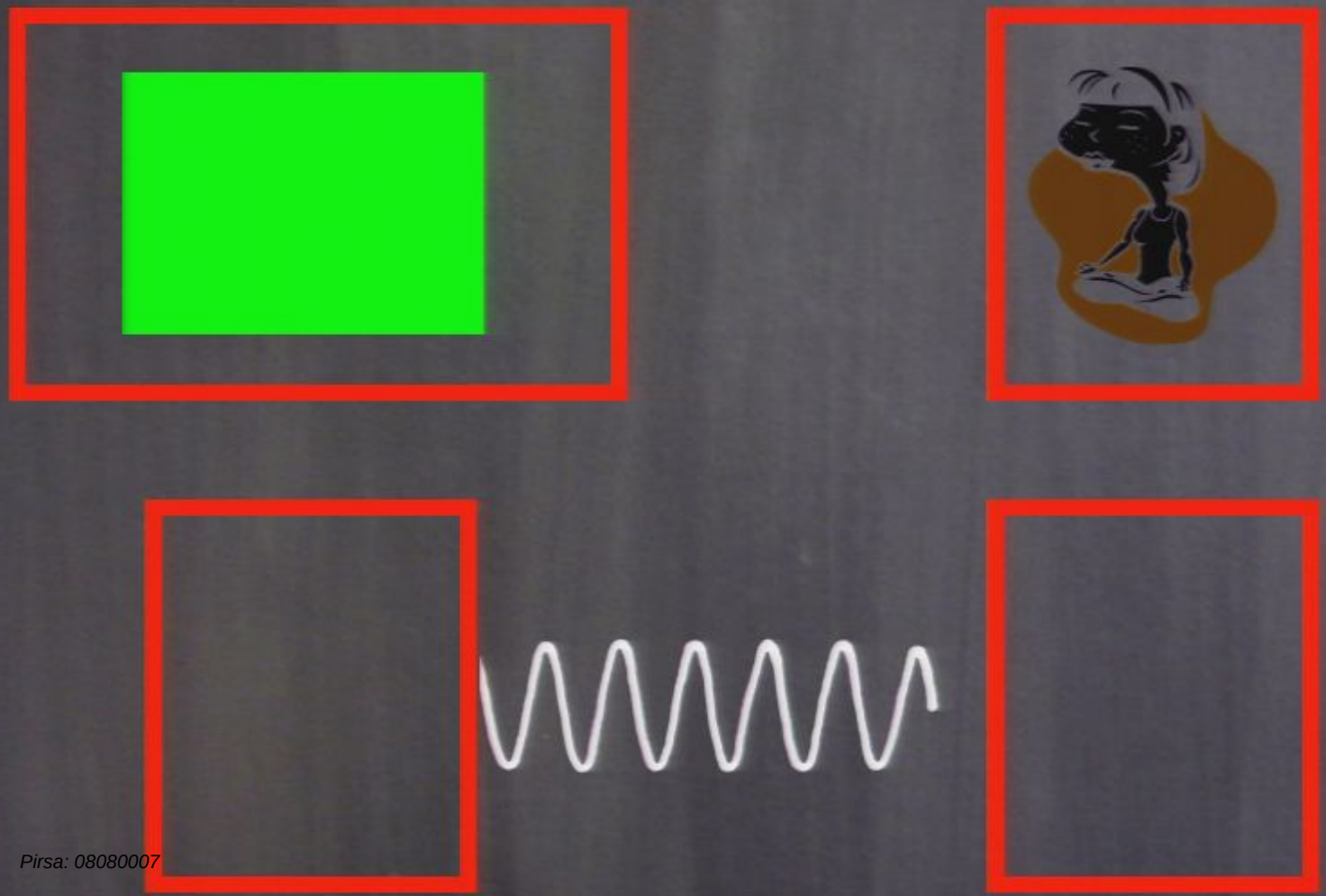

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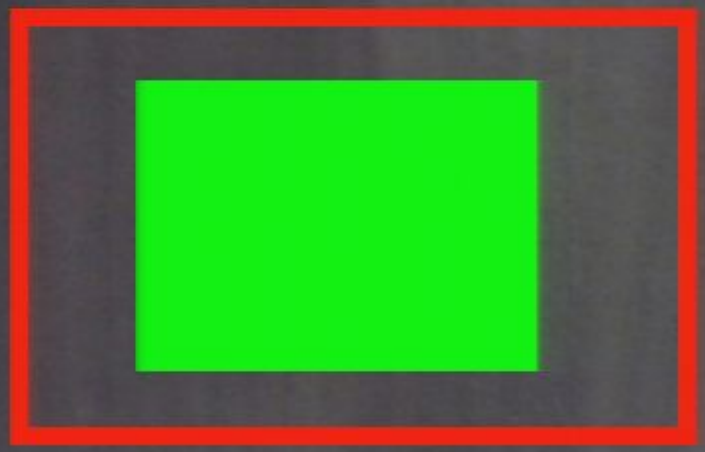

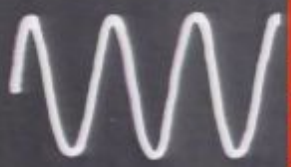

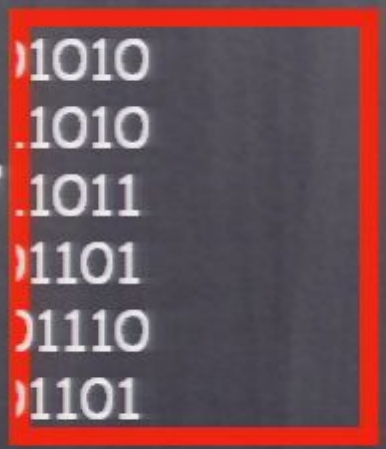

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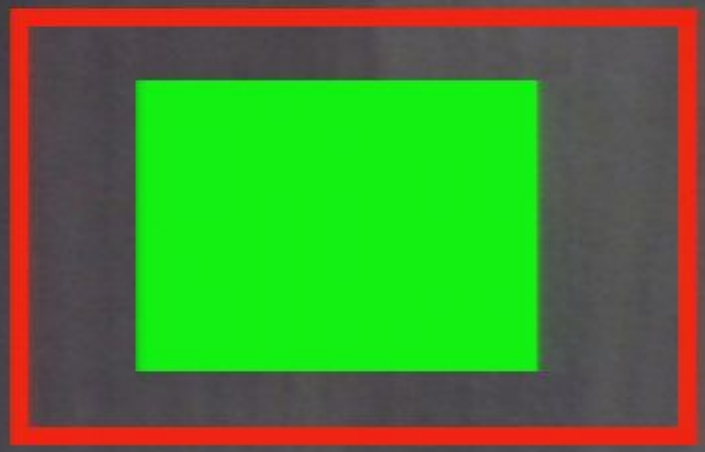

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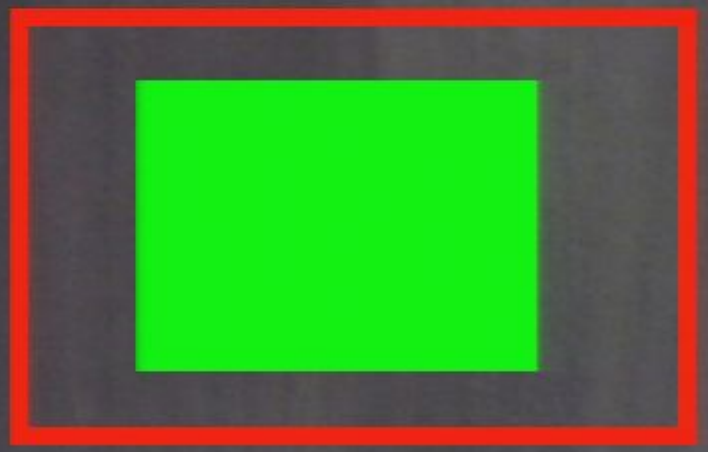

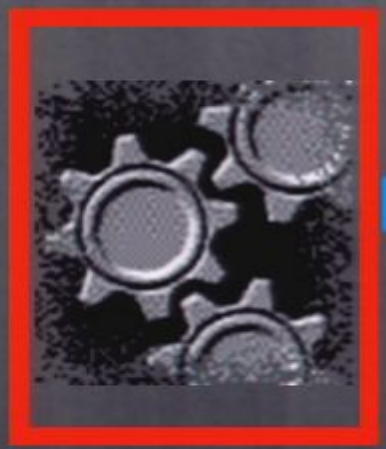

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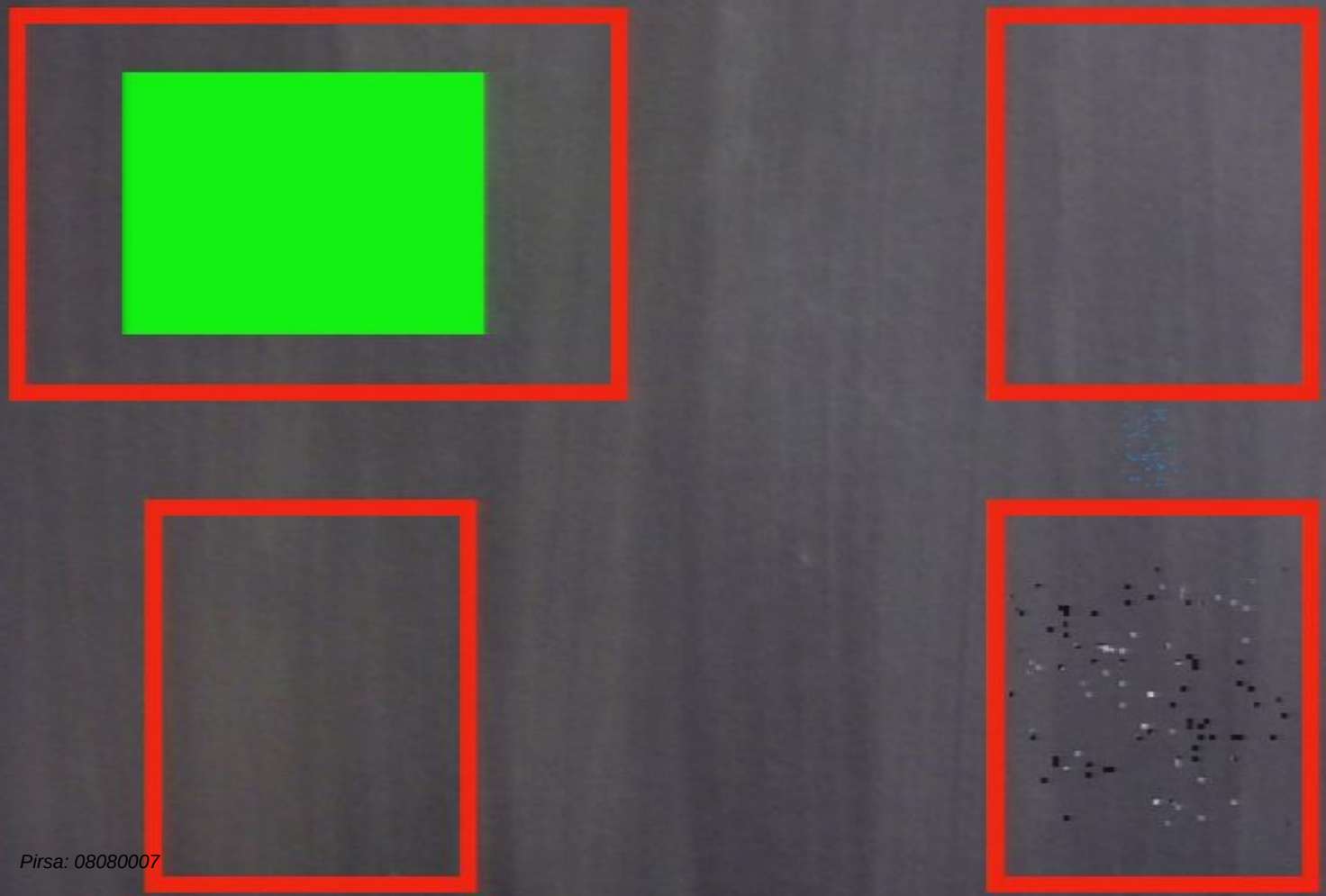

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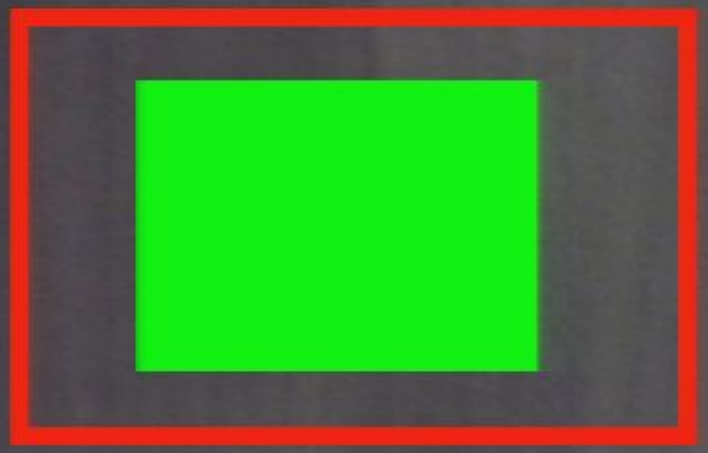

A *quantum identical* version of Alice on Mars!

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Our Weird Quantum World…

…is crazier and more beautiful than we imagined, and the subtleties just keep getting deeper…

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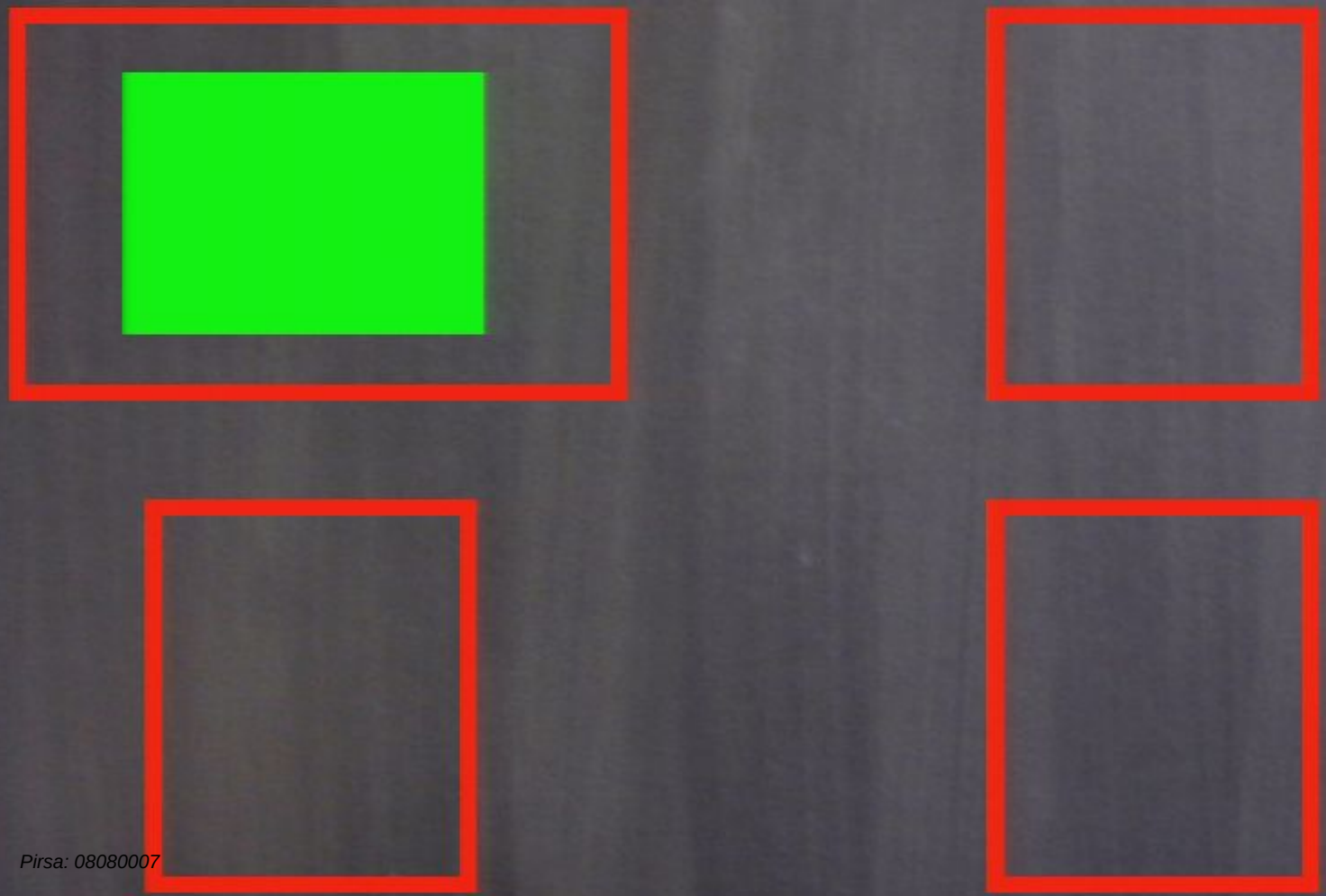

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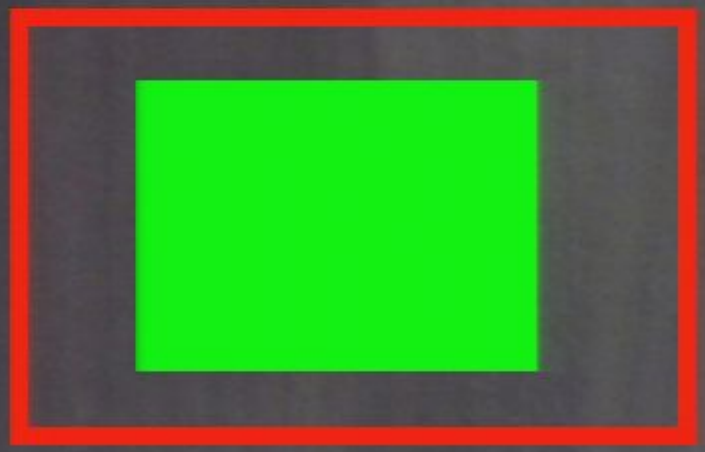

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