

Barcoding the Stars

How We Know What's in Space

The Milky Way (we are in it)

Large Magellanic Cloud
(nearby galaxy)



~100,000 light years (almost billion billion miles)

Andromeda galaxy: a nearby galaxy
like the Milky Way

1 of ~100 billion stars in this galaxy.



~100,000 light years (almost billion billion miles)

Big Questions

- What is a star?
- How can we learn what they're made of?
- Why do we care?

Big Questions

- What is a star?
- How can we learn what they're made of?
- Why do we care?

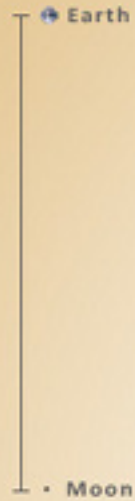
You will learn the answers!



What is a star?

Just look up at night

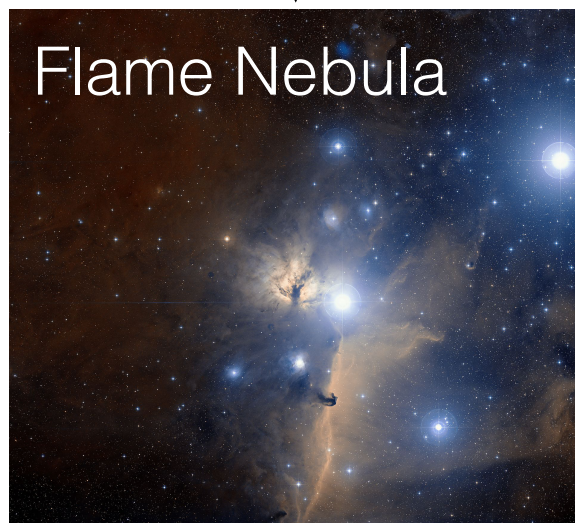
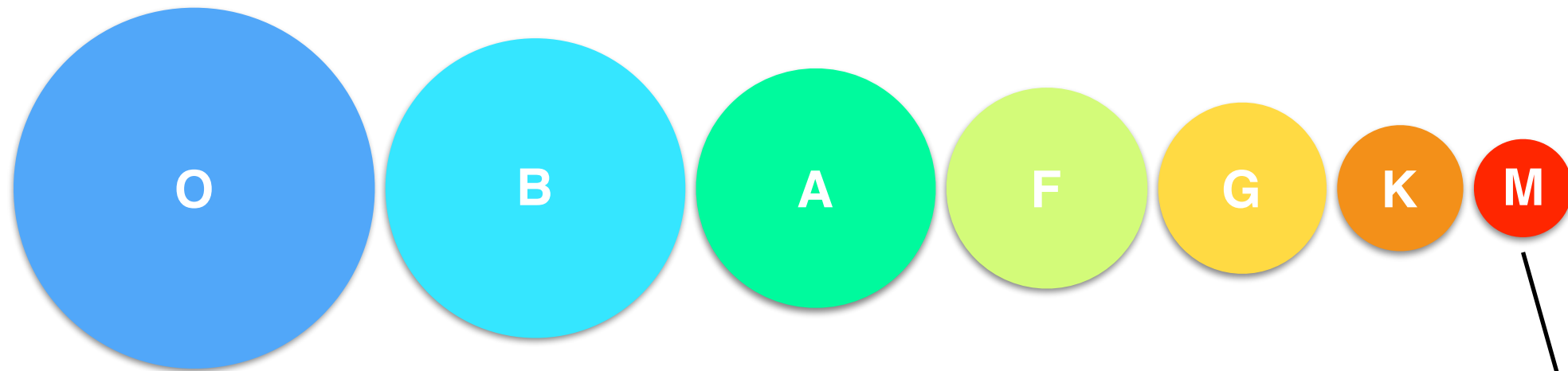
Or at the Sun (not directly)



What is a star?

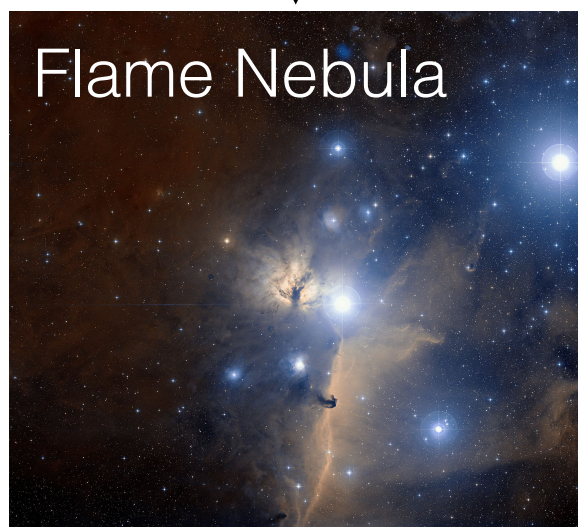
“Luminous sphere of plasma held together by its own gravity”... powered by fusion.

Stars are diverse



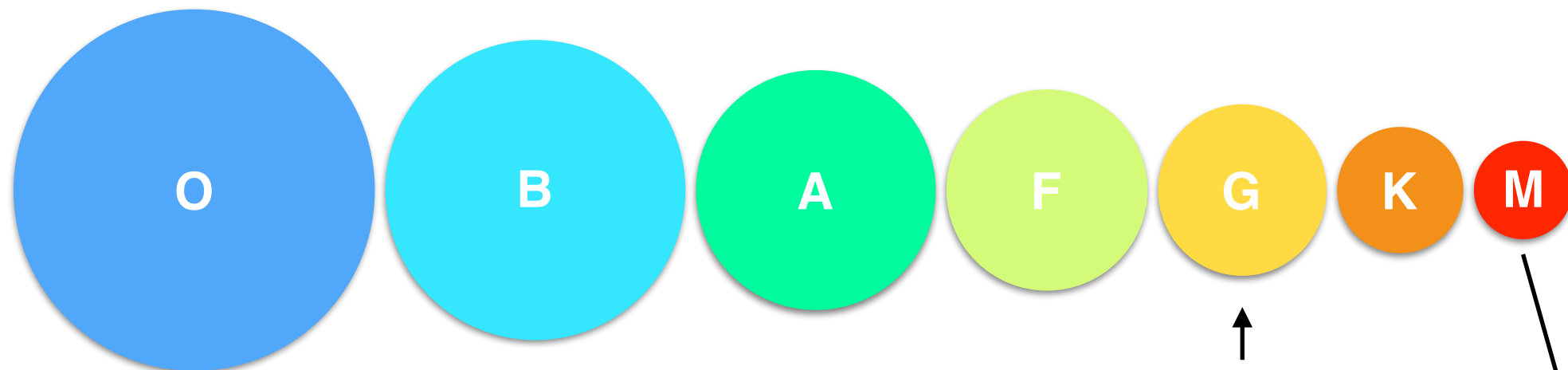
Stars are diverse

- Come in **O**, **B**, **A**, **F**, **G**, **K**, **M** flavors:

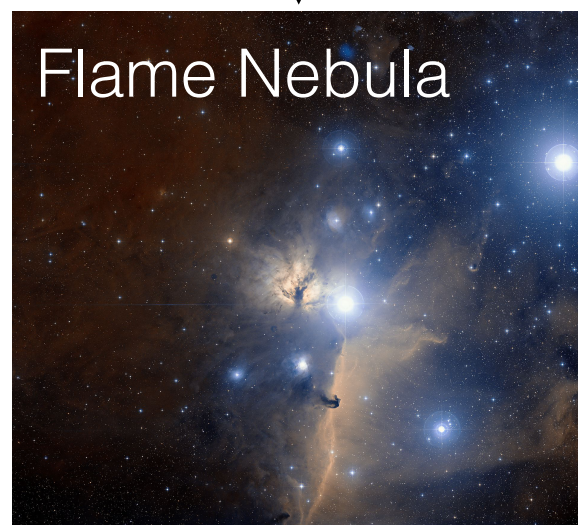


Stars are diverse

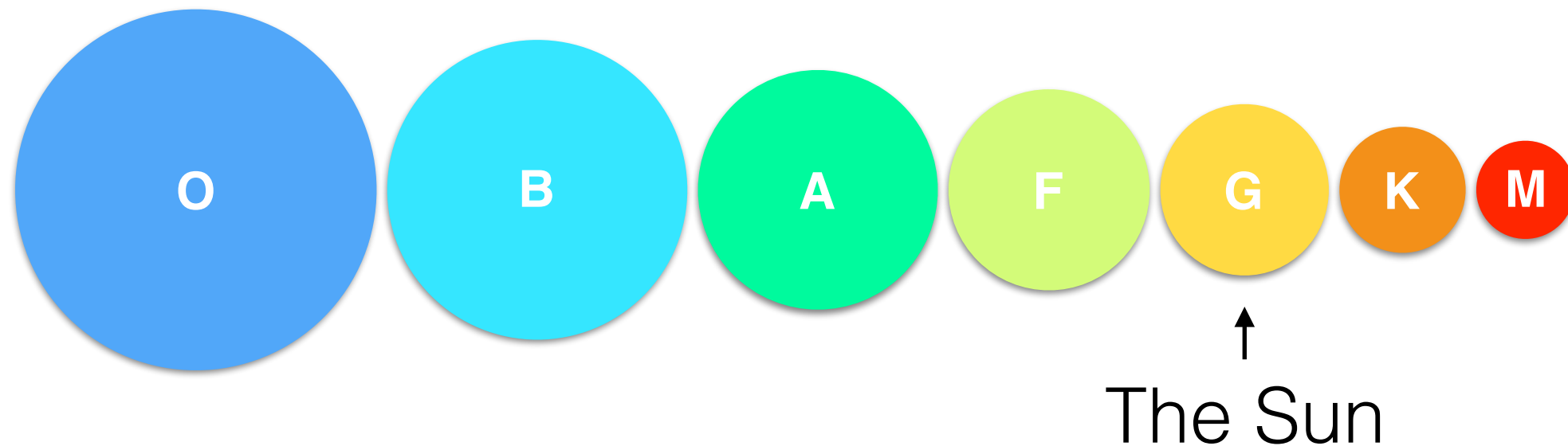
- Come in **O**, **B**, **A**, **F**, **G**, **K**, **M** flavors:



↑
The Sun



They are big and bright



~1 **million miles** across
100 **trillion-trillion watts!**

They are big and bright



↑
The Sun

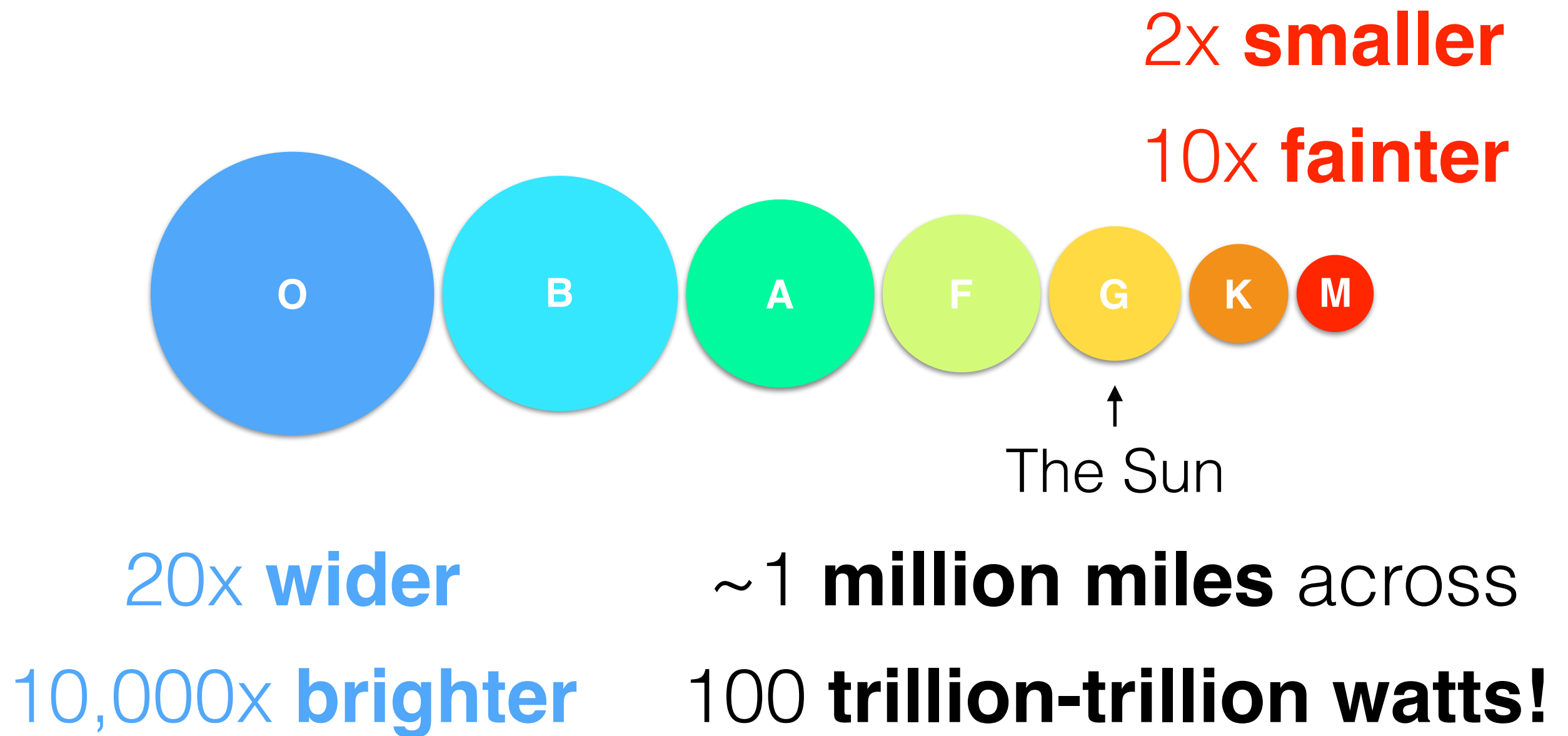
20x **wider**

10,000x **brighter**

~1 **million miles** across

100 **trillion-trillion watts!**

They are big and bright



They are hot and...less hot



↑
The Sun
5000 **degrees**



They are hot and...less hot



10x **hotter**

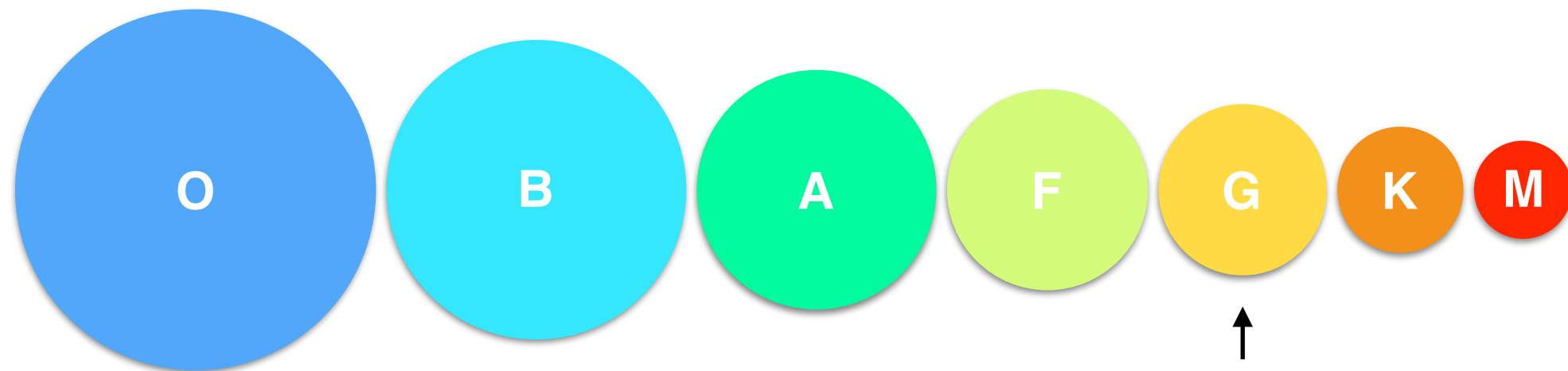
↑
The Sun
5000 **degrees**



They are hot and...less hot



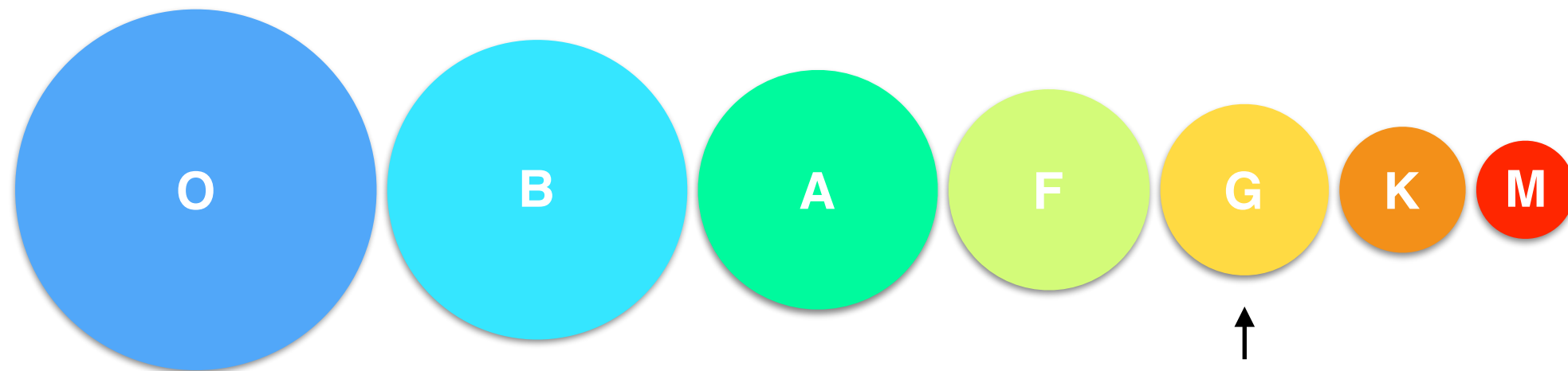
They are old and young



↑
The Sun

lives 10 **billion** years

They are old and young

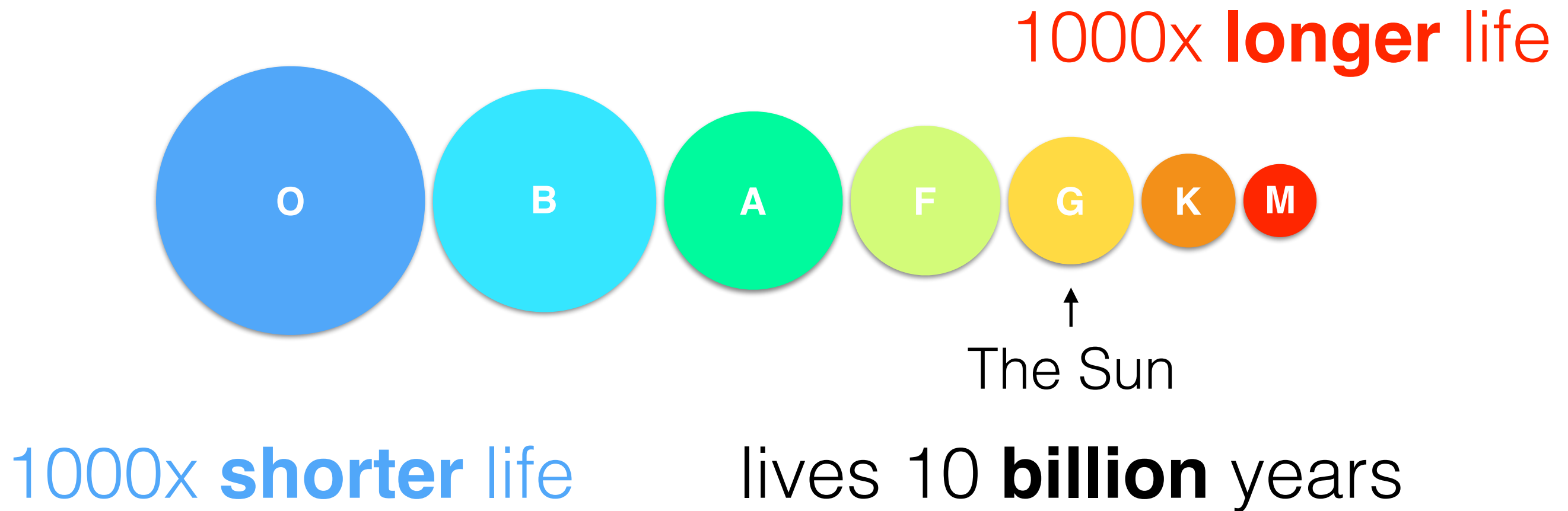


↑
The Sun

1000x **shorter** life

lives 10 **billion** years

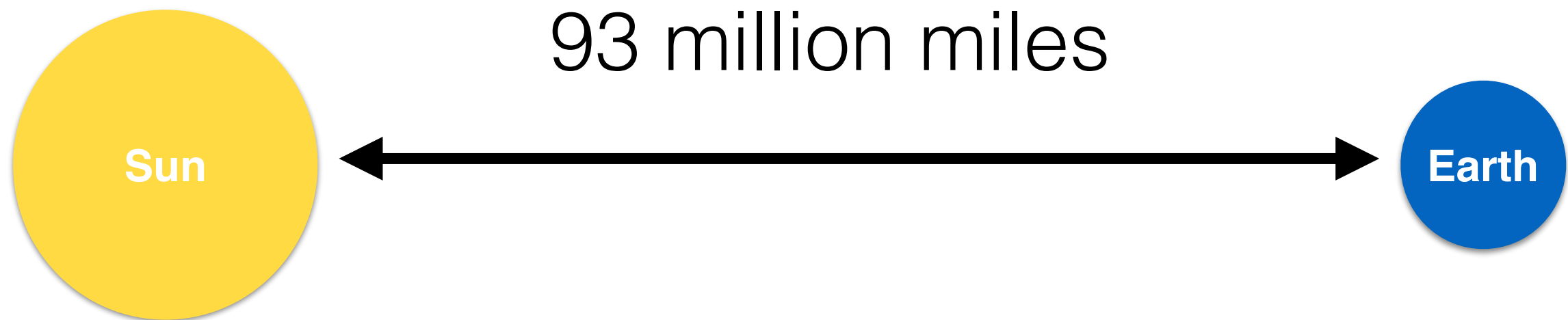
They are old and young



They are *really* far away



They are *really* far away



They are *really* far away



They are *really* far away



They are *really* far away

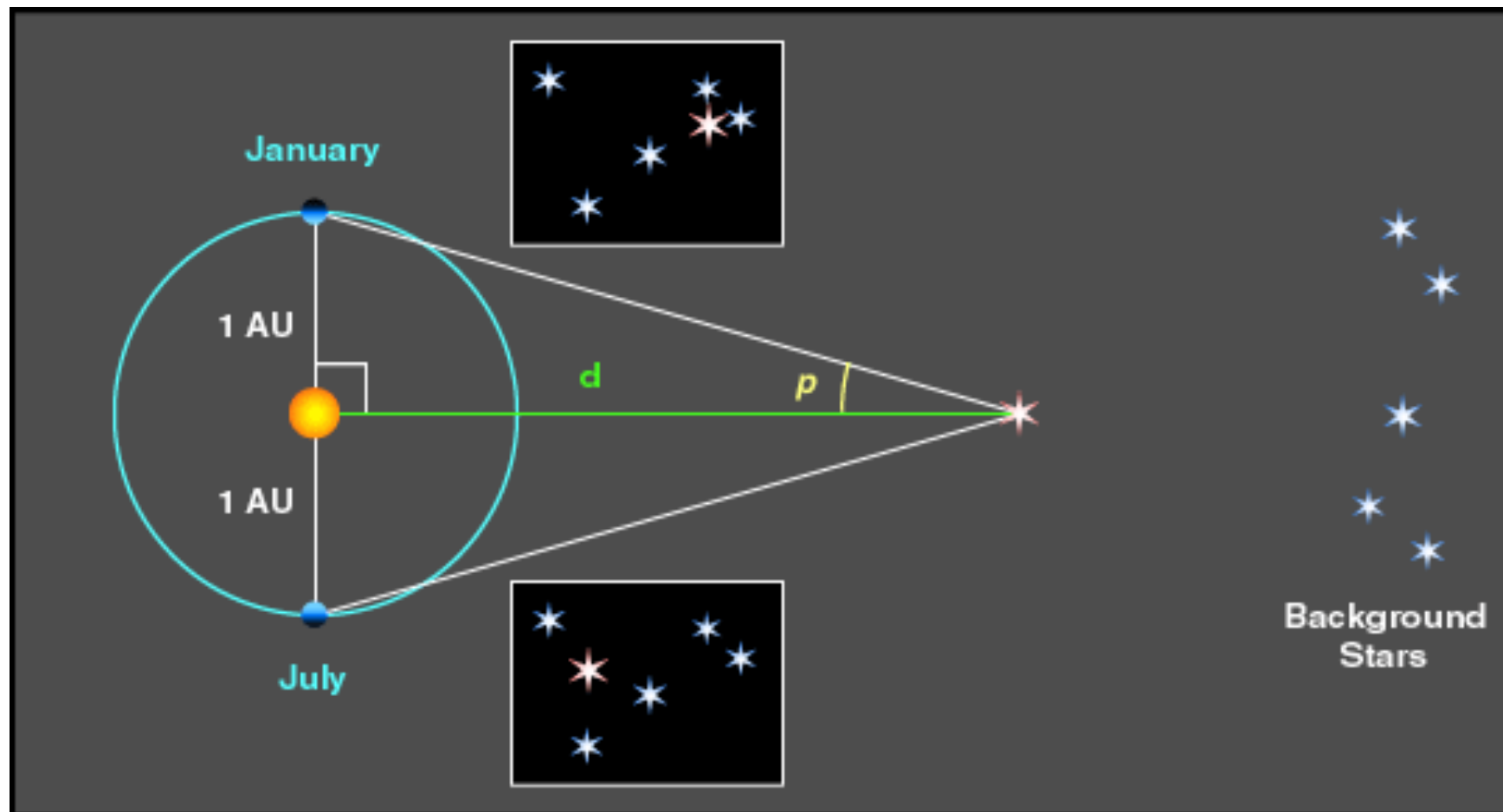


(And that's to the next ***nearest*** star! Alpha and Proxima Centauri)

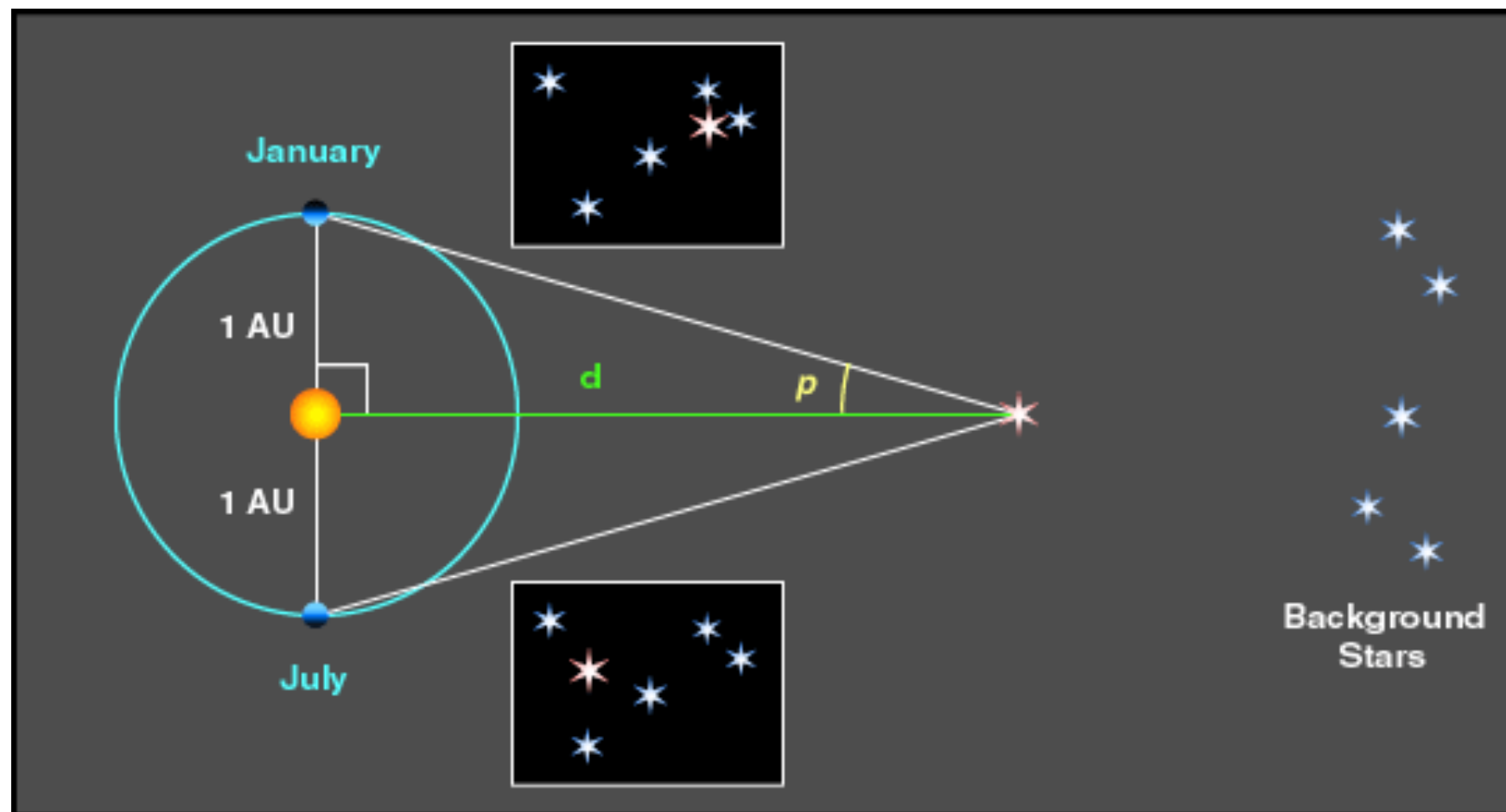
How do we know? Parallax

Sun

Alpha Centauri



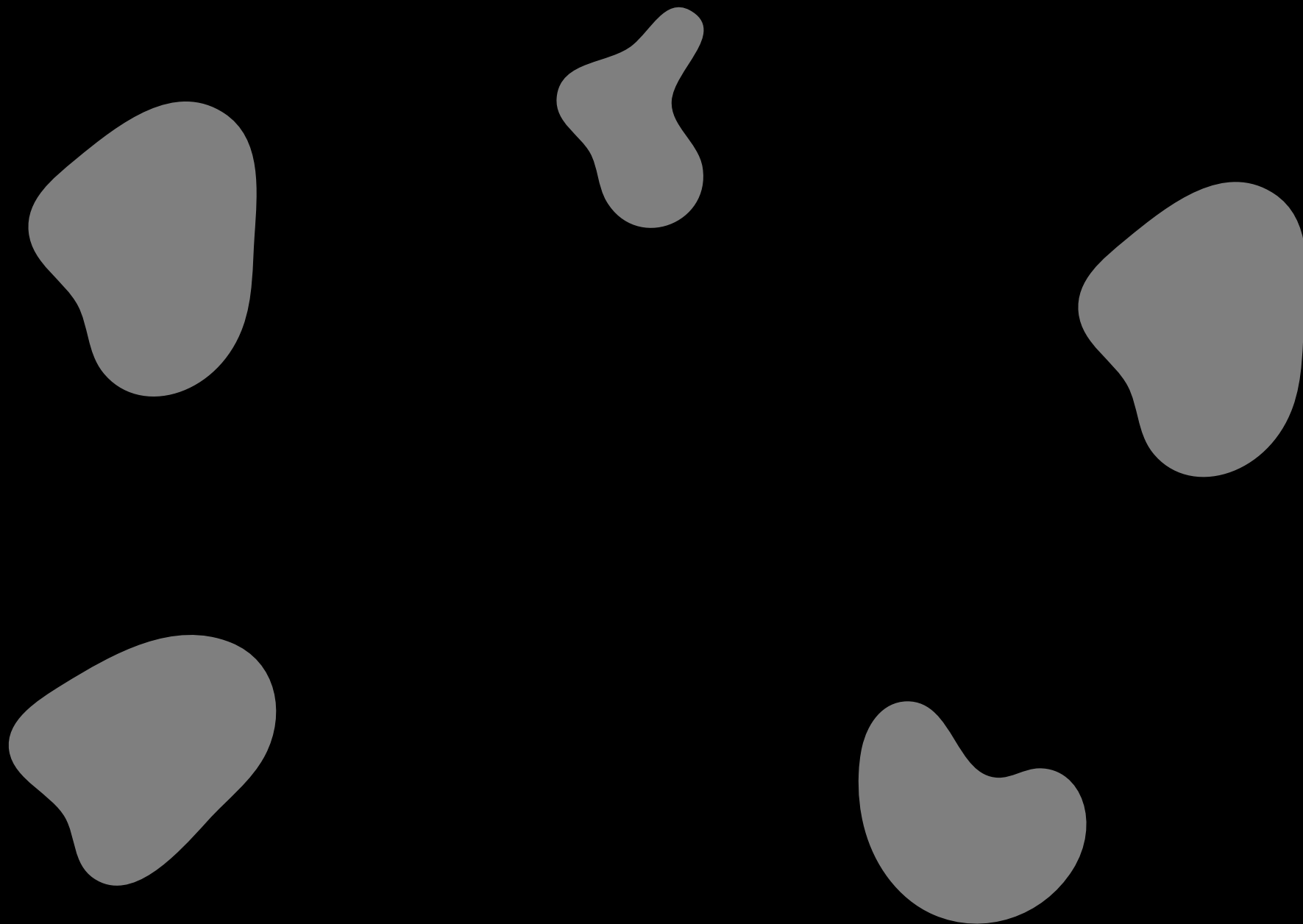
How do we know? Parallax



They have life cycles

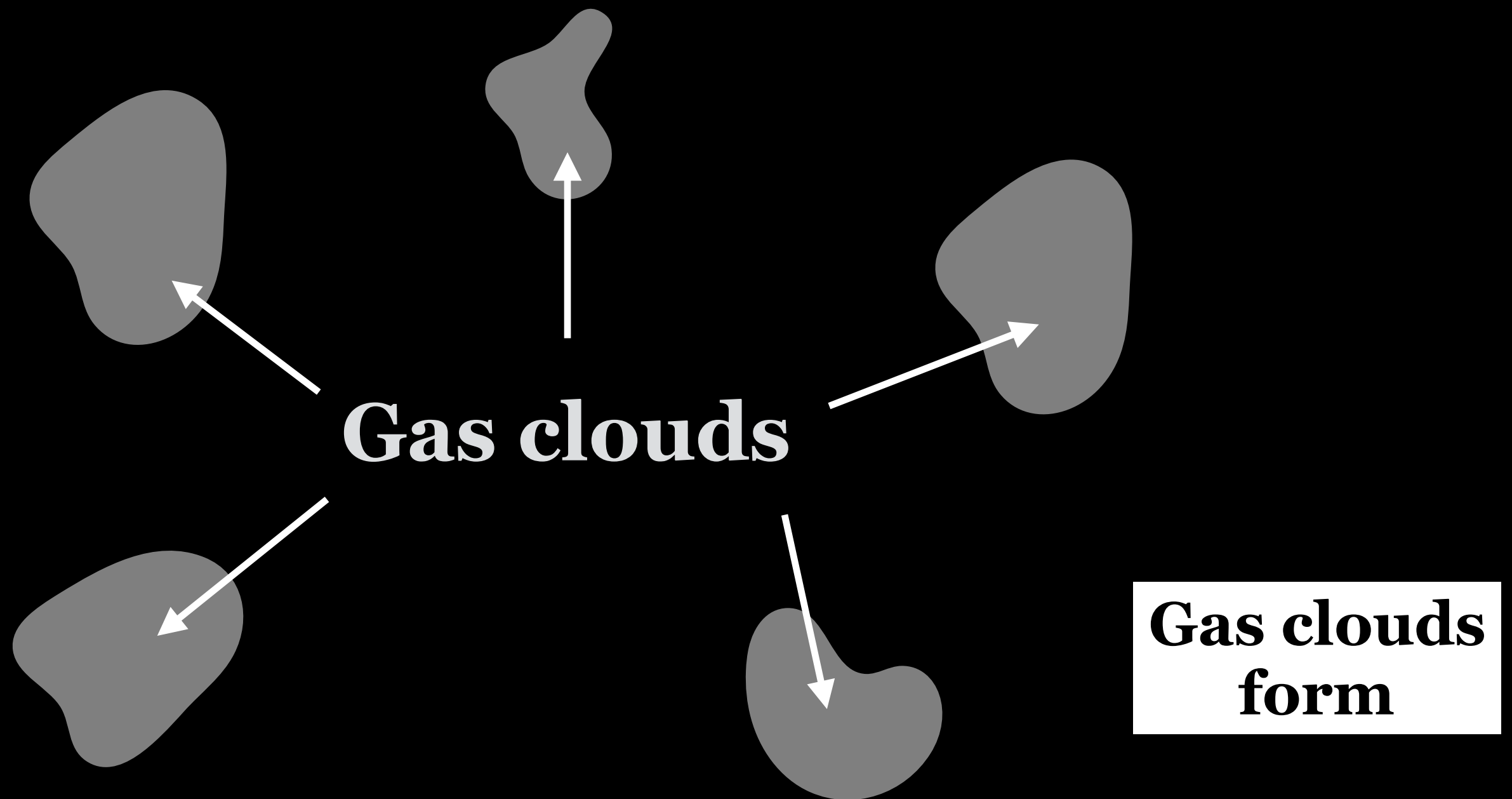
Birth

Birth of stars...

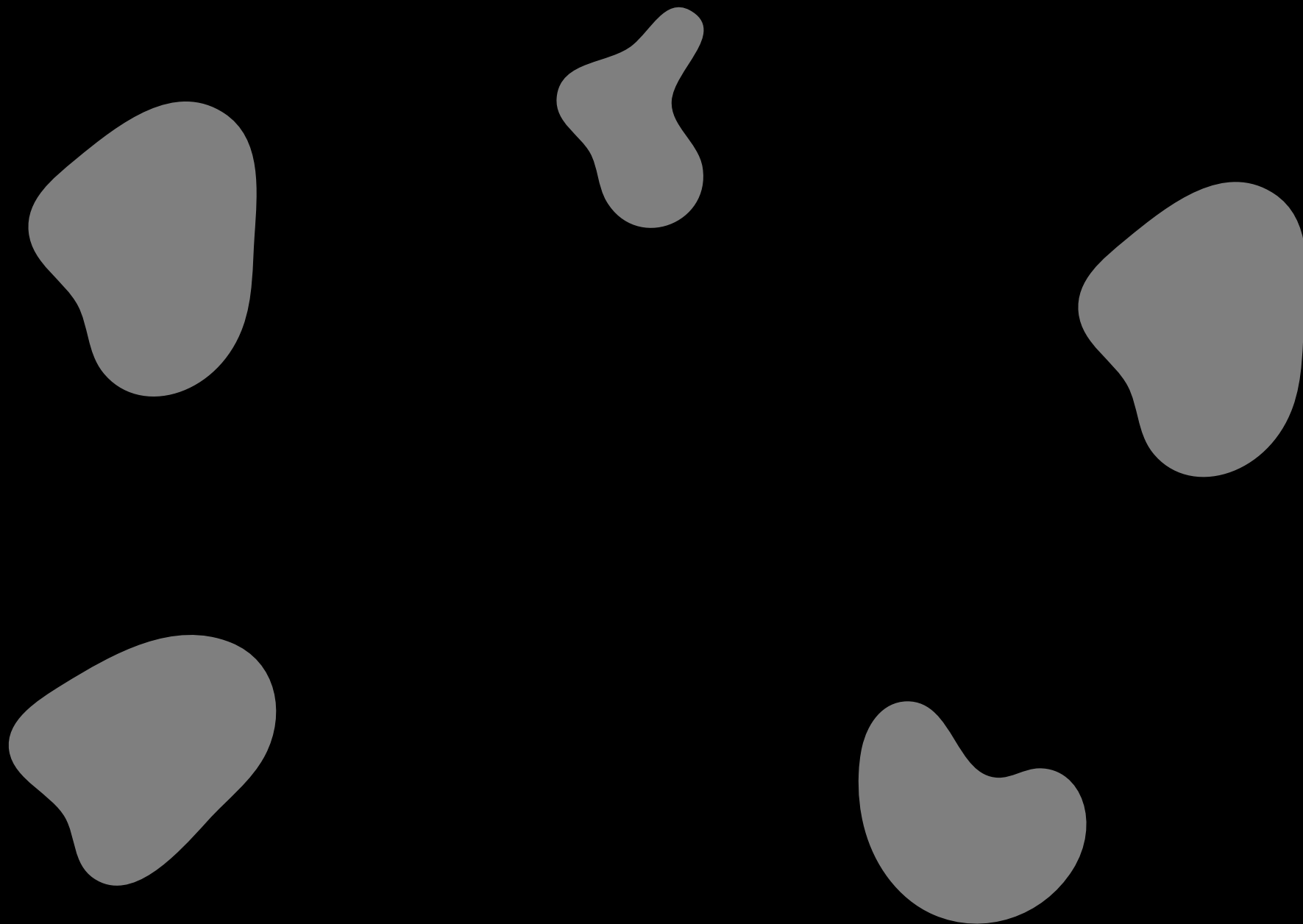


**Gas clouds
form**

Birth of stars...

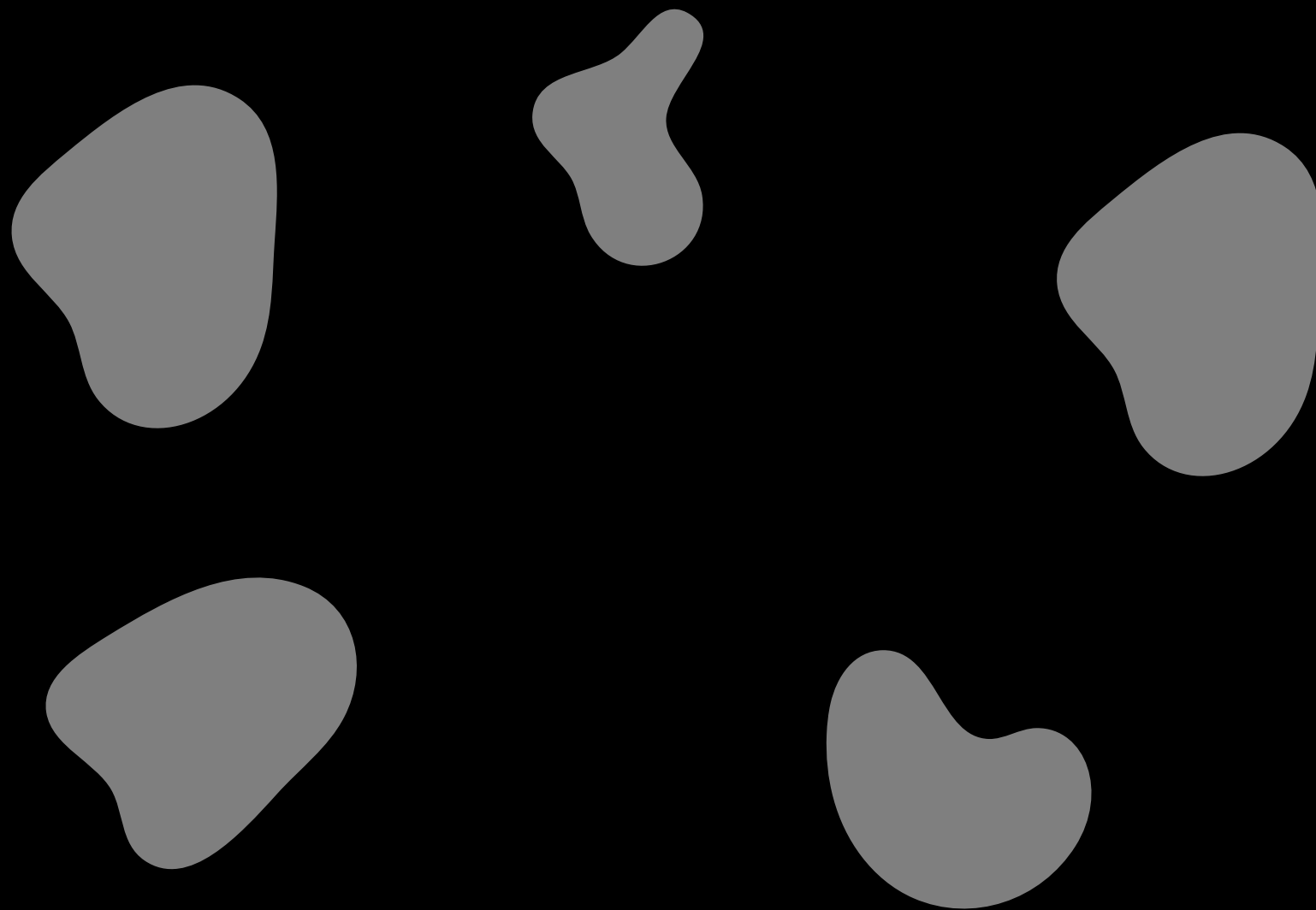


Birth of stars...



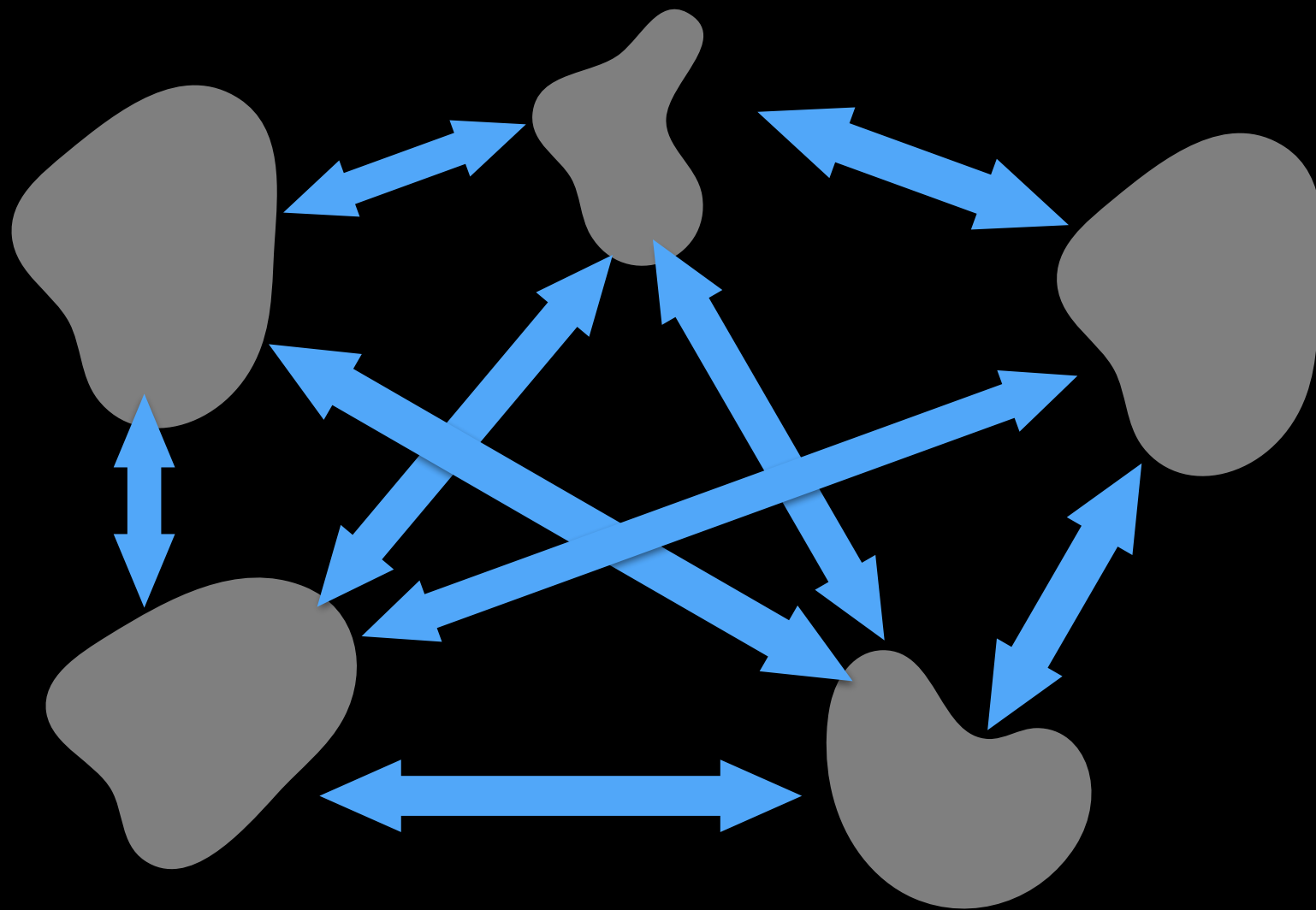
**Gas clouds
form**

Slightly after the beginning...



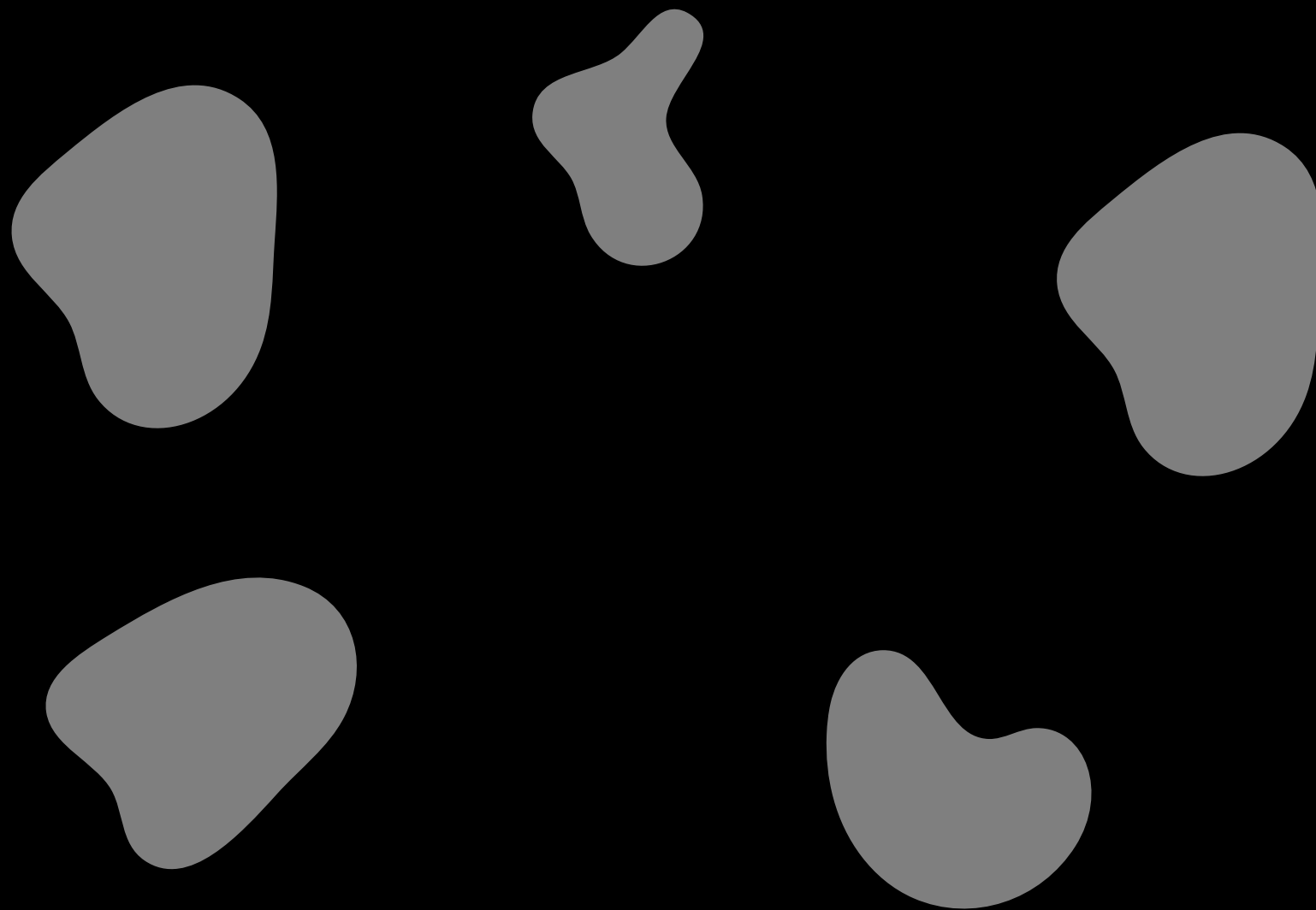
**Gravity pulls
gas clouds
together**

Slightly after the beginning...



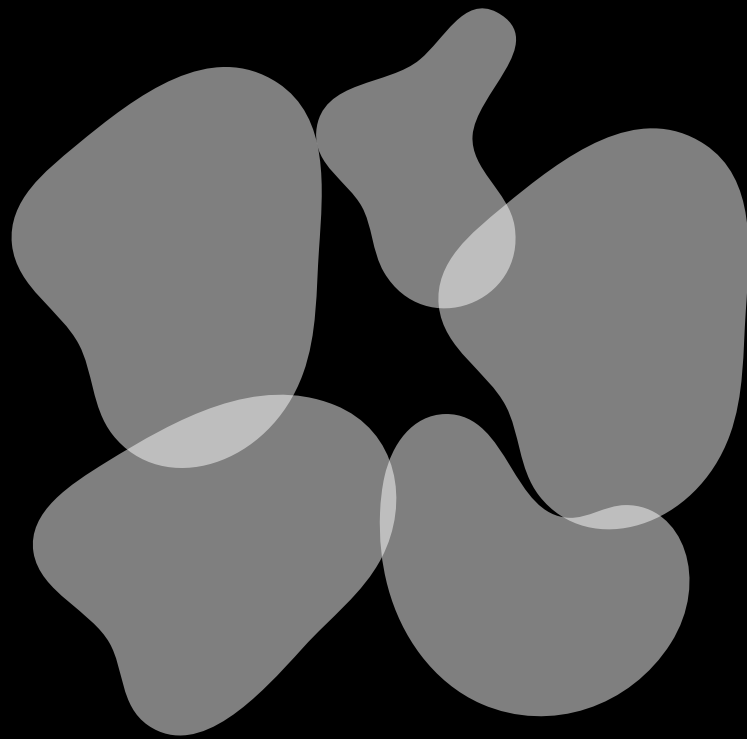
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Slightly after the beginning...



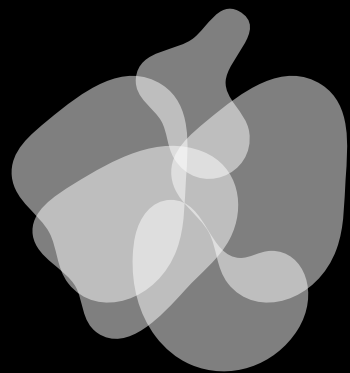
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Slightly after the beginning...



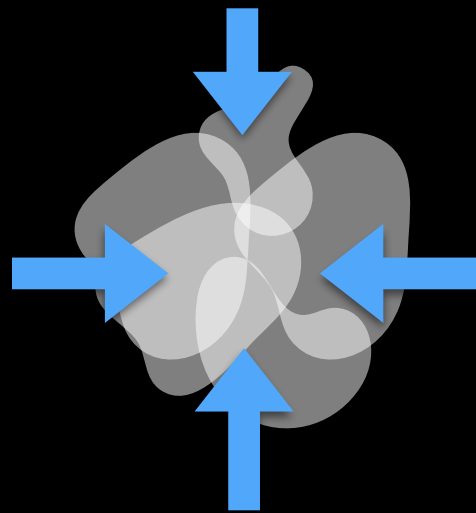
**Gas clouds
begin to merge**

A little later...



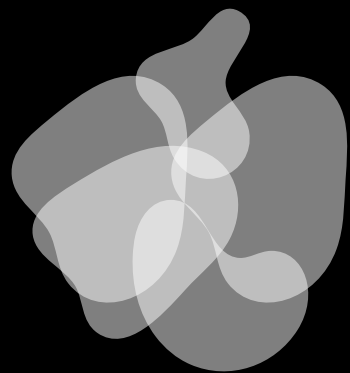
**Gravity
compresses
the cloud,
making it
*denser***

A little later...



**Gravity
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A little later...



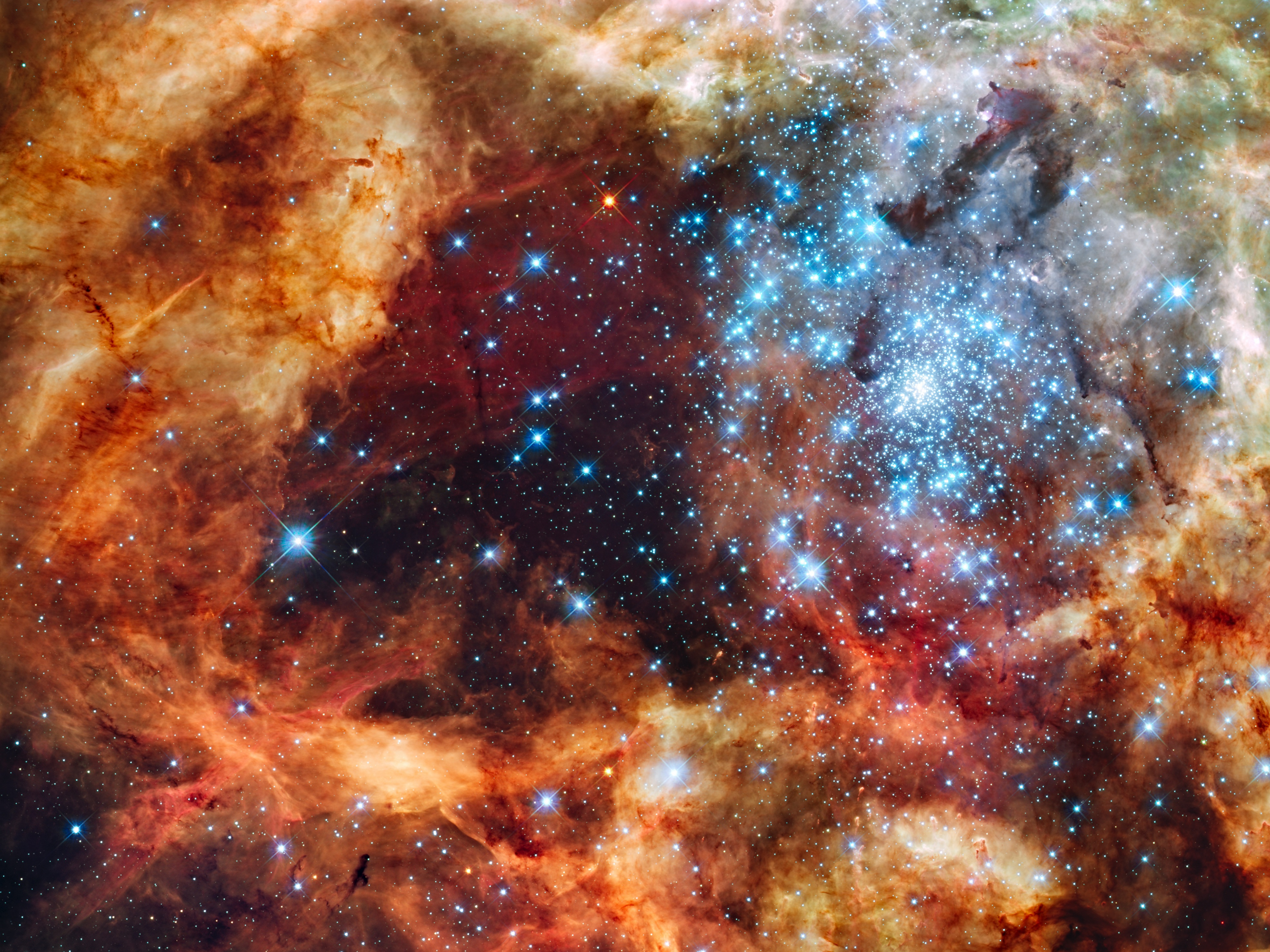
**Gravity
compresses
the cloud,
making it
*denser***

And then...



**Stars
are
born! when
nuclear
fusion starts**







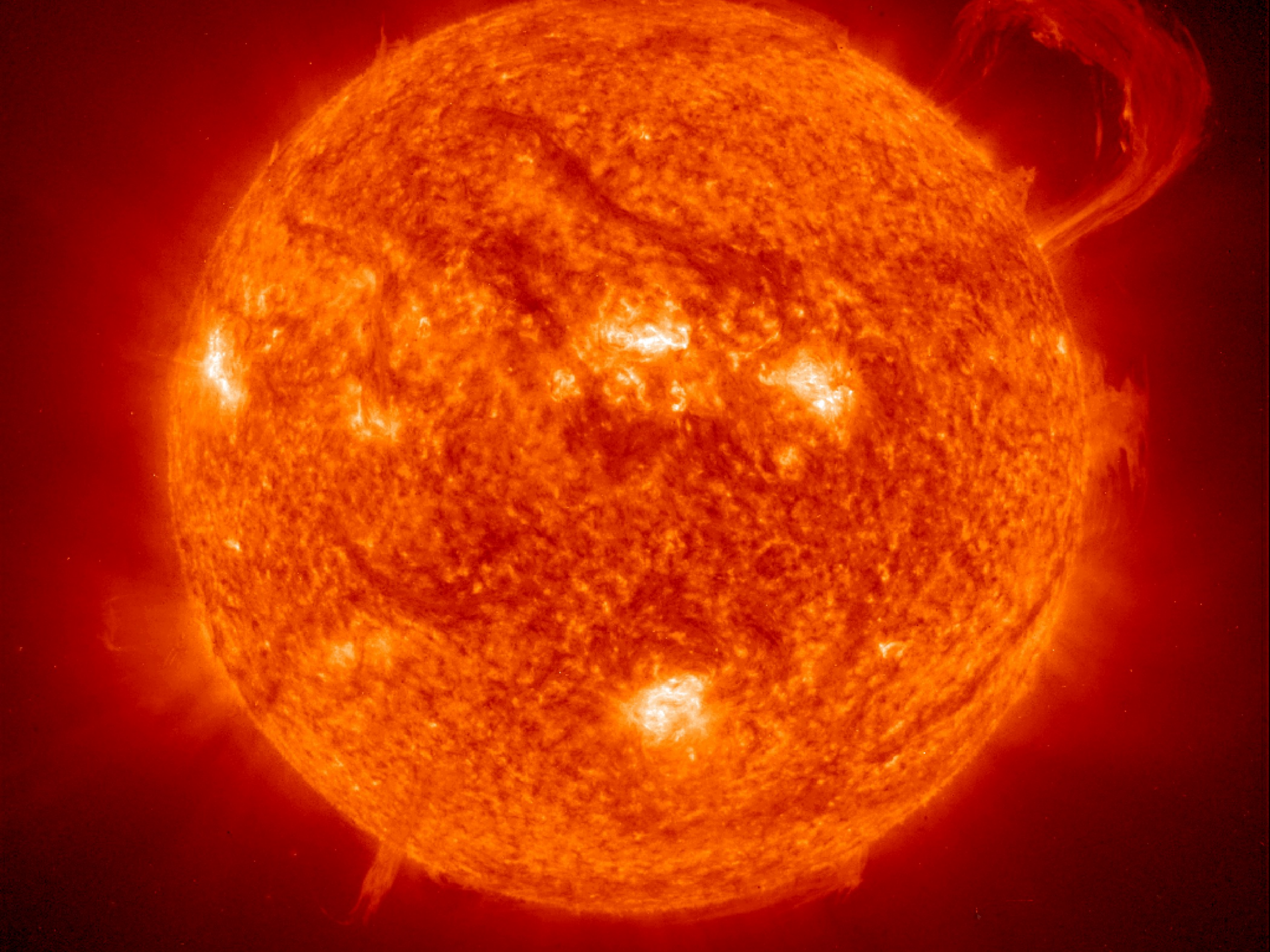








Life

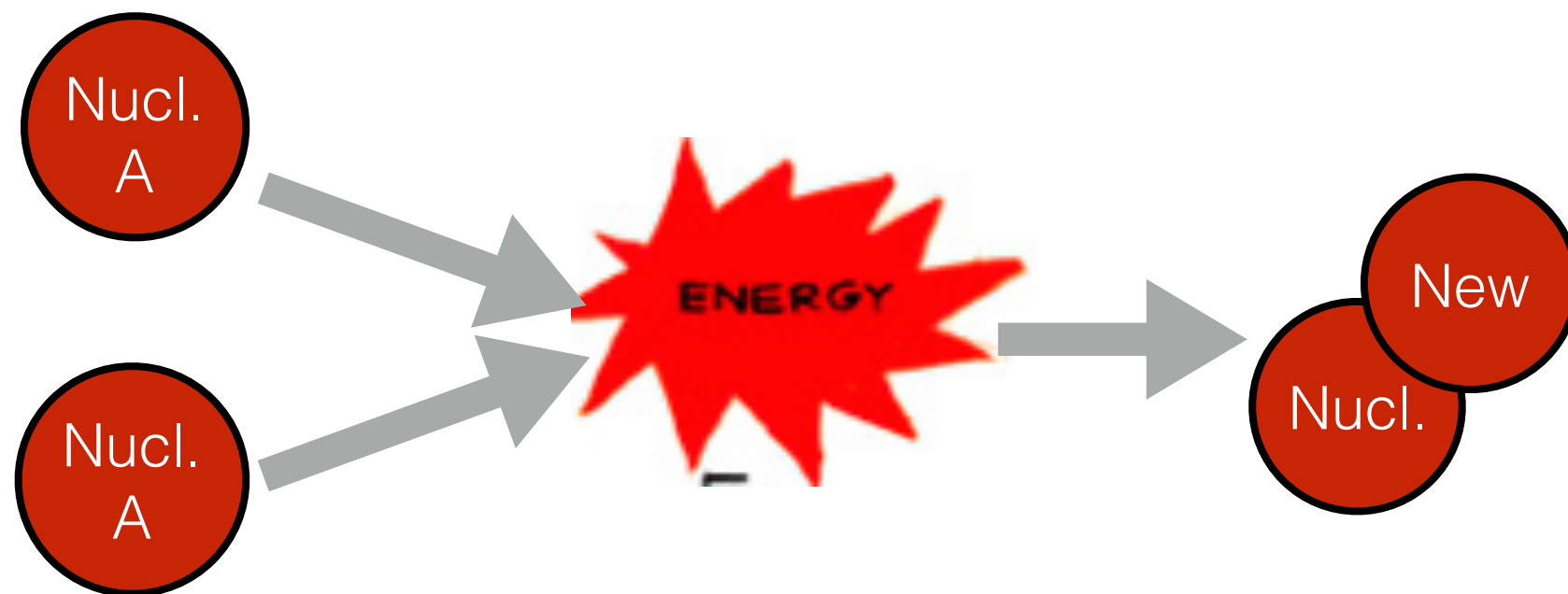


How do stars shine?

- **Stars are dense**, so atoms are close together.
- **Stars are hot**, so atoms are flying *really fast*.
 - ➔ Atoms hit each other...**really hard!**

How do stars shine?

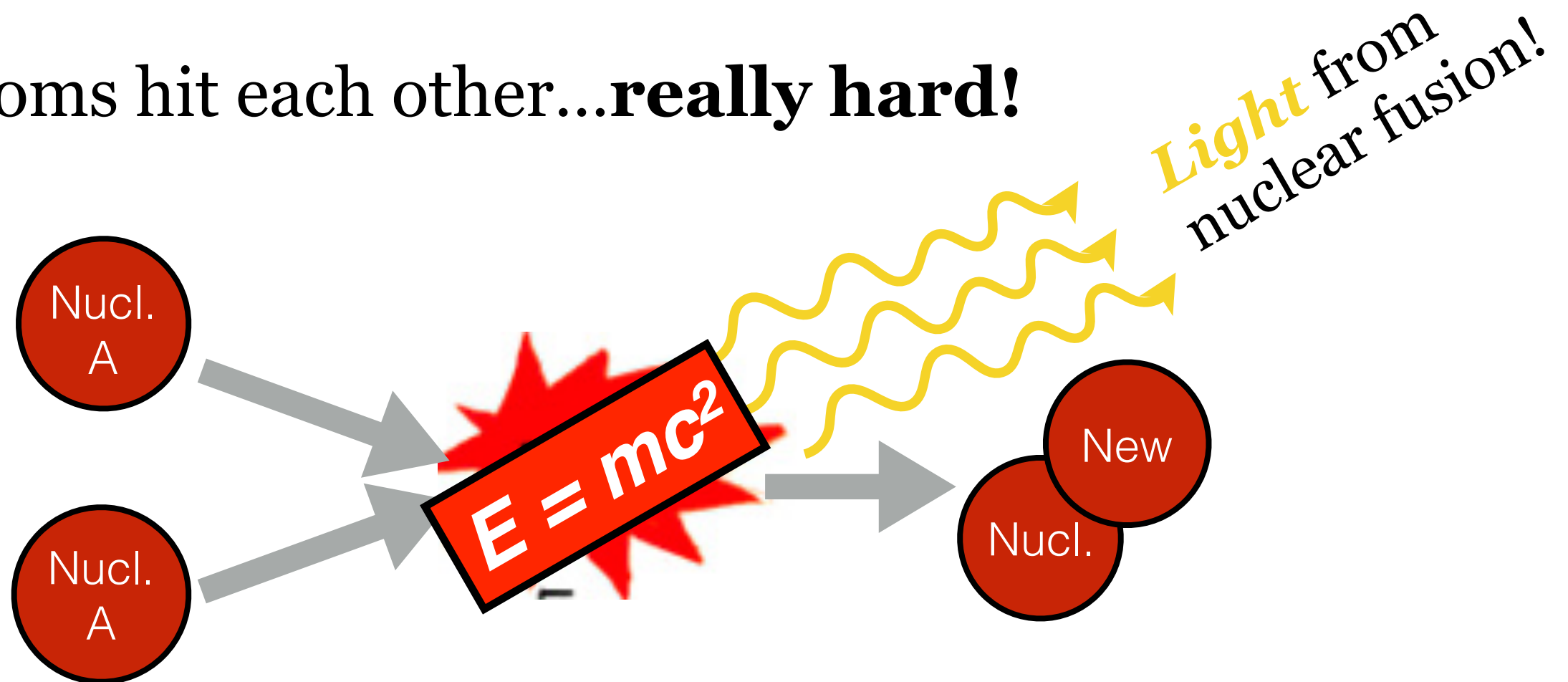
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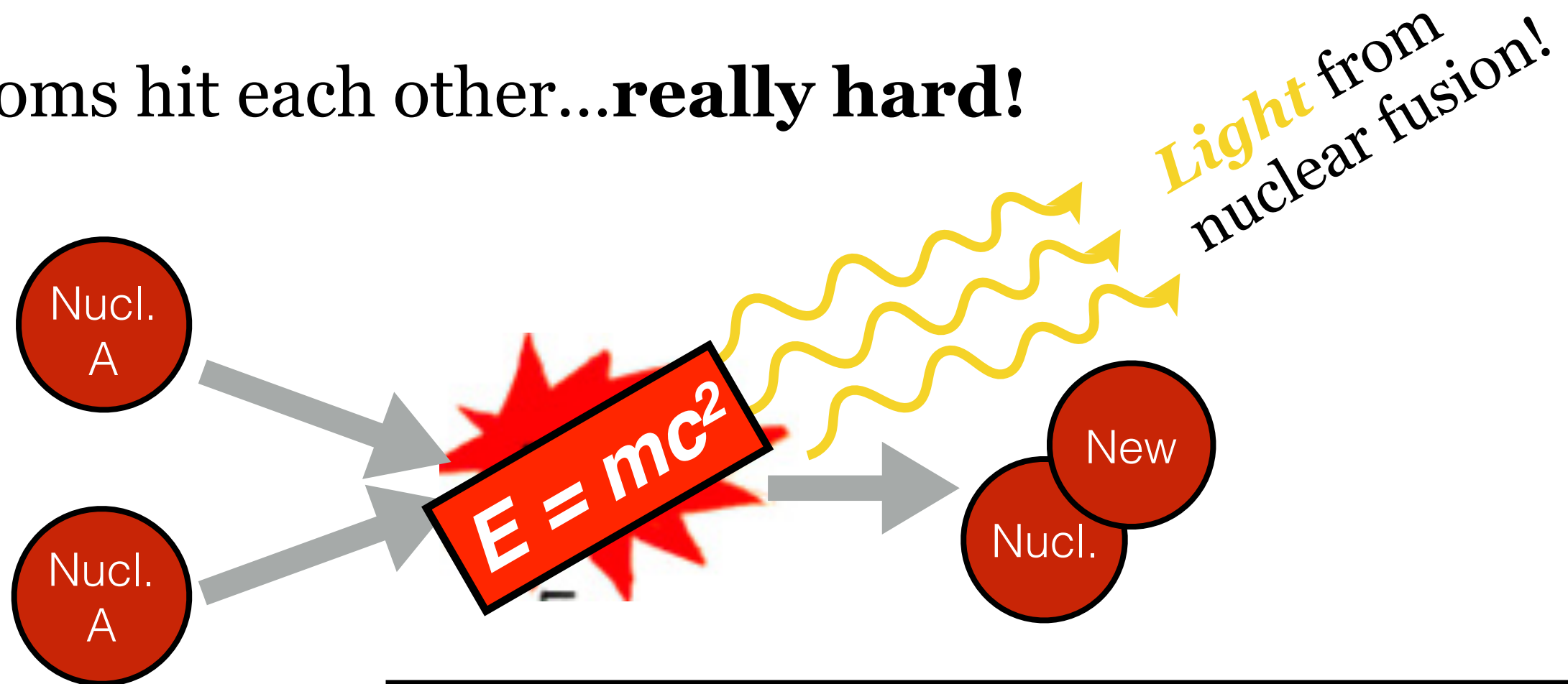
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Figured out in 1938 by Hans Bethe

Same process as a hydrogen bomb. Can power the Sun for
~10 billion years



**How do we know
all that stuff?**

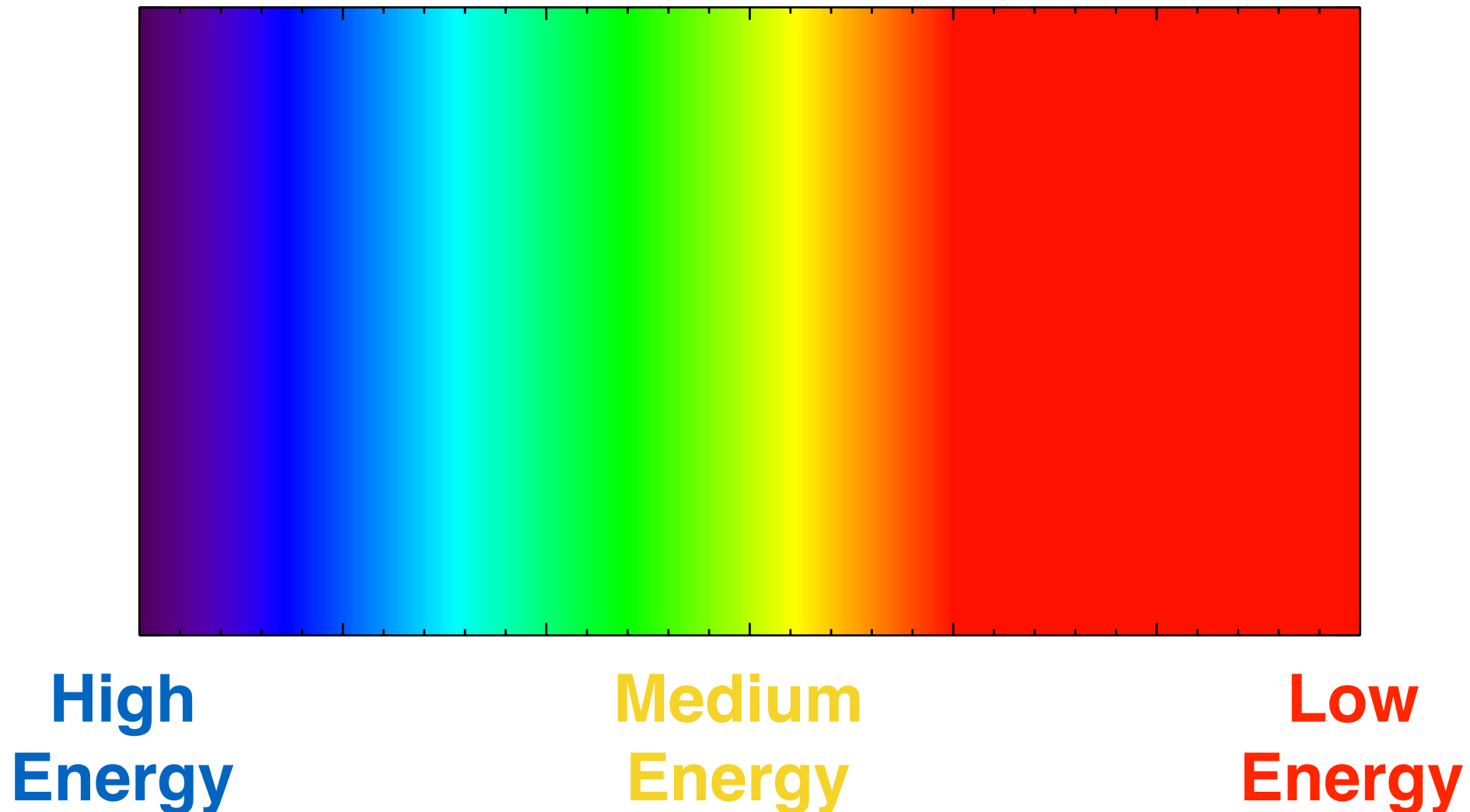




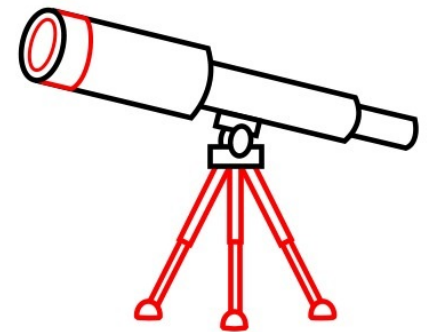
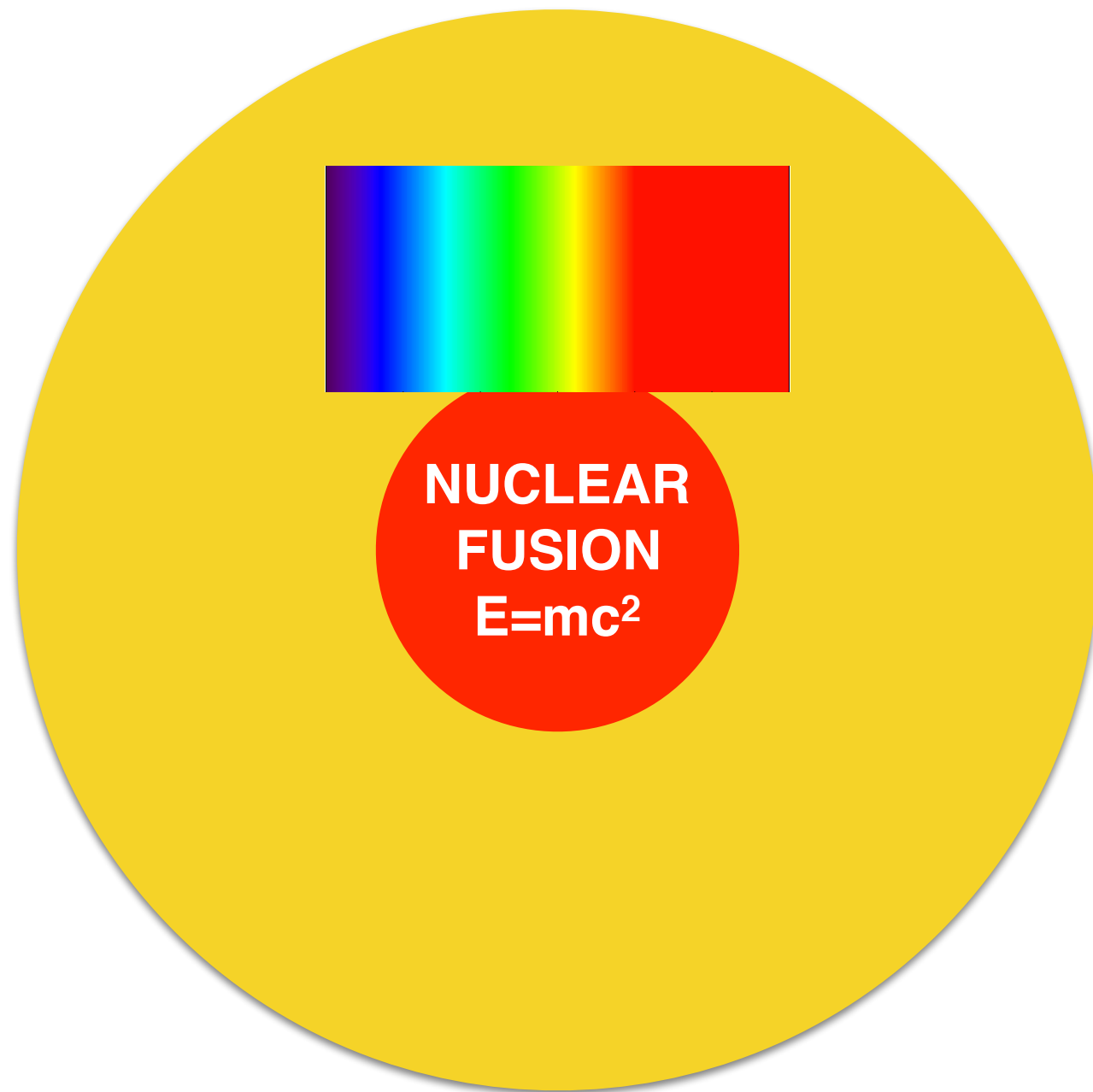
Like this.

Rainbow = spectrum

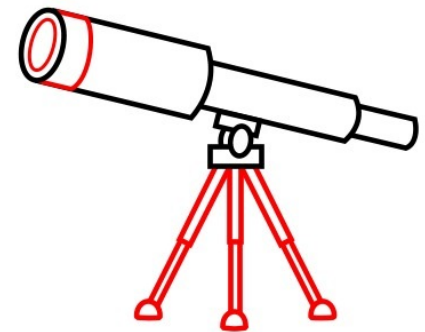
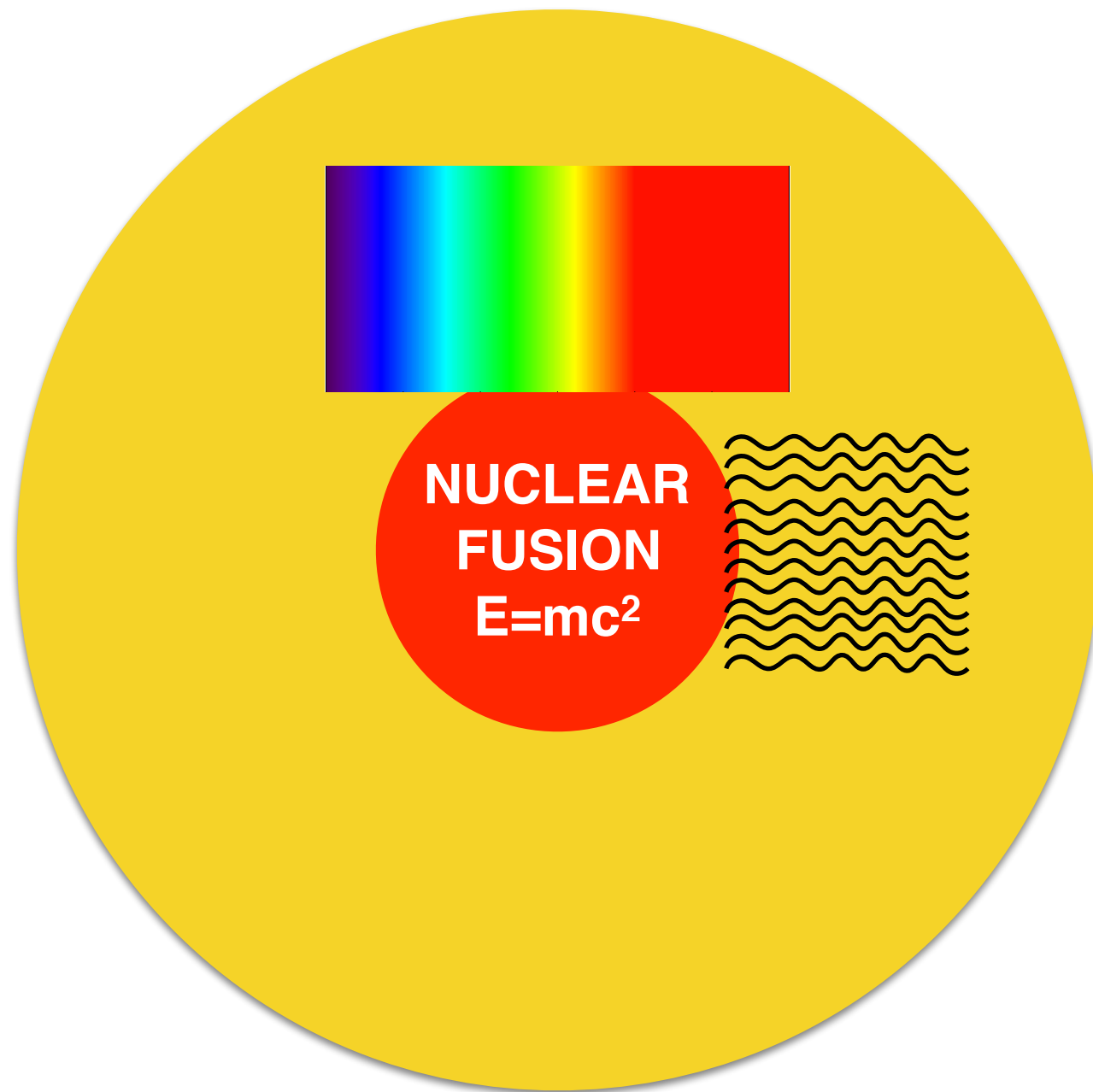
- Light carries energy:



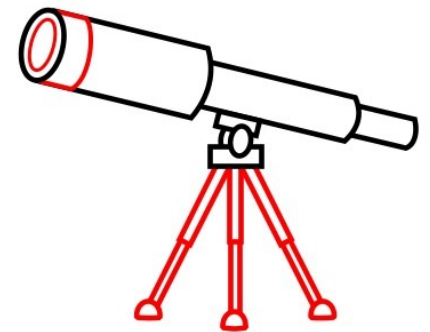
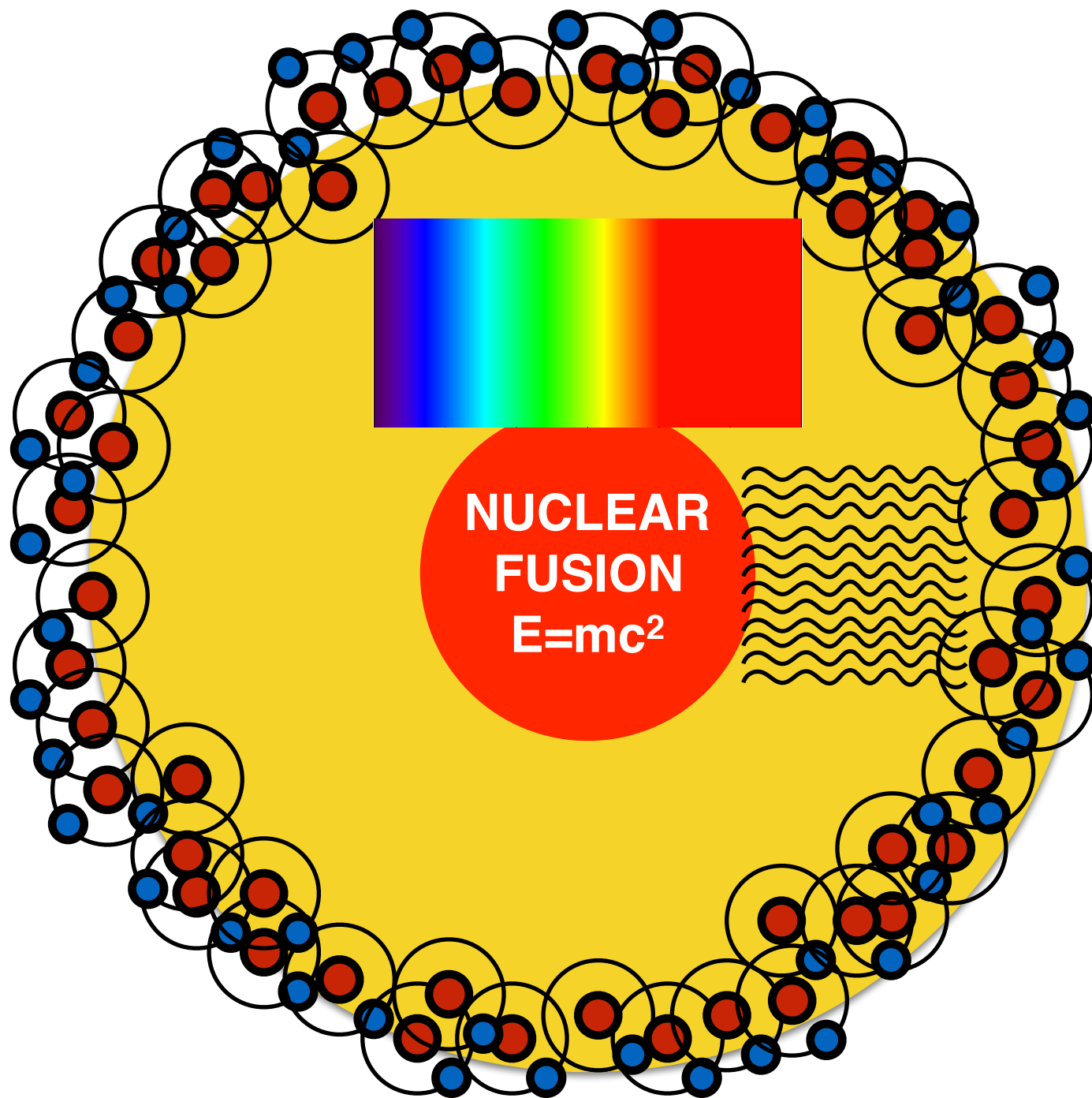
In a star...



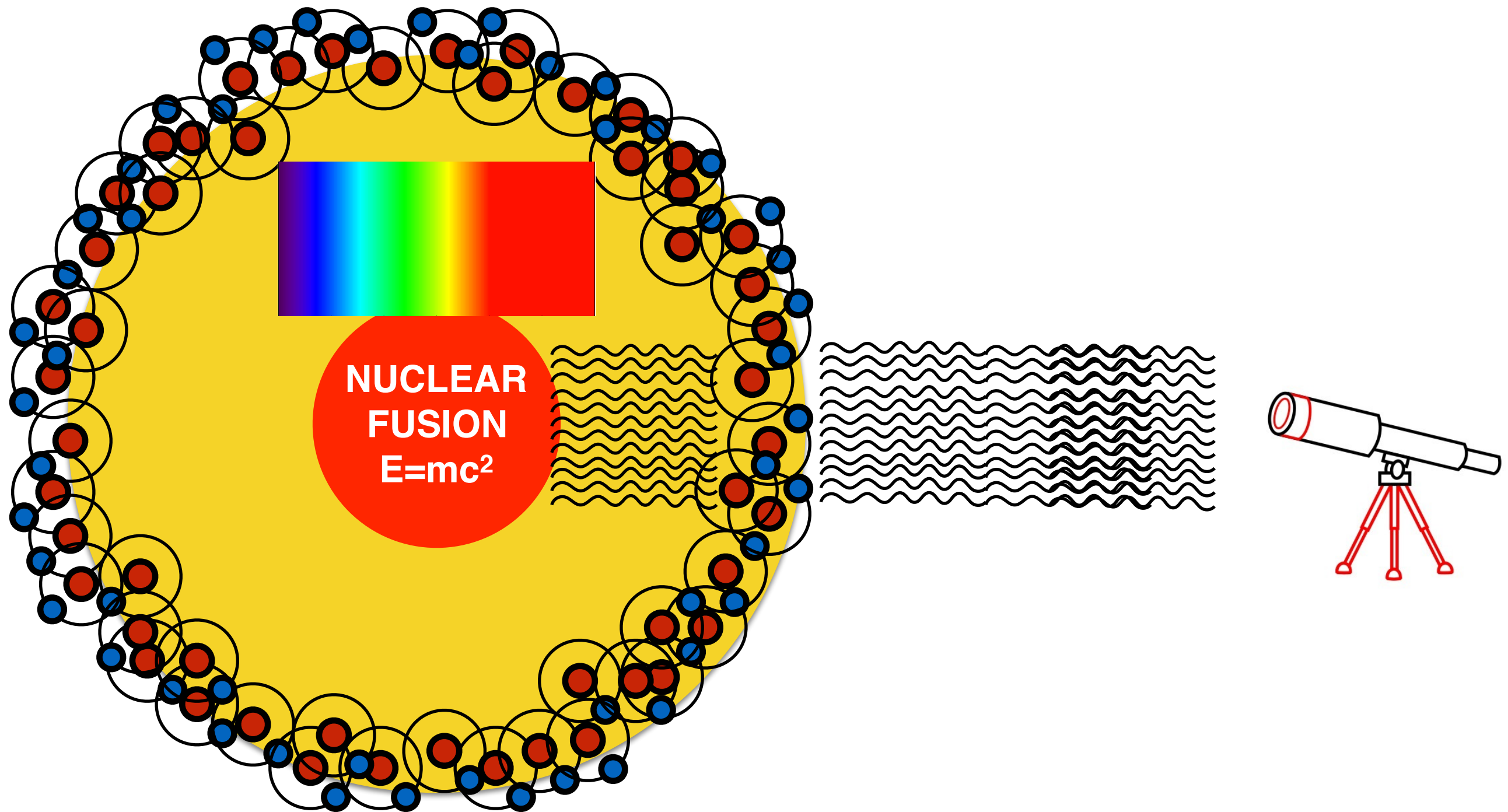
In a star...



In a star...

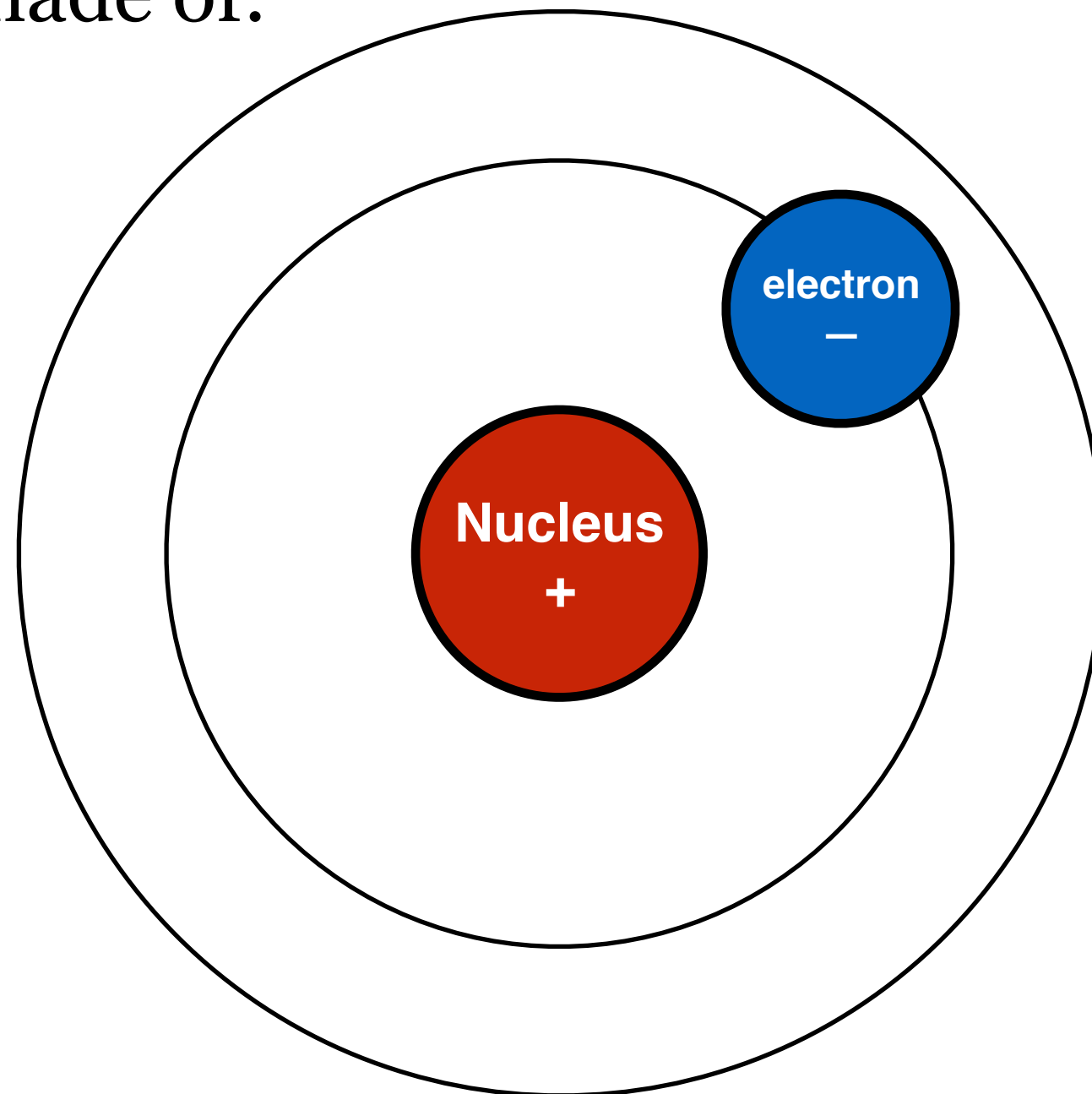


In a star...



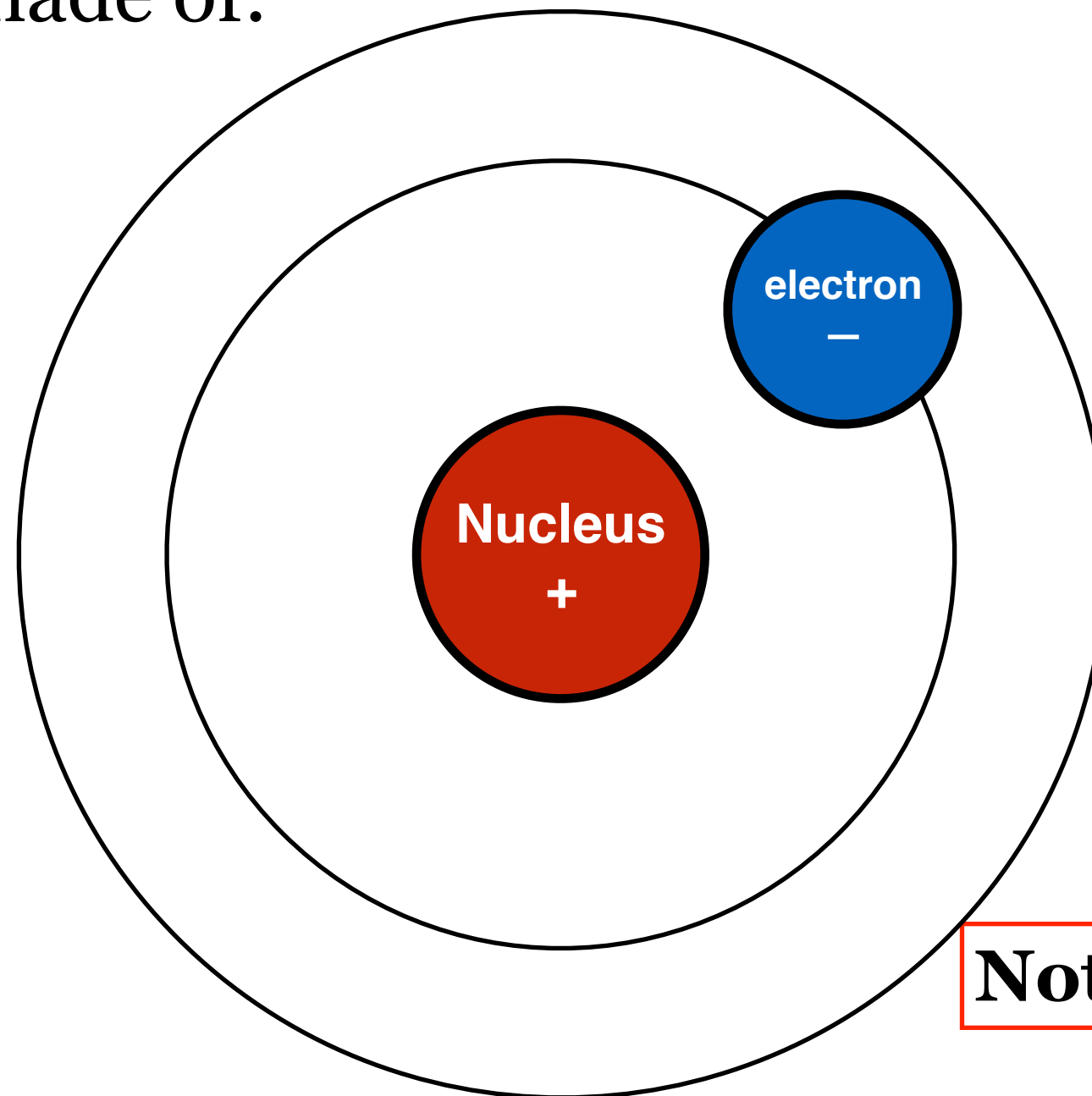
More on atoms

- Gas is made of atoms.
- An atom is made of:



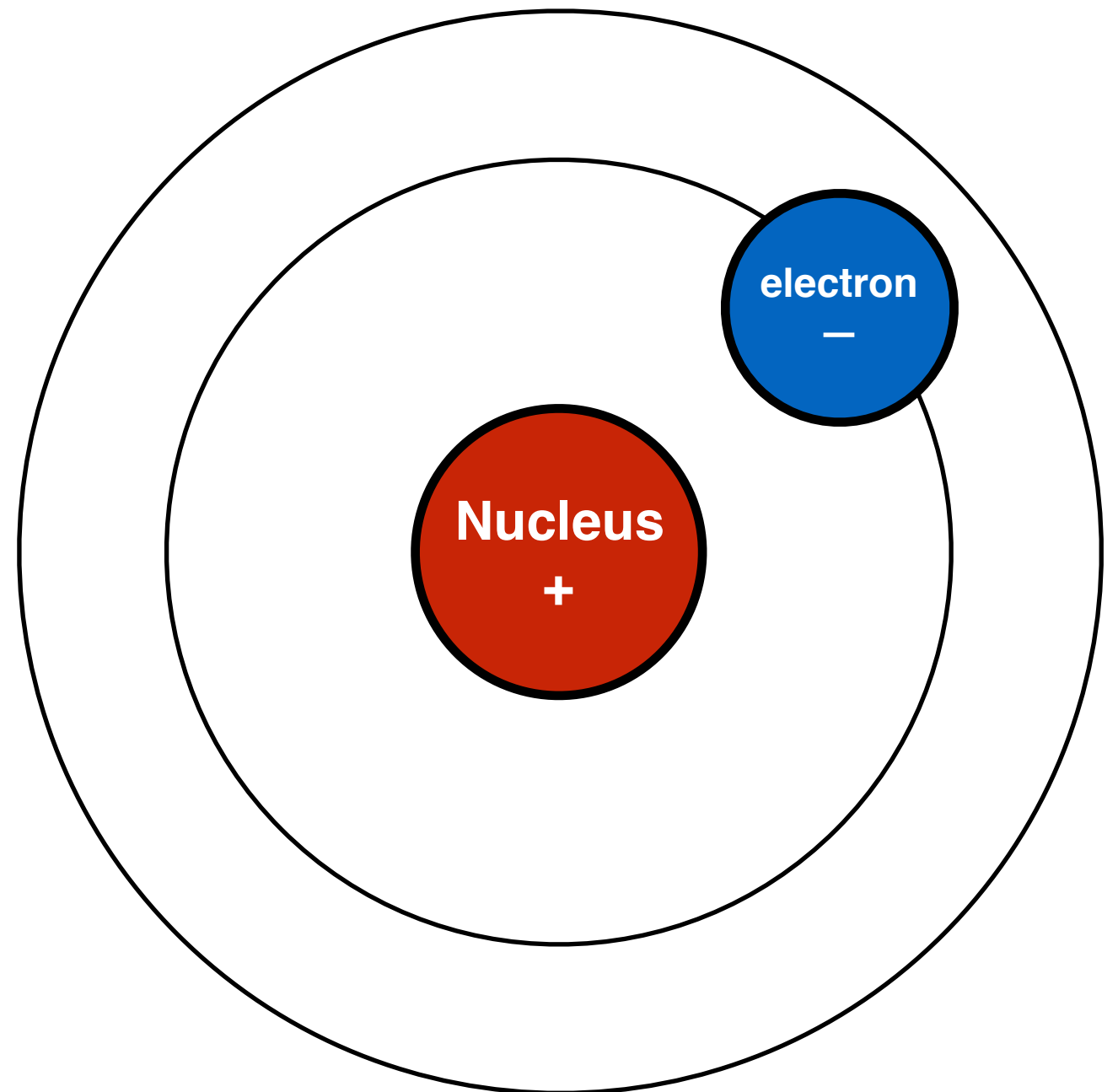
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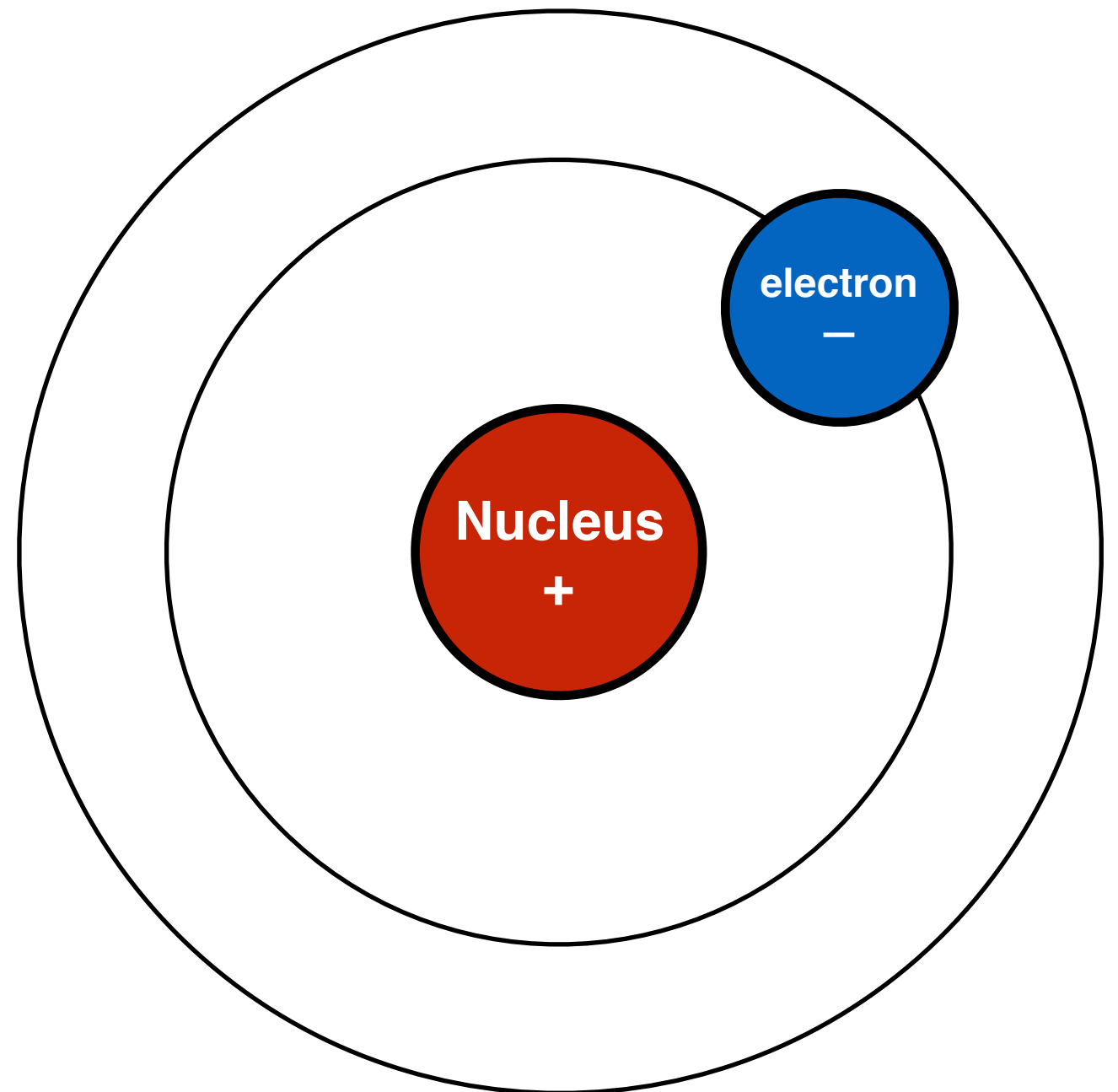
Atoms & light

- Electron “orbits” have specific energies



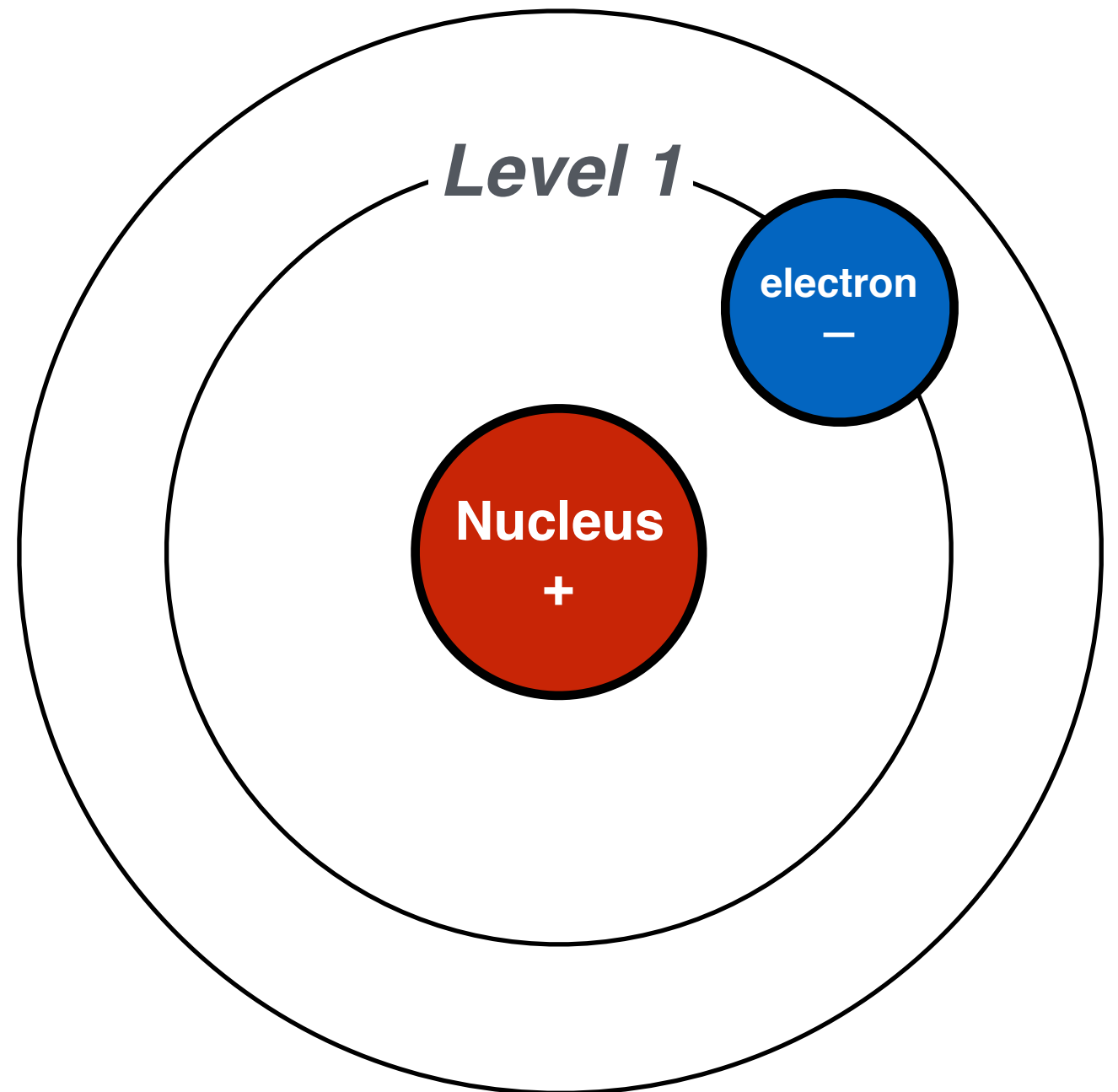
Atoms & light

- Electron “orbits” have specific energies
- Separated like stairs on a staircase.



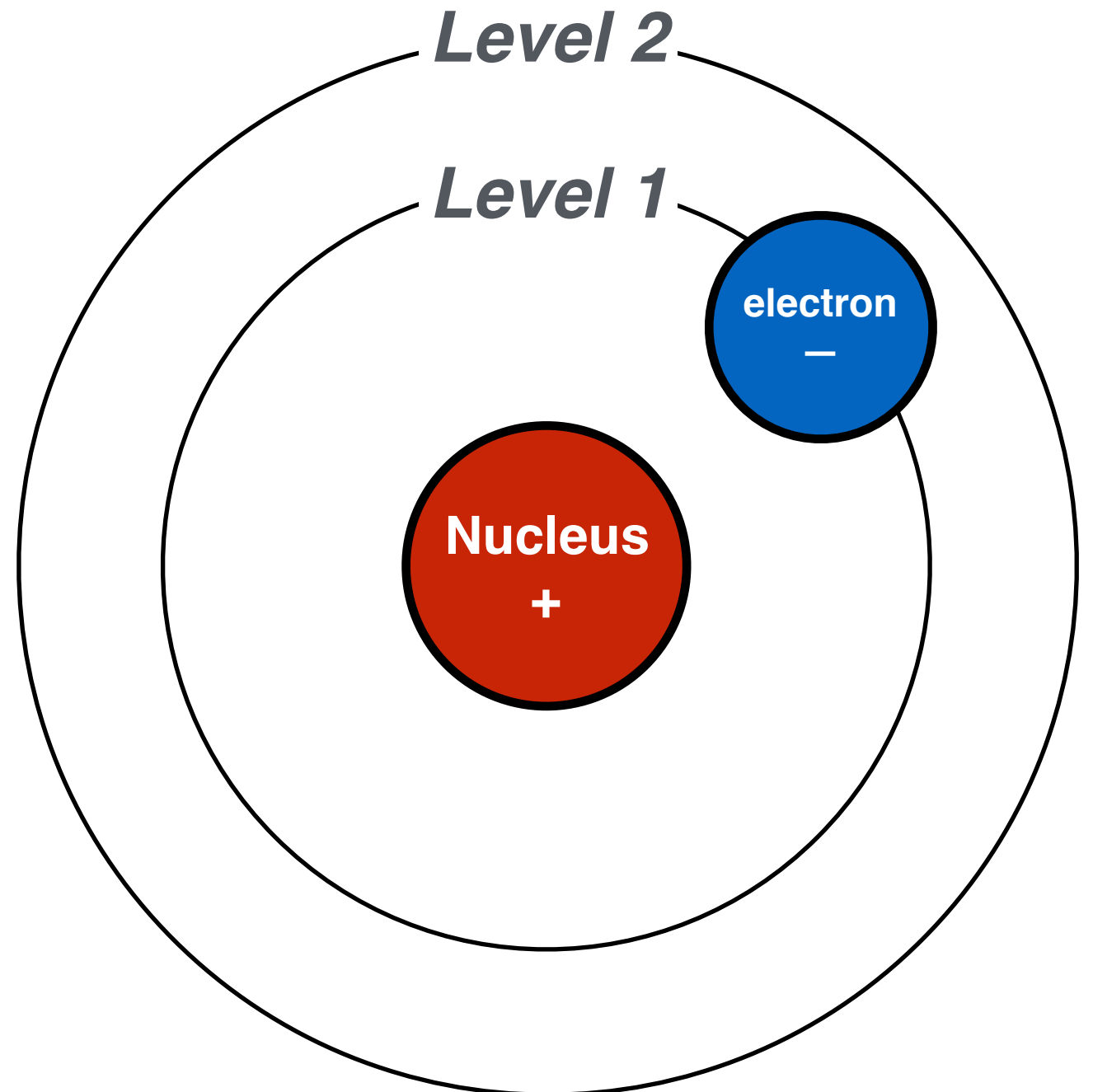
Atoms & light

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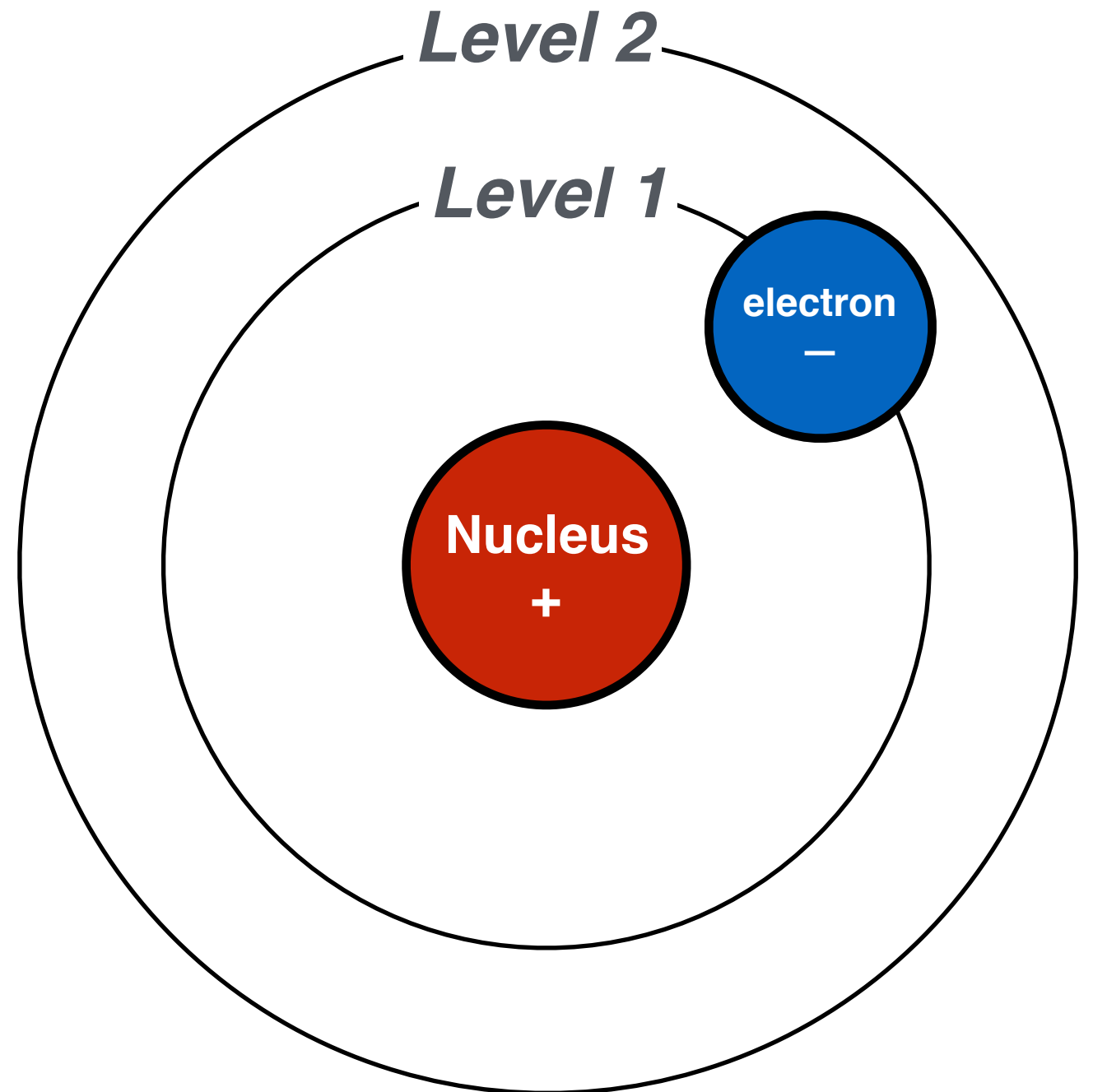
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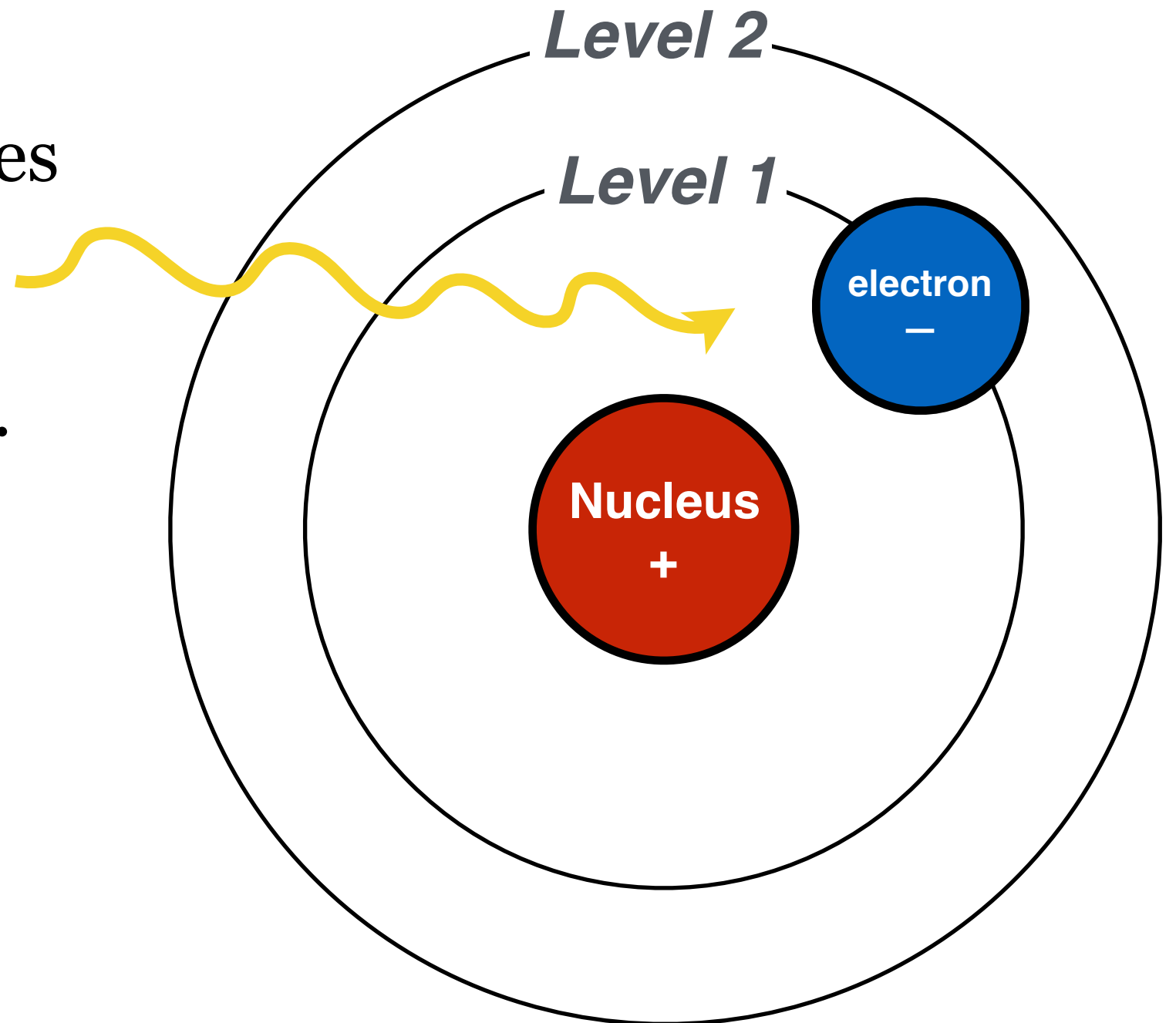
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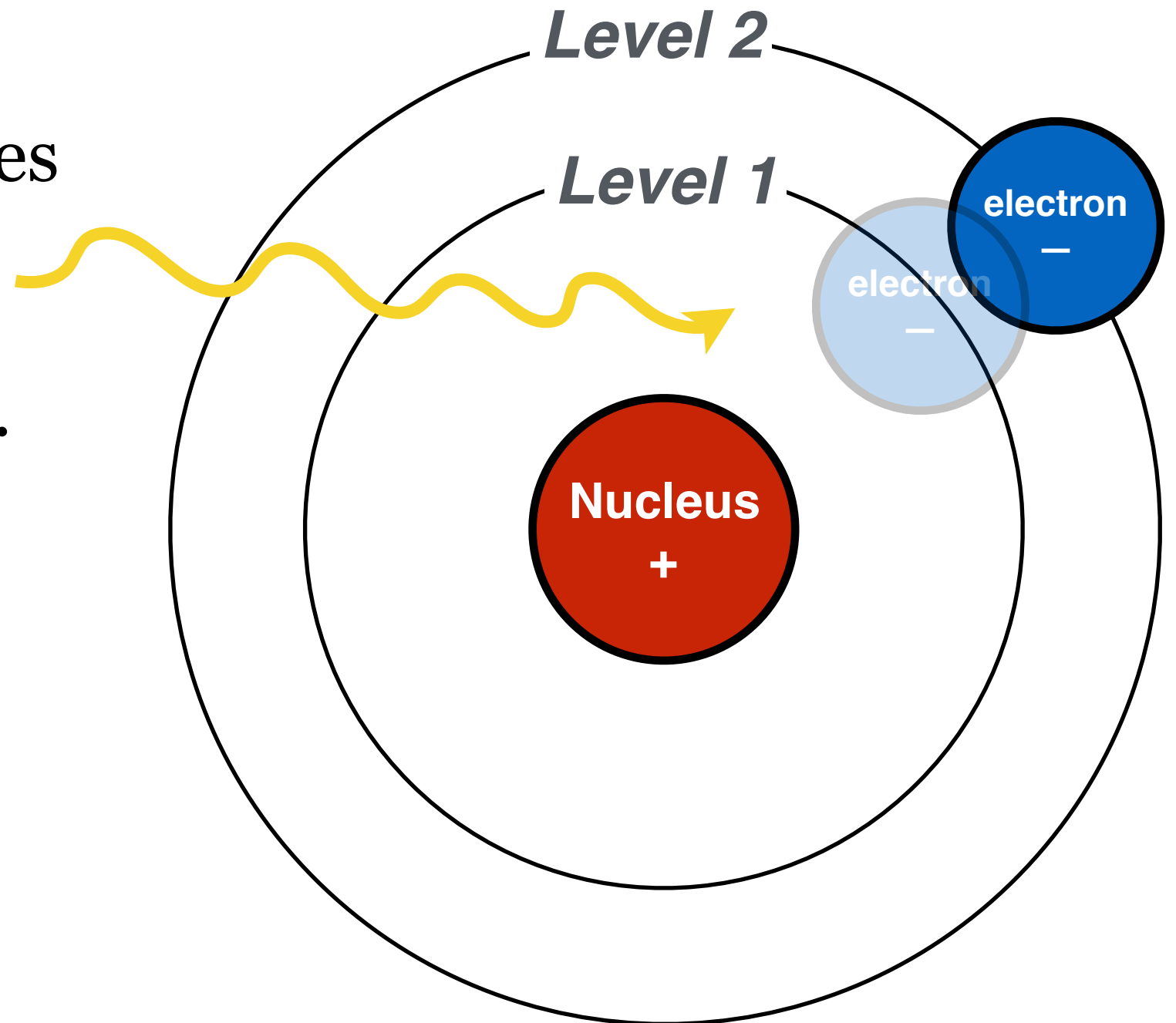
Atoms & light

- Electron “orbits” have specific energies
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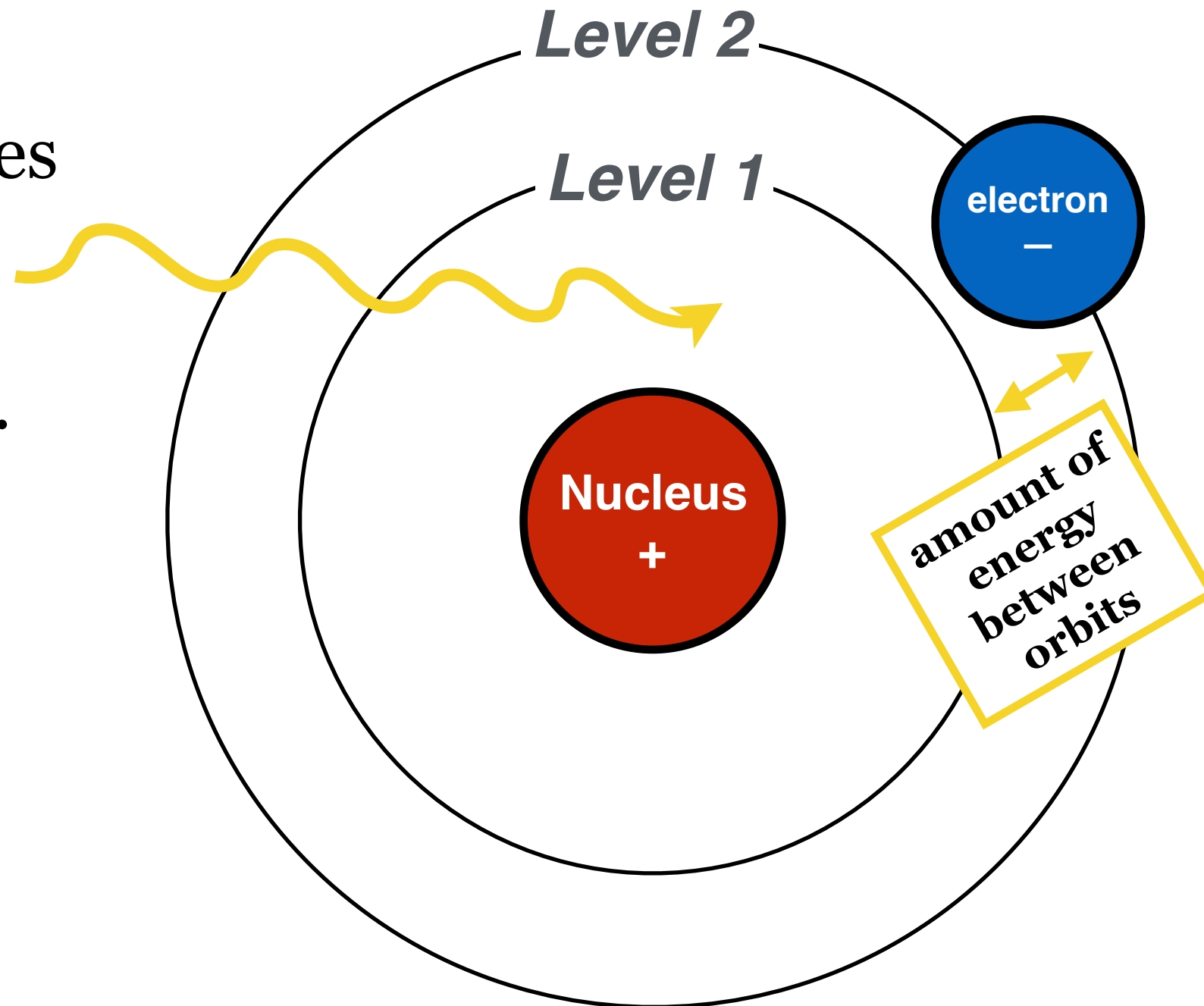
Atoms & light

- Electron “orbits” have specific energies
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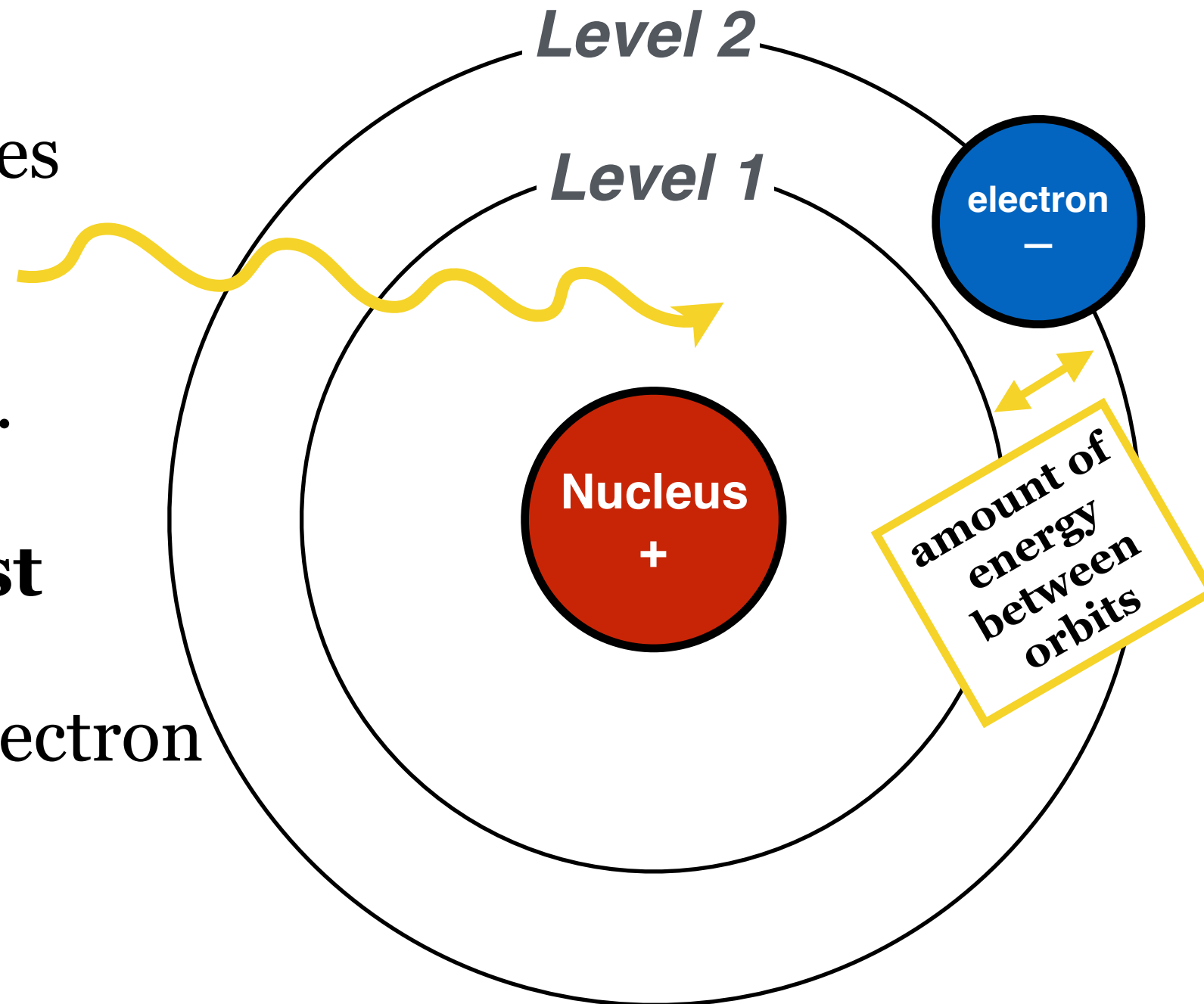
Atoms & light

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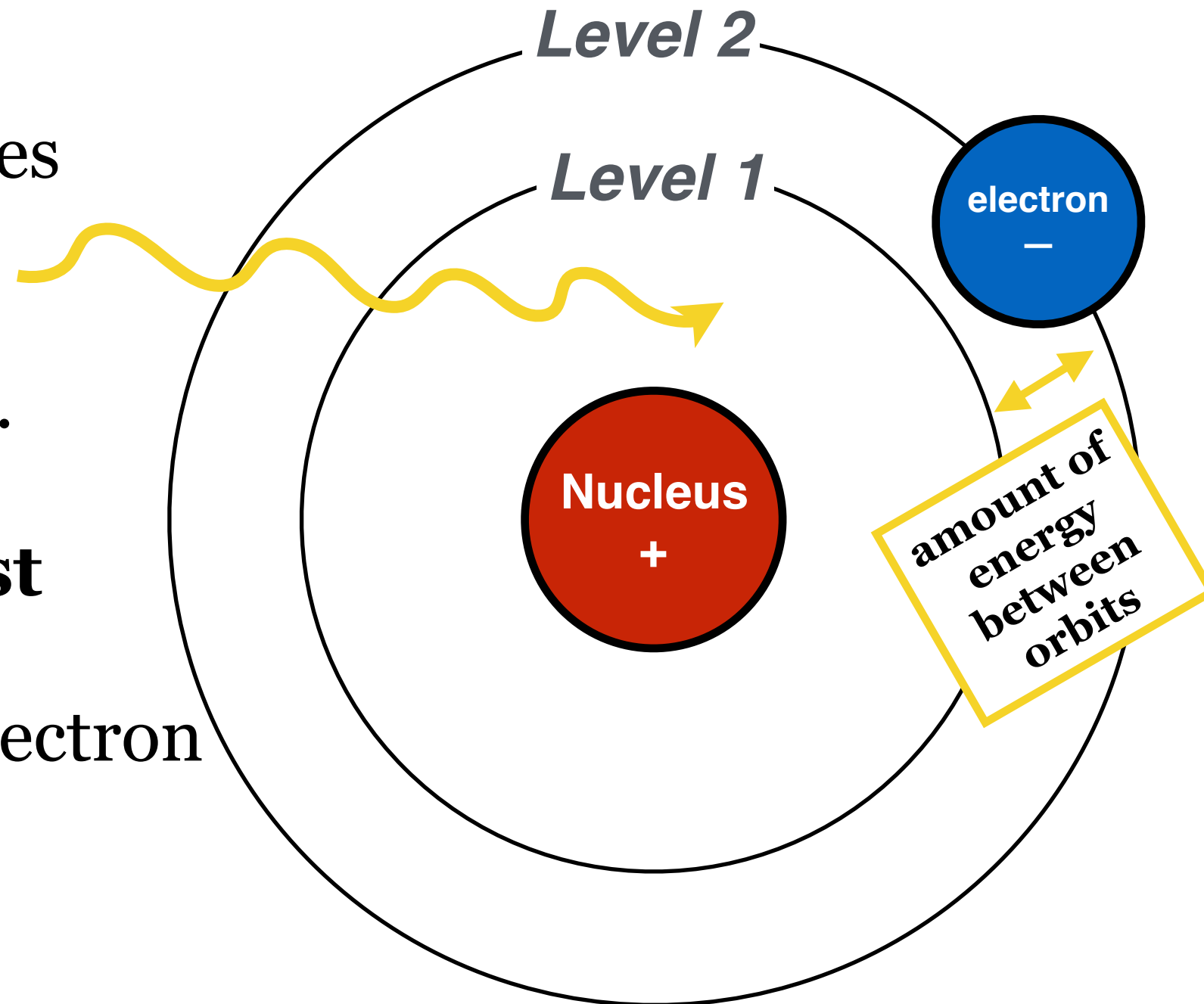
Atoms & light

- Electron “orbits” have specific energies
- Separated like stairs on a staircase.
- Light must have **just the right color** (energy) to bump electron



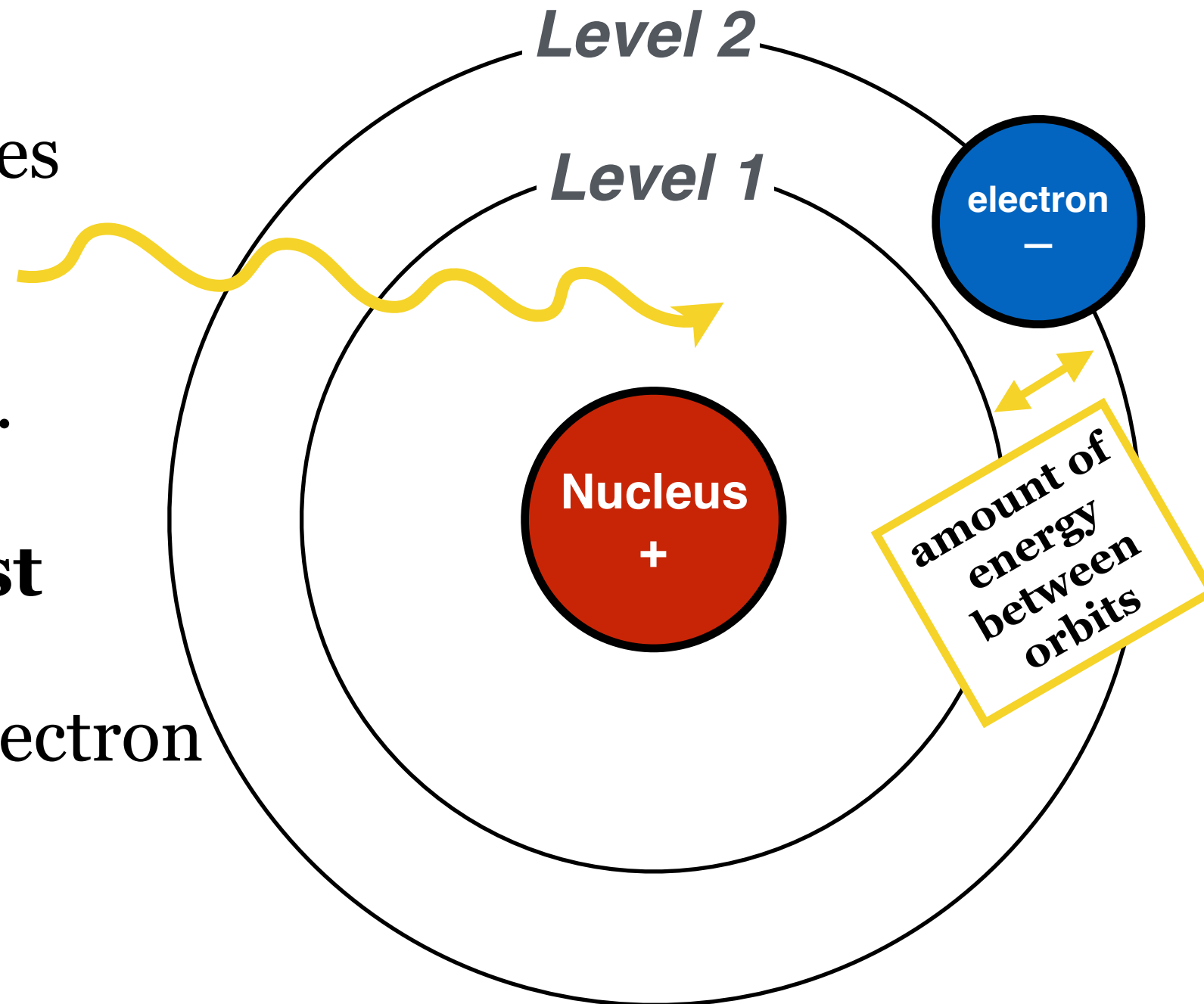
Atoms & light

- Electron “orbits” have specific energies
- Separated like stairs on a staircase.
- Light must have **just the right color** (energy) to bump electron
 - Not too **much**!

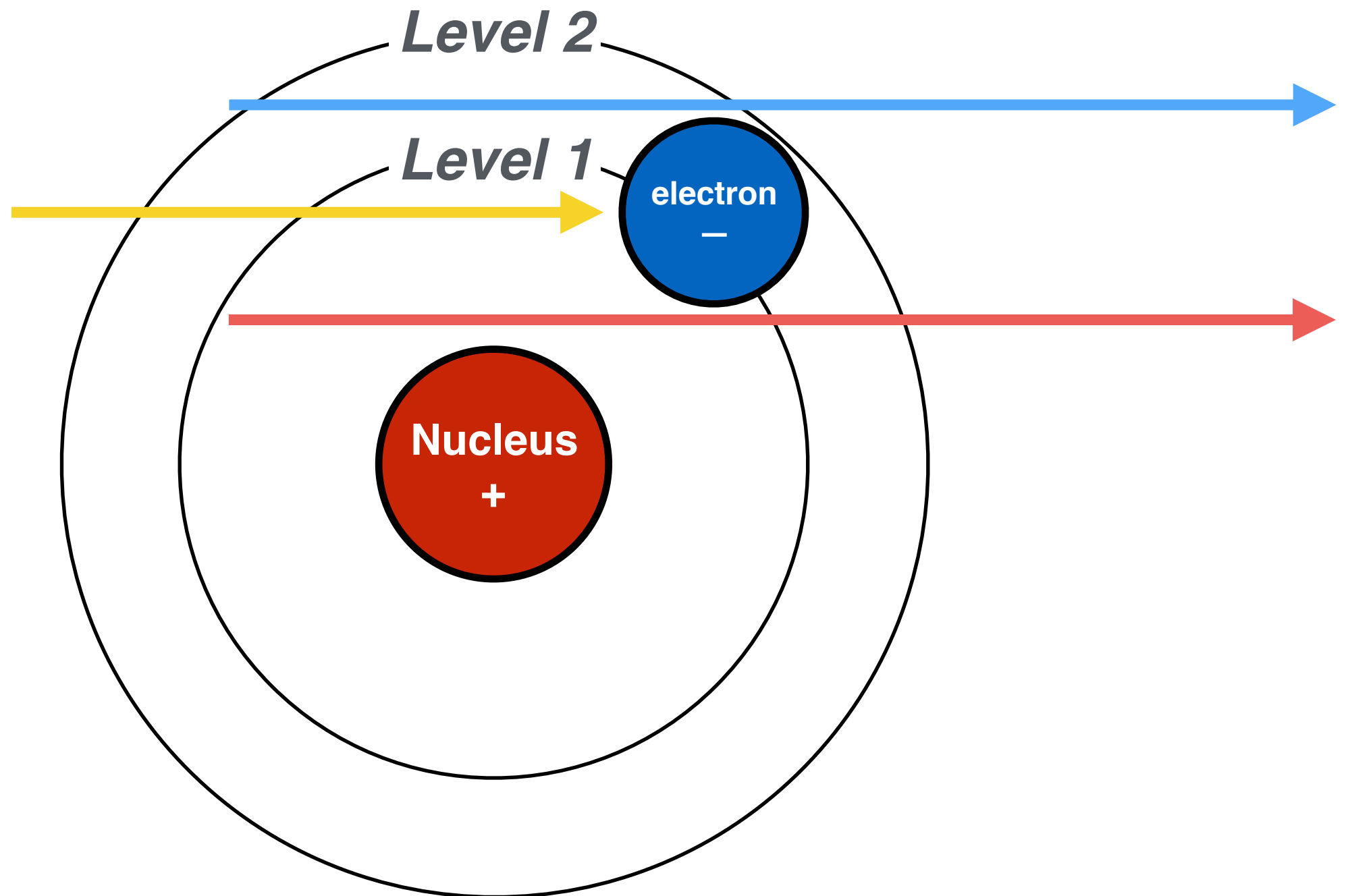


Atoms & light

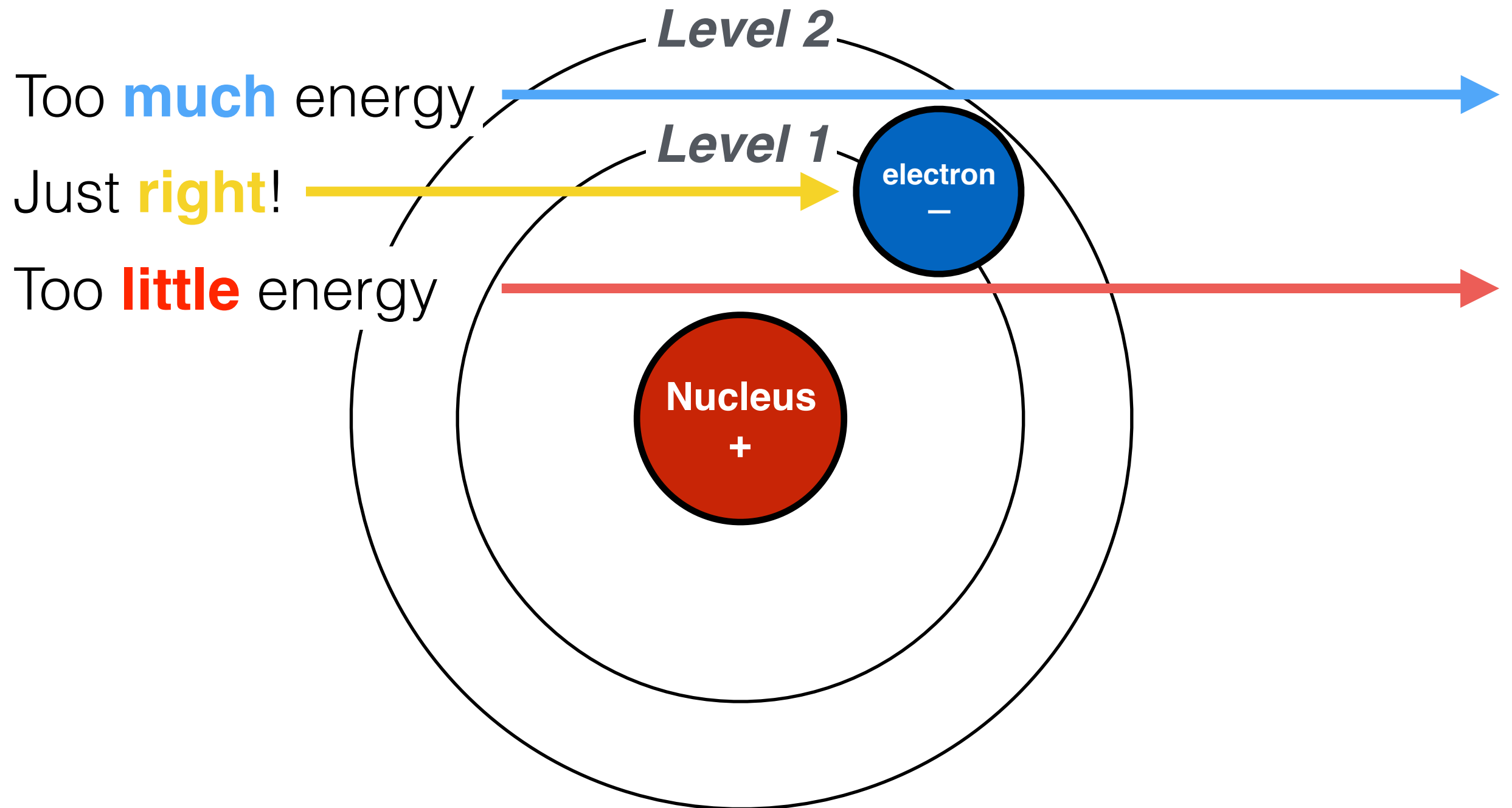
- Electron “orbits” have specific energies
- Separated like stairs on a staircase.
- Light must have **just the right color** (energy) to bump electron
 - Not too **much**!
 - Not too **little**!



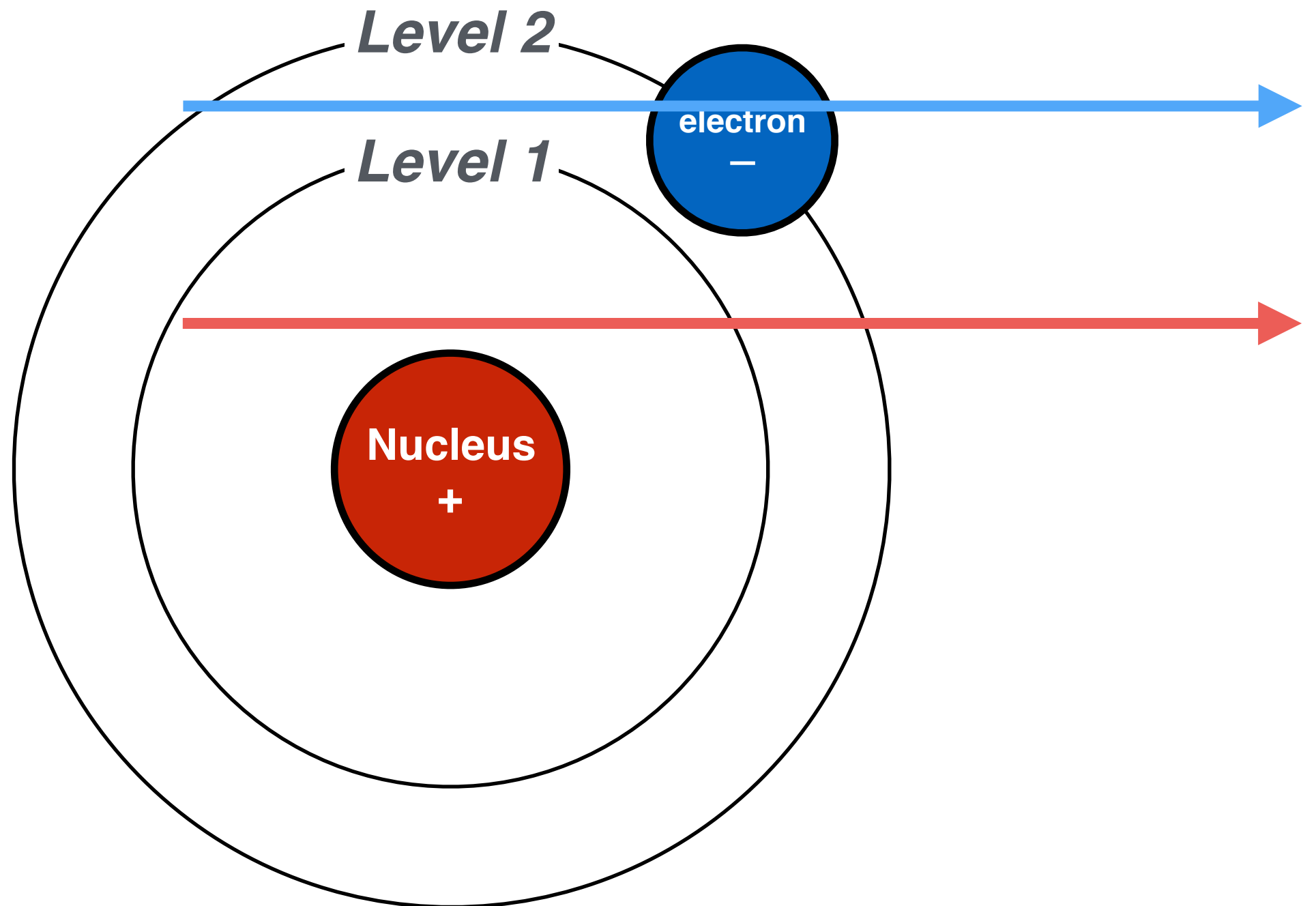
Atoms & light



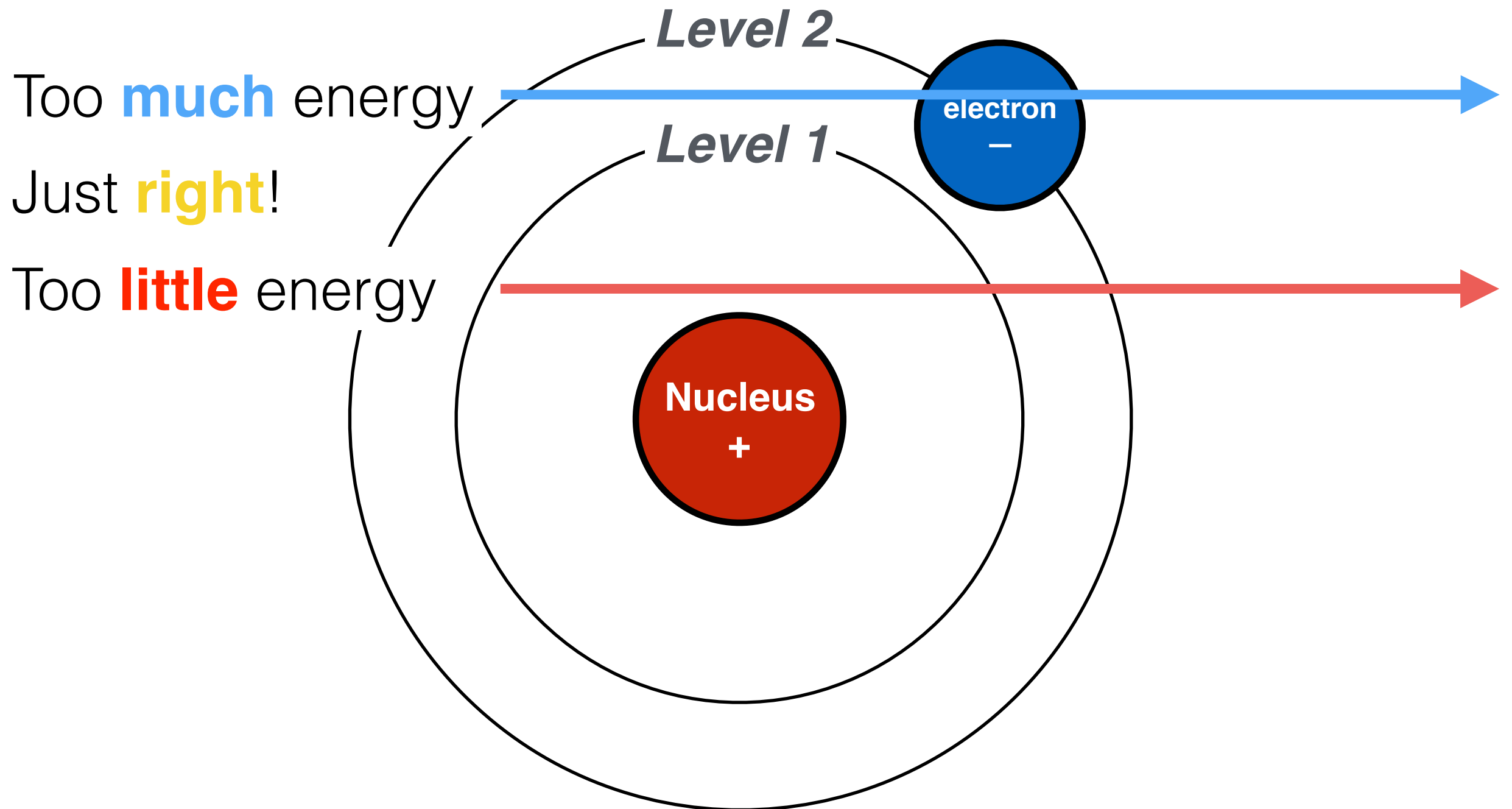
Atoms & light



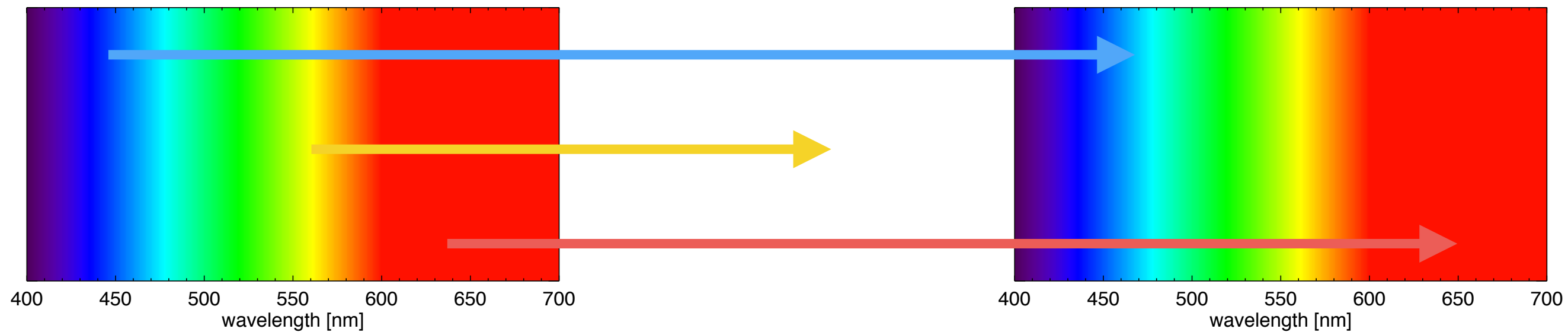
Atoms & light



Atoms & light

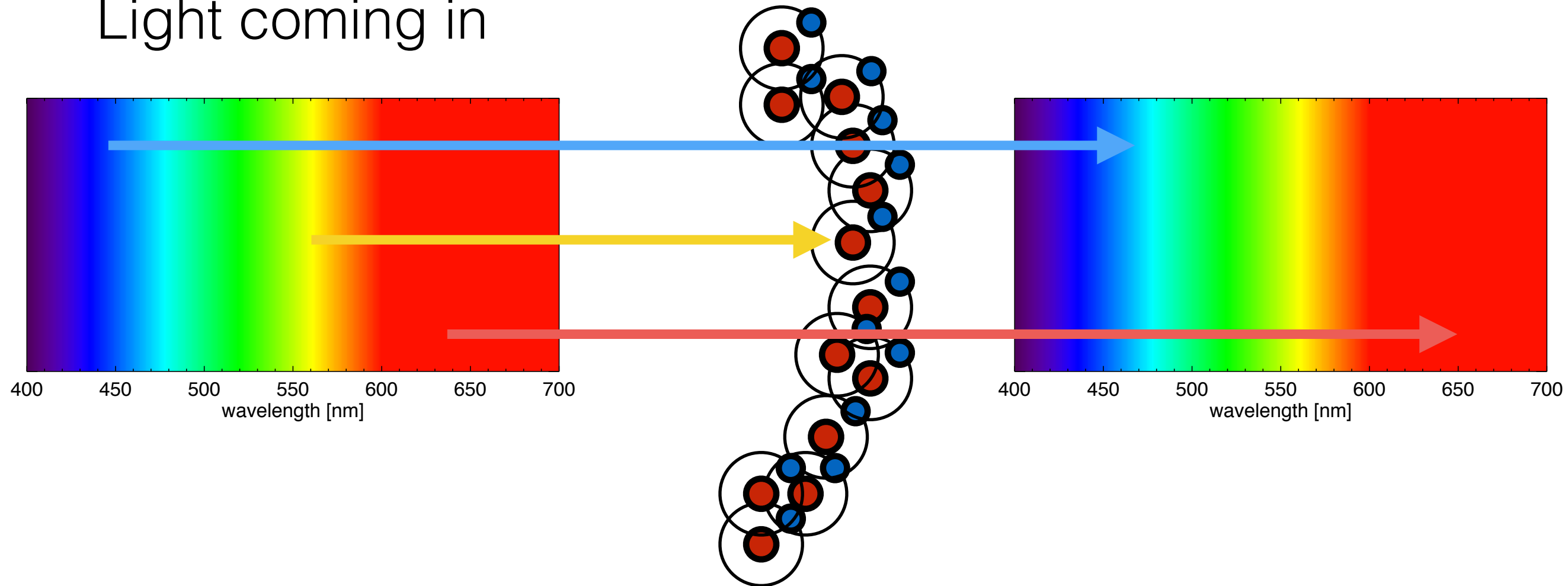


Atoms & light



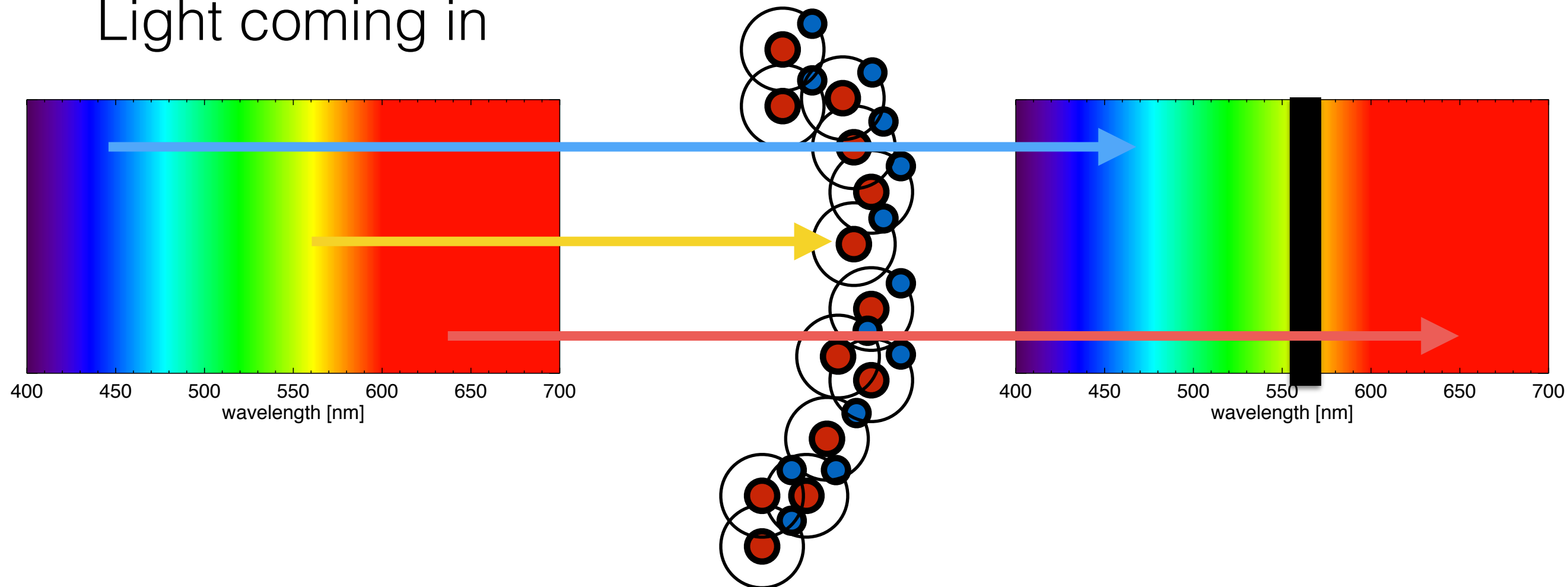
Atoms & light

Light coming in

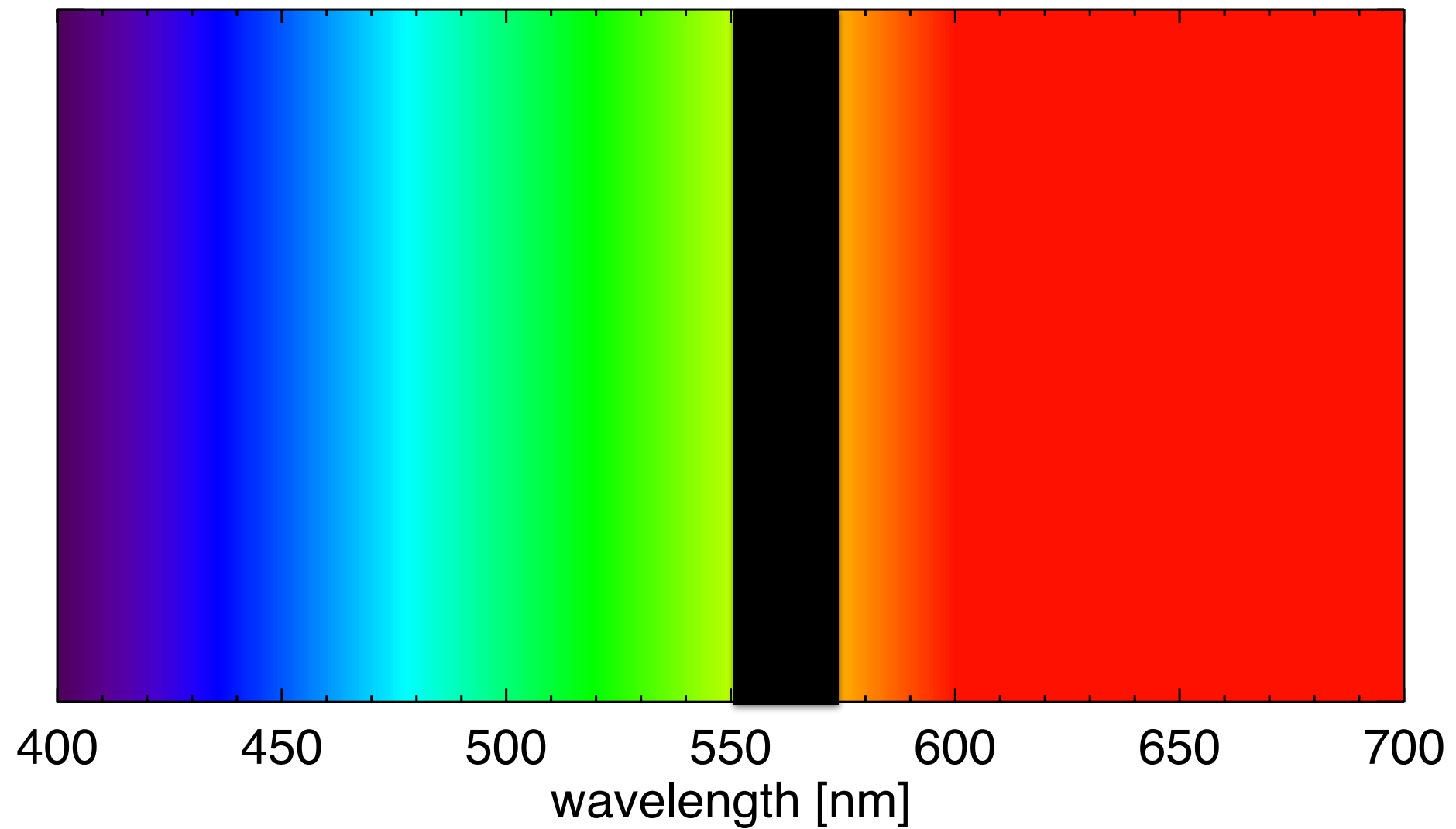


Atoms & light

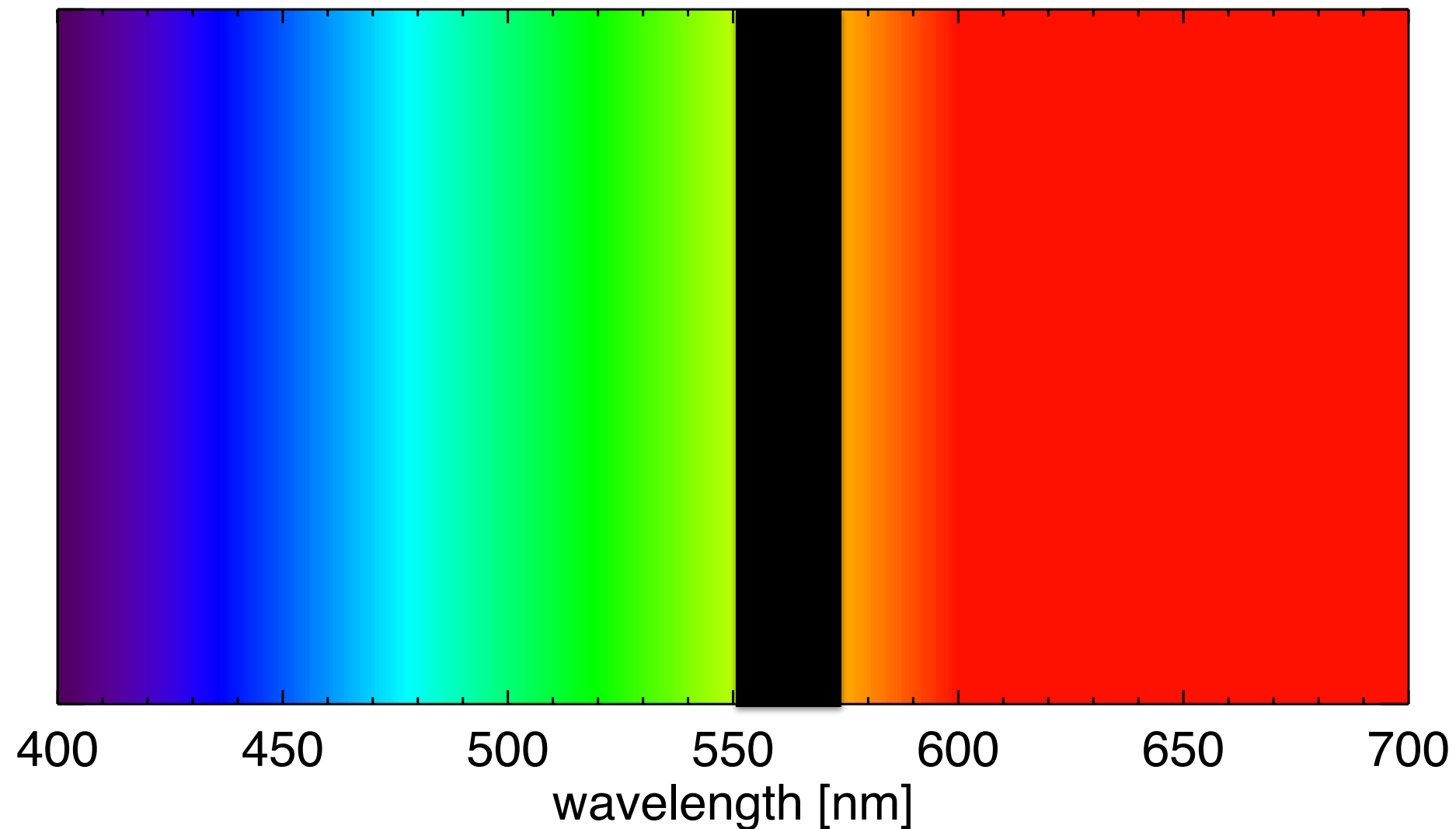
Light coming in



Atoms & light



Atoms & light

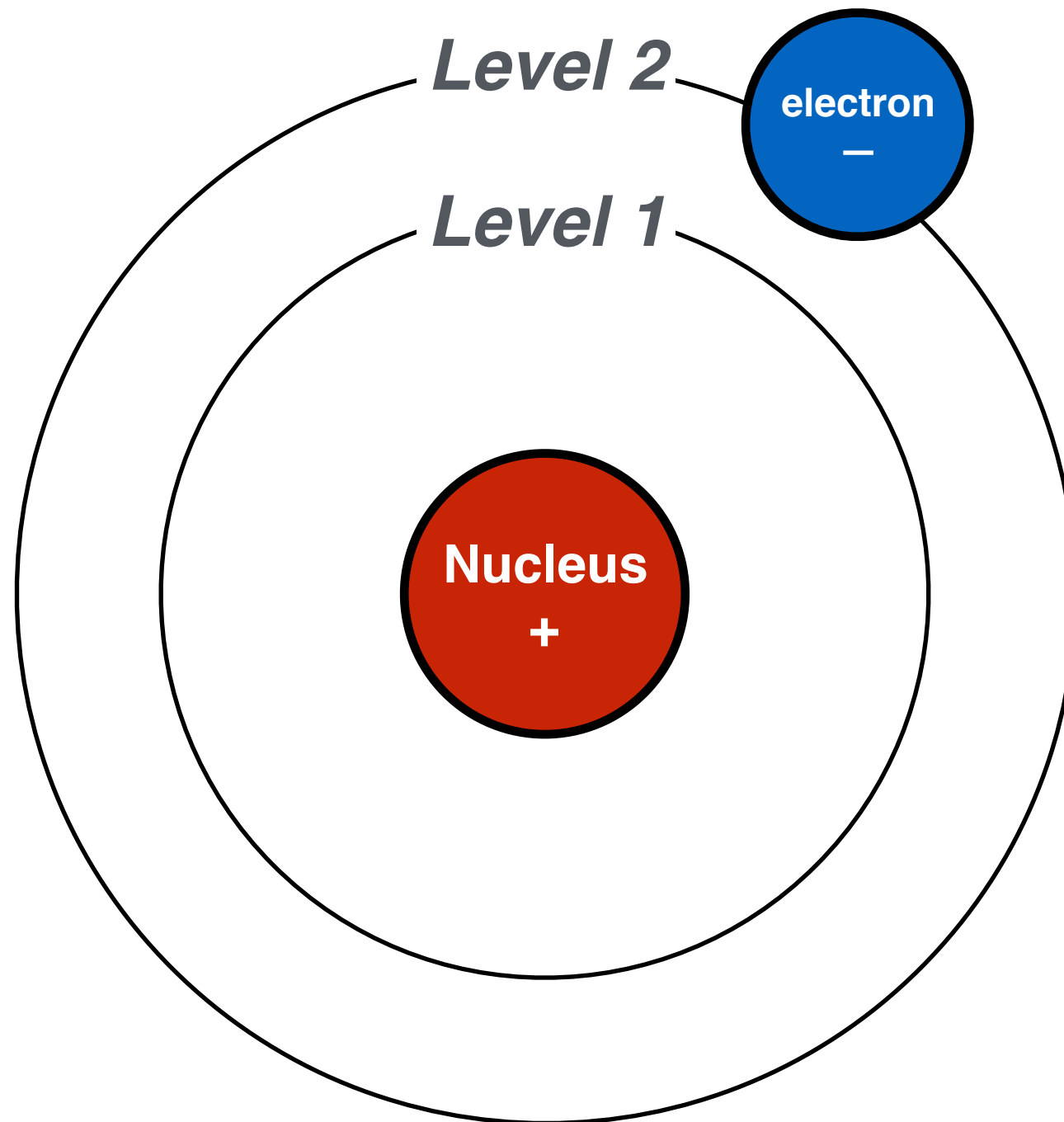


Yellow light was **absorbed** by atoms!

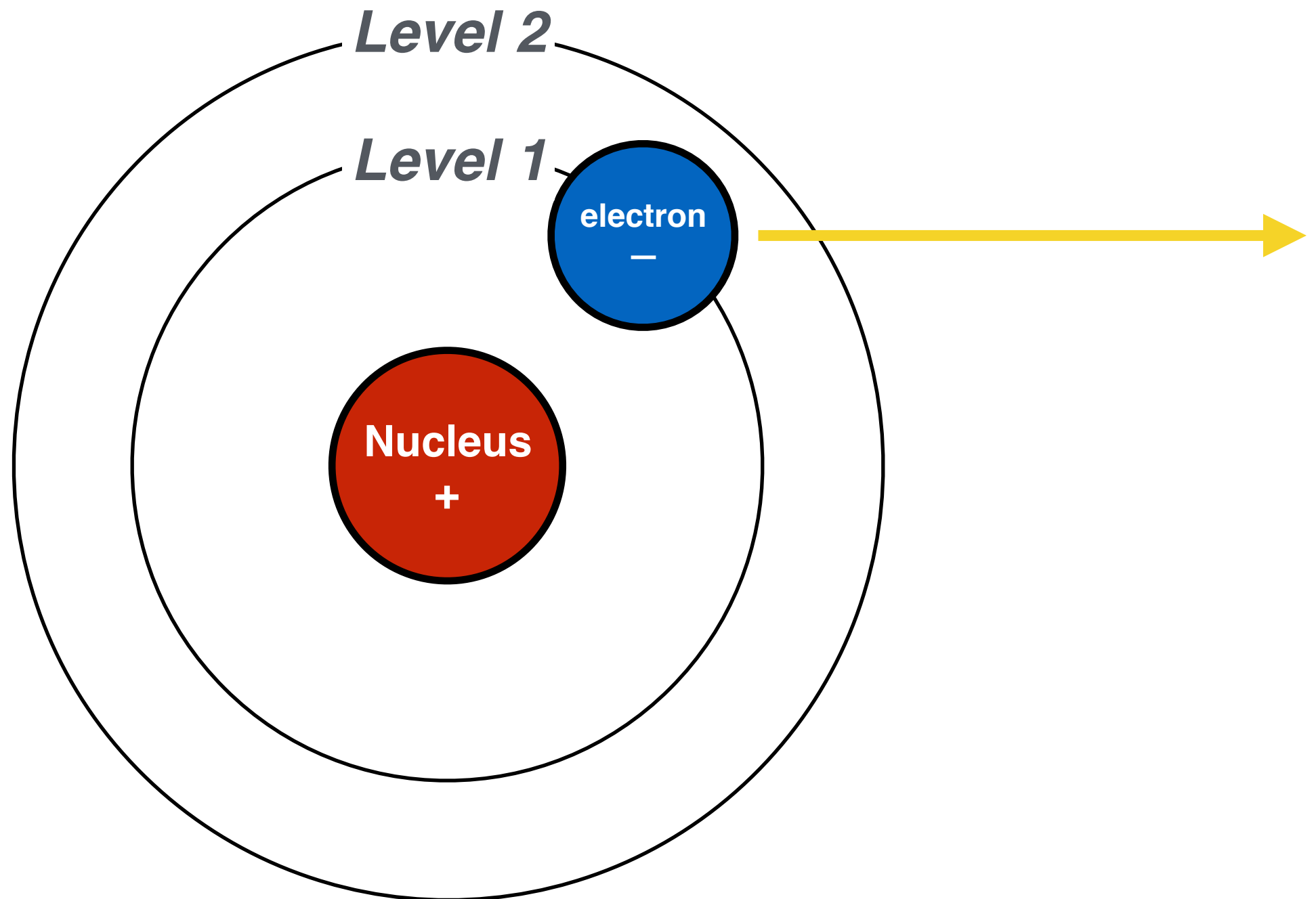
Also happens in reverse

*Atoms emit the
same color that they
absorb!*

Atoms & light



Atoms & light



Upshot

- A star's **colors** tell us what **atoms** it is made of.

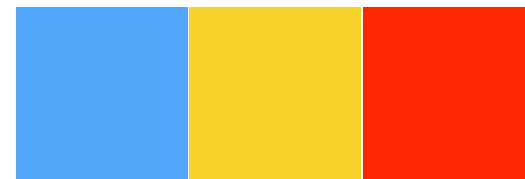
Upshot

- A star's **colors** tell us what **atoms** it is made of.

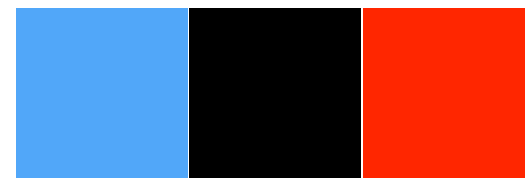
 \Rightarrow **stellar composition**

Atoms & light

- Colors going **in**:

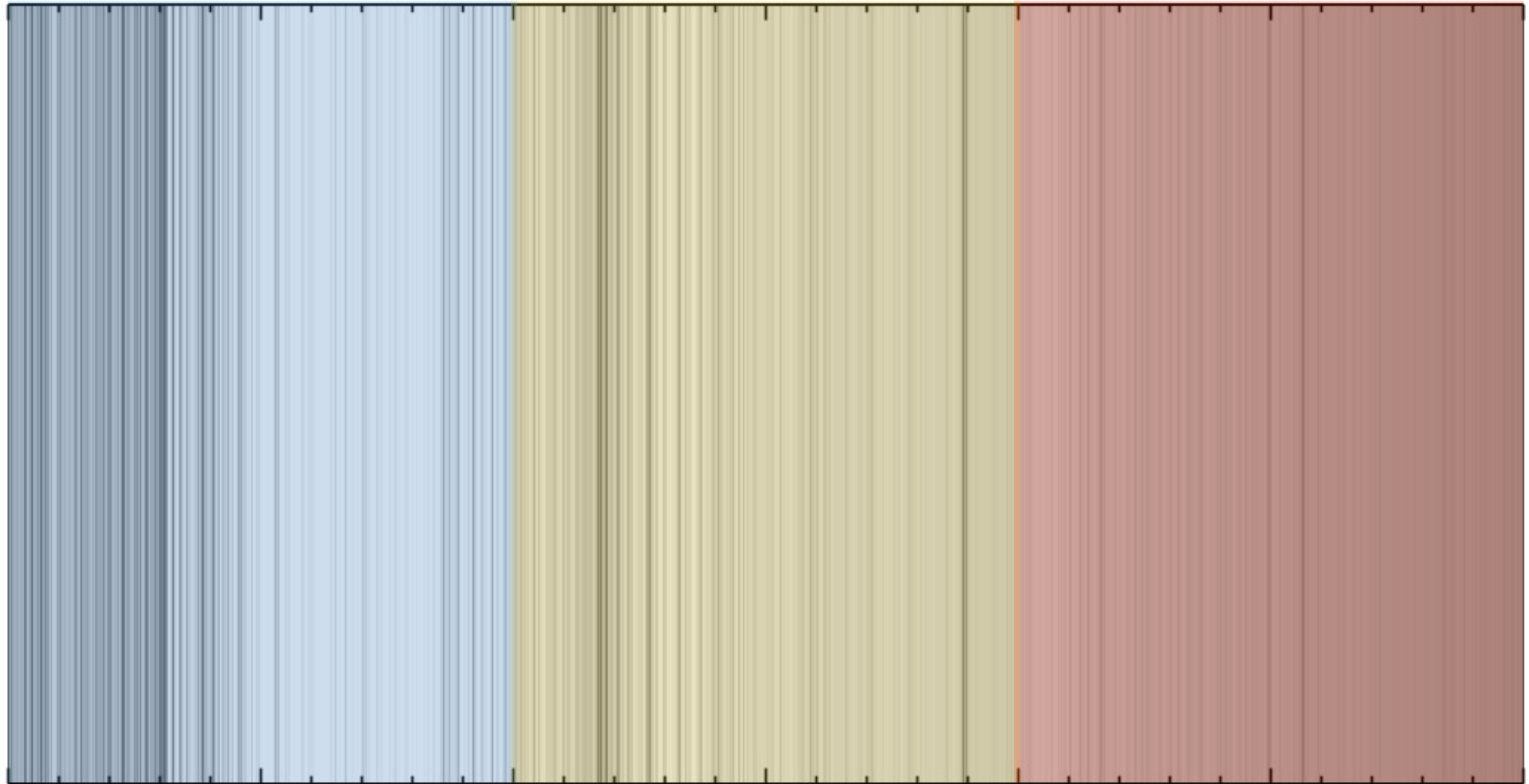


- Colors coming **out**:



- *Missing light is the shadows of electrons!*

Example spectrum of a star



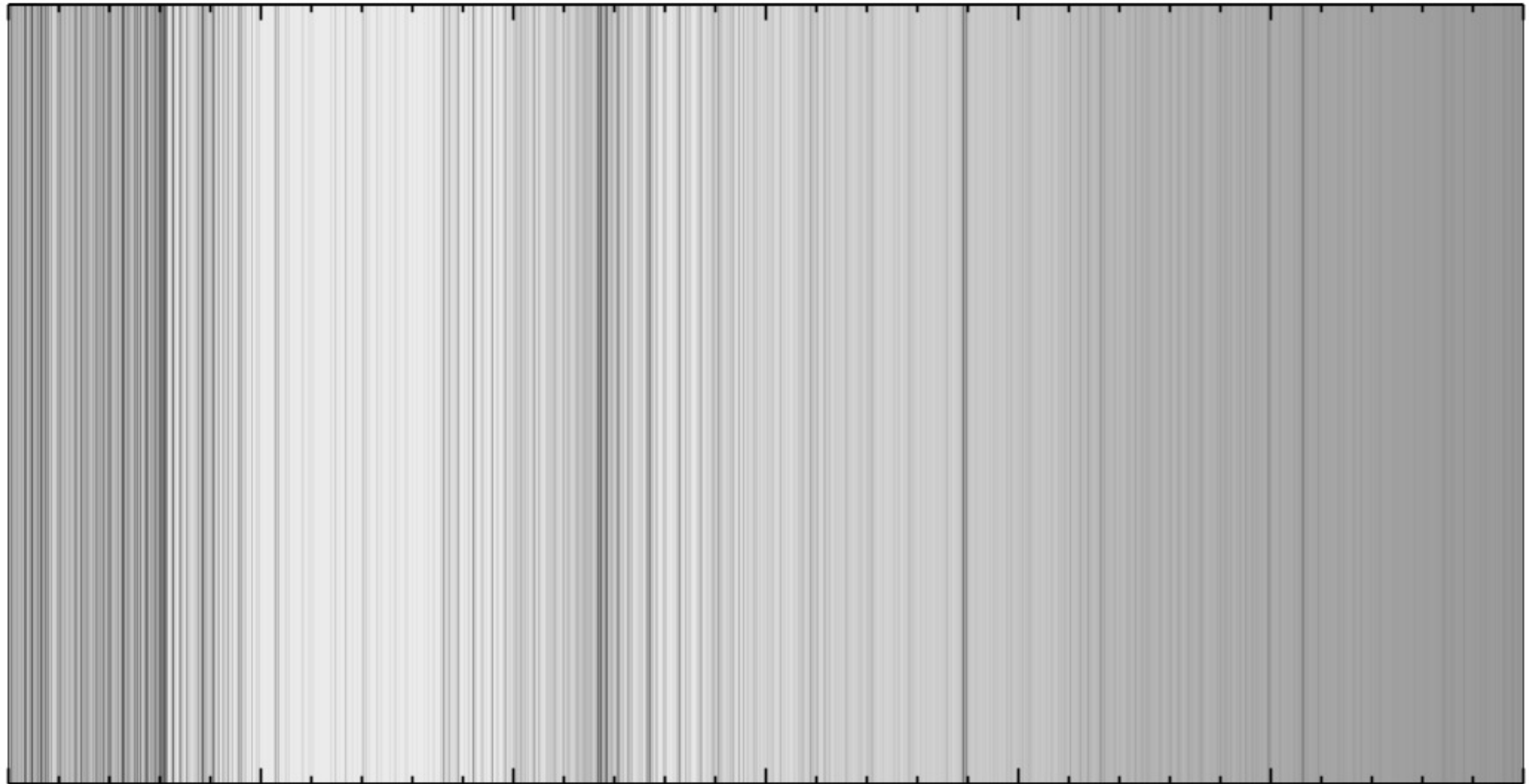
Blue

Yellow

Red

Color of light

Example spectrum of a star



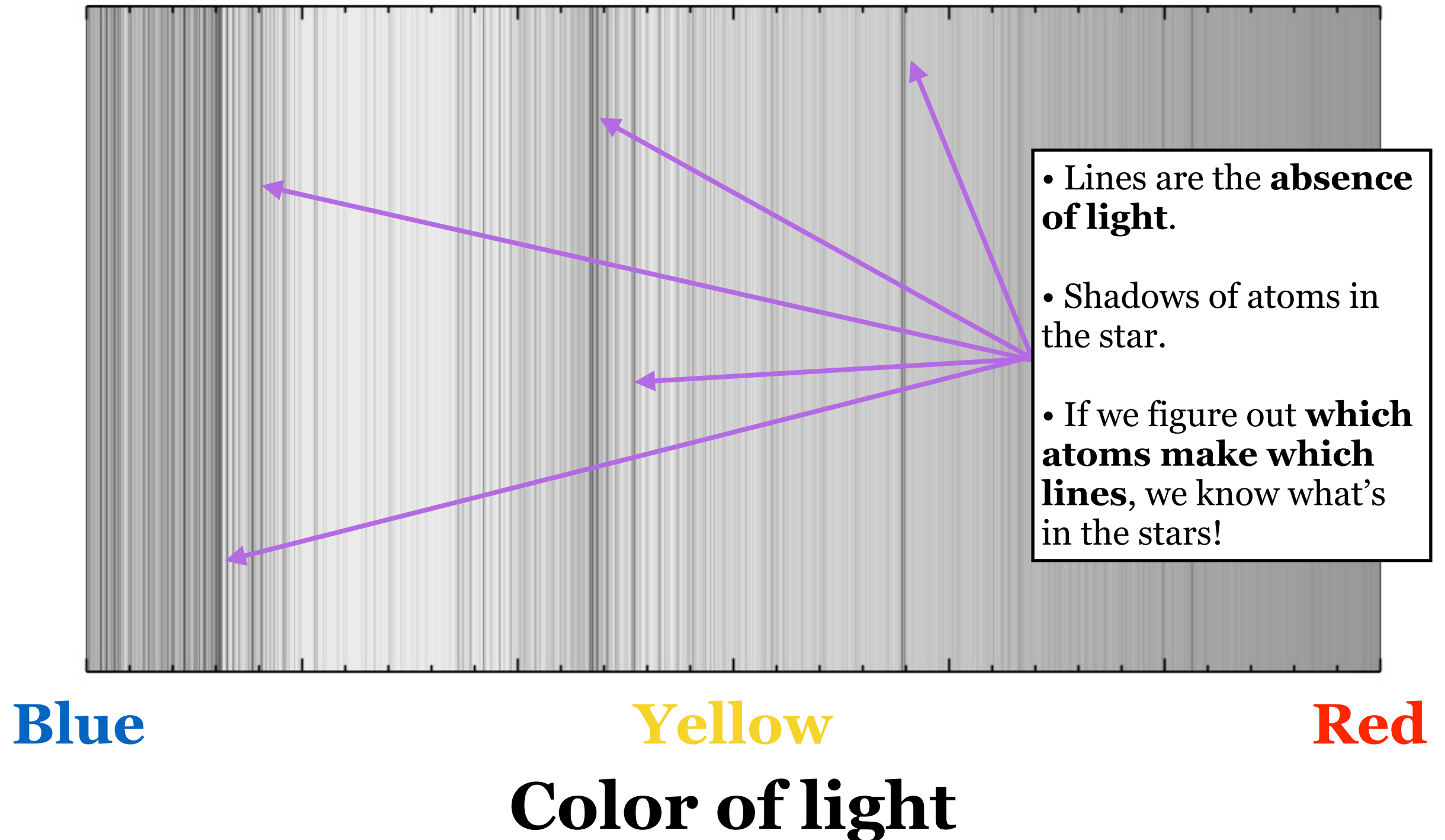
Blue

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Color of light

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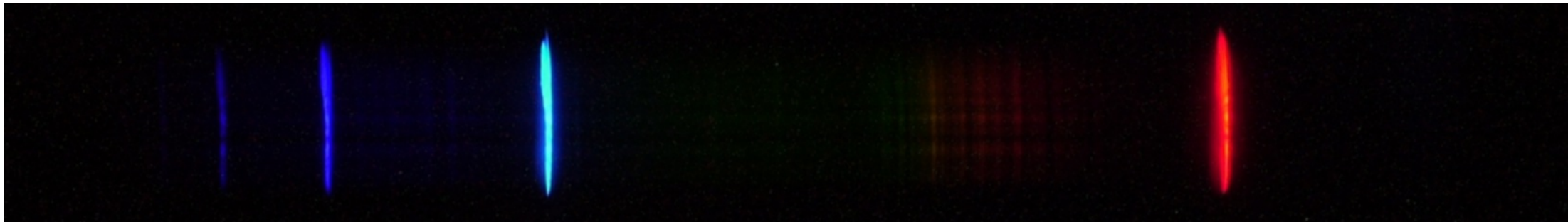


Let's try it!

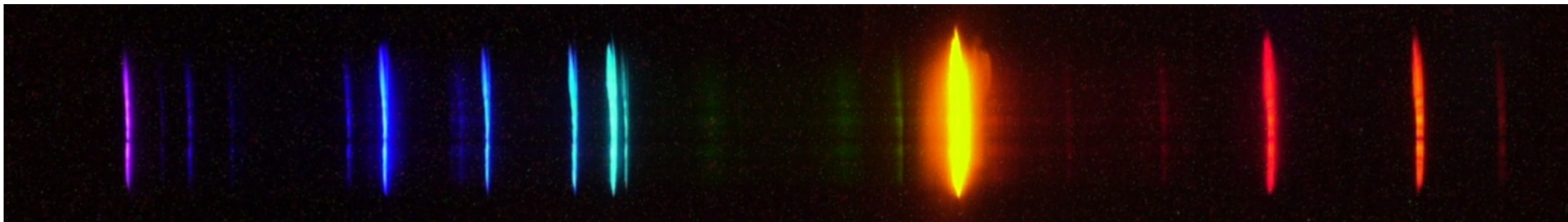
(Do some spectroscopy)

(What you should've
seen...)

Hydrogen

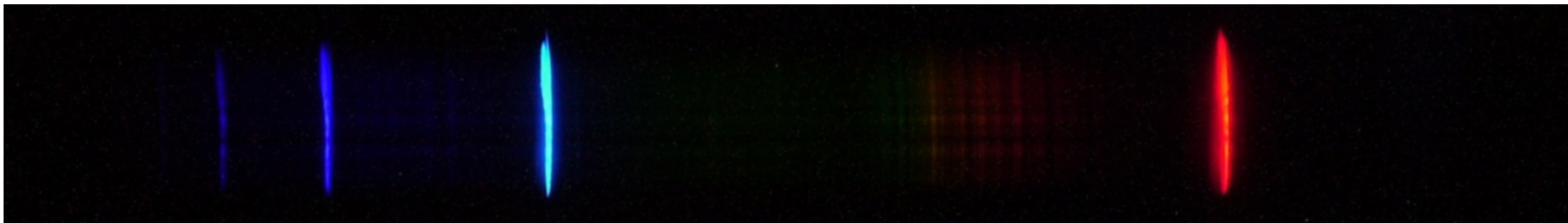


Helium

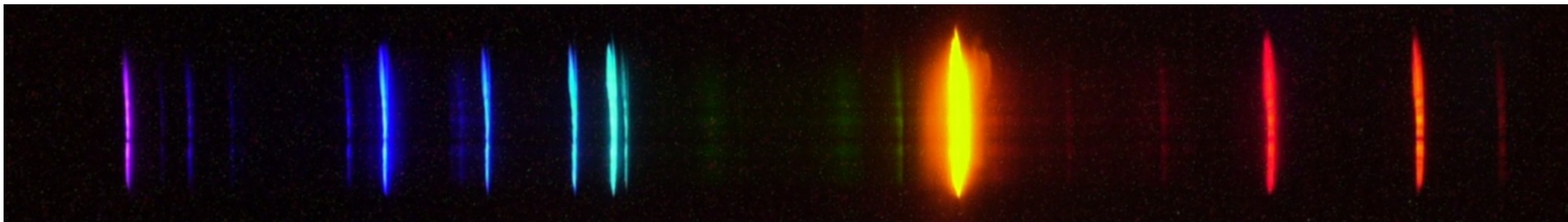


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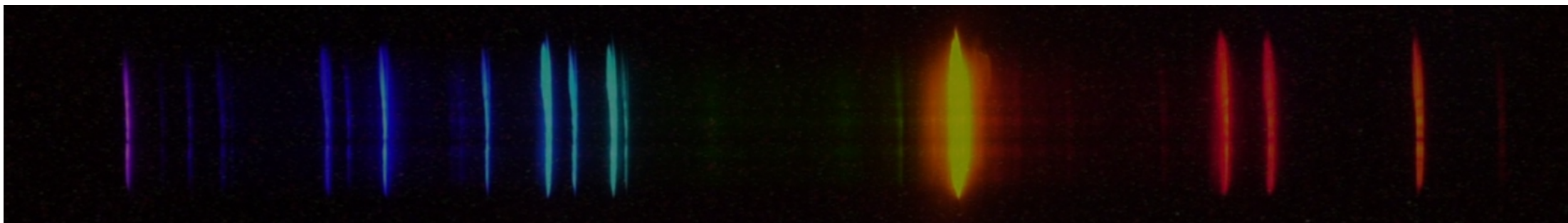
Hydrogen



Helium



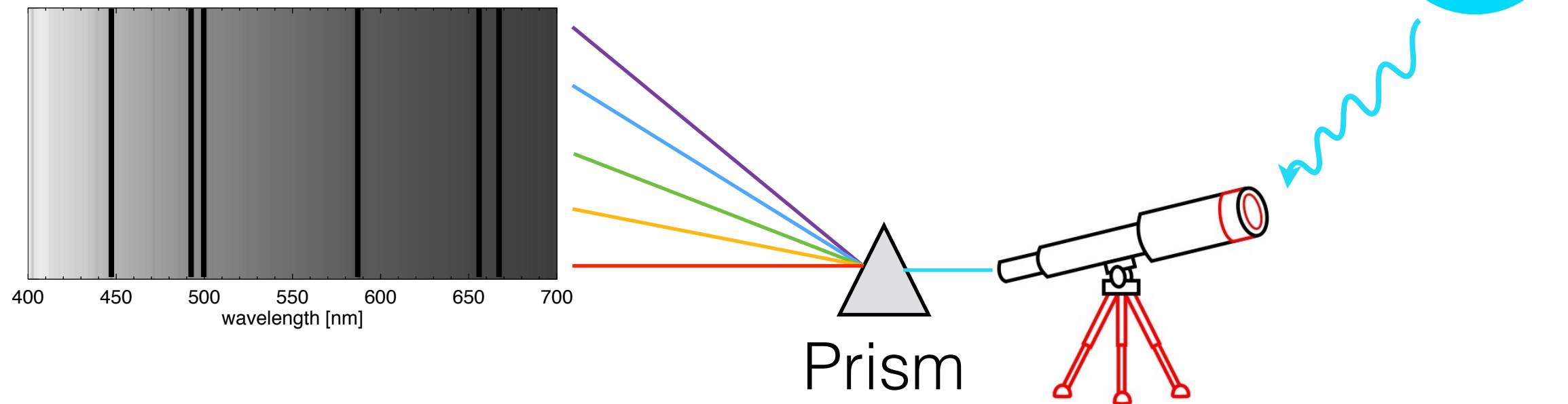
H+He...



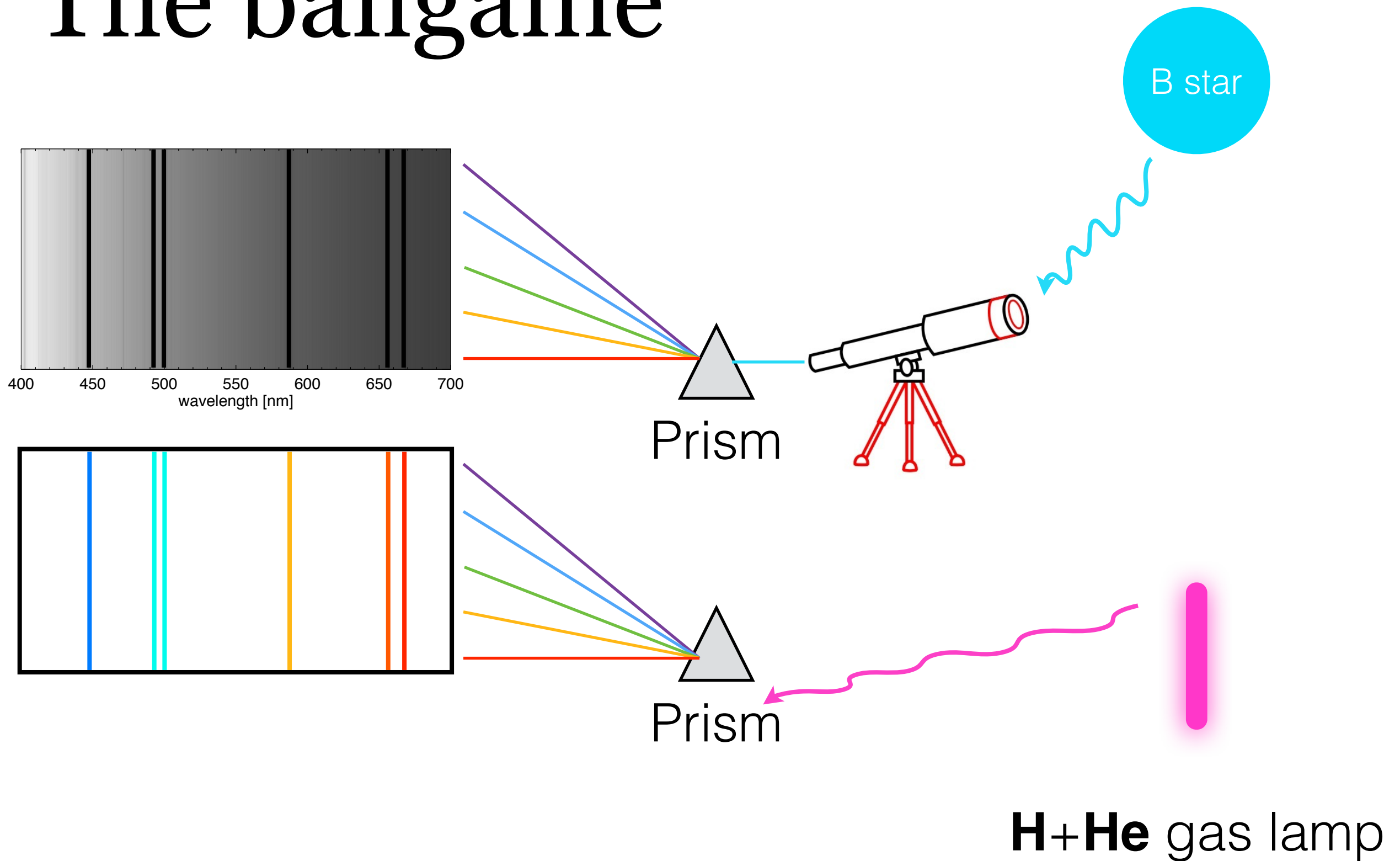
Breaking up light



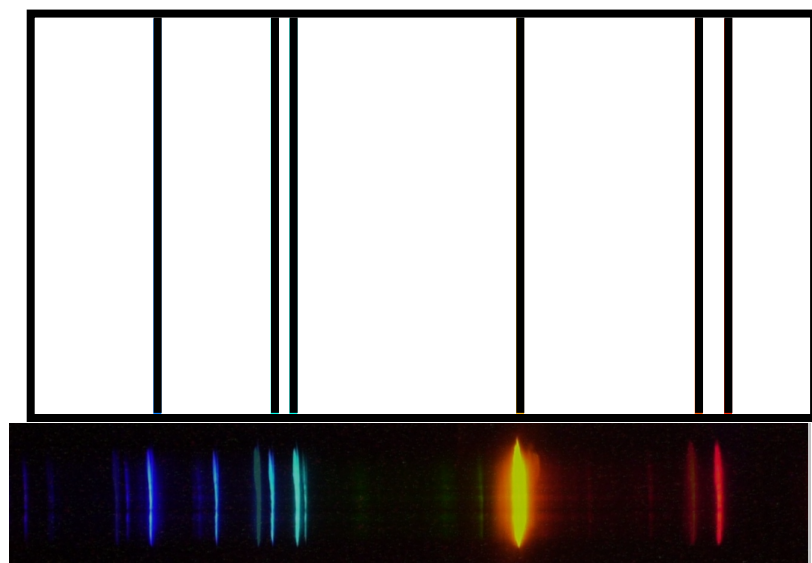
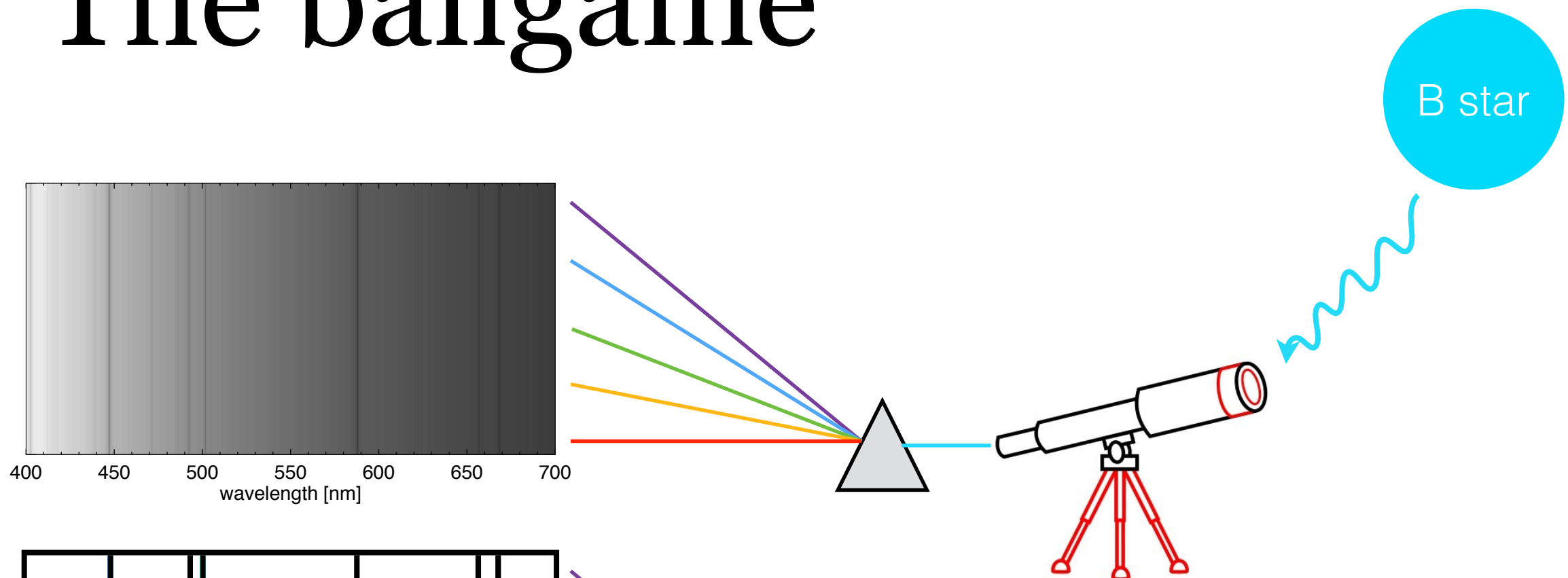
The ballgame



The ballgame



The ballgame

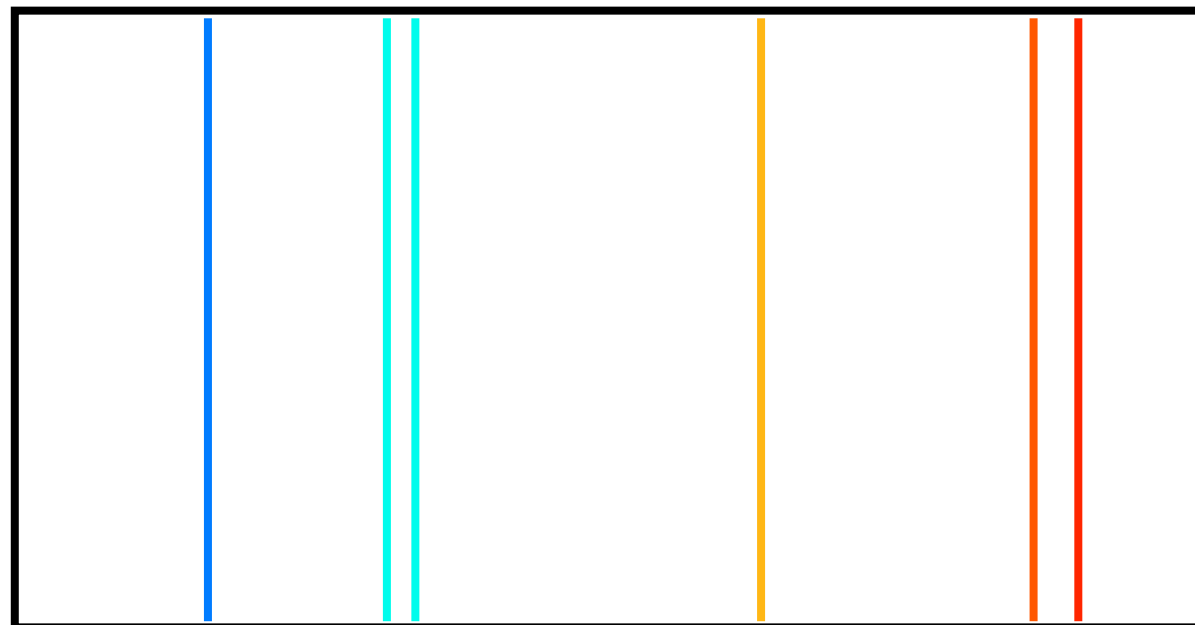
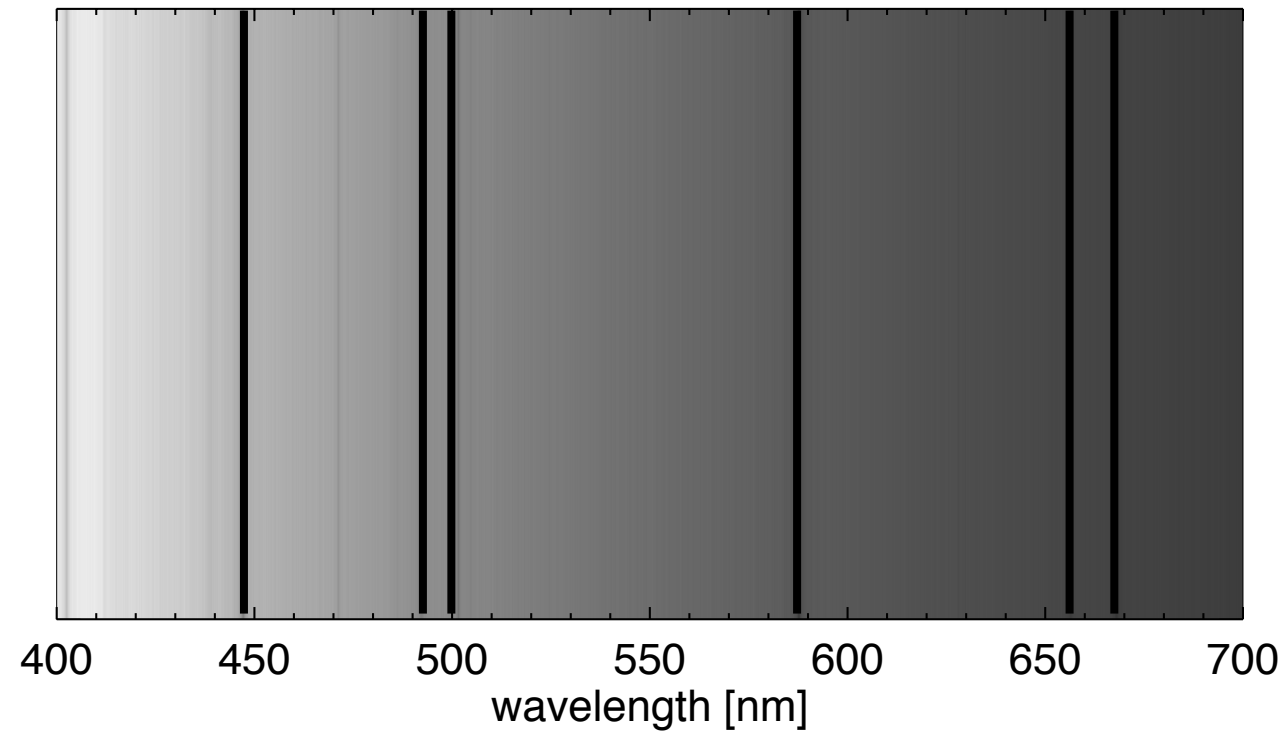


The star is made of
Helium and **Hydrogen**!



H+He gas lamp

The ballgame



The ballgame



The ballgame

**We barcode the stars
to learn what they're made of!**

But why?



Earth

(1)



Telescopes
(+ spectrographs)

Earth
(+ atmosphere)



The Milky Way
(our neighborhood)

Telescopes
(+ spectrographs)

Earth
(our home)



THE UNIVERSE

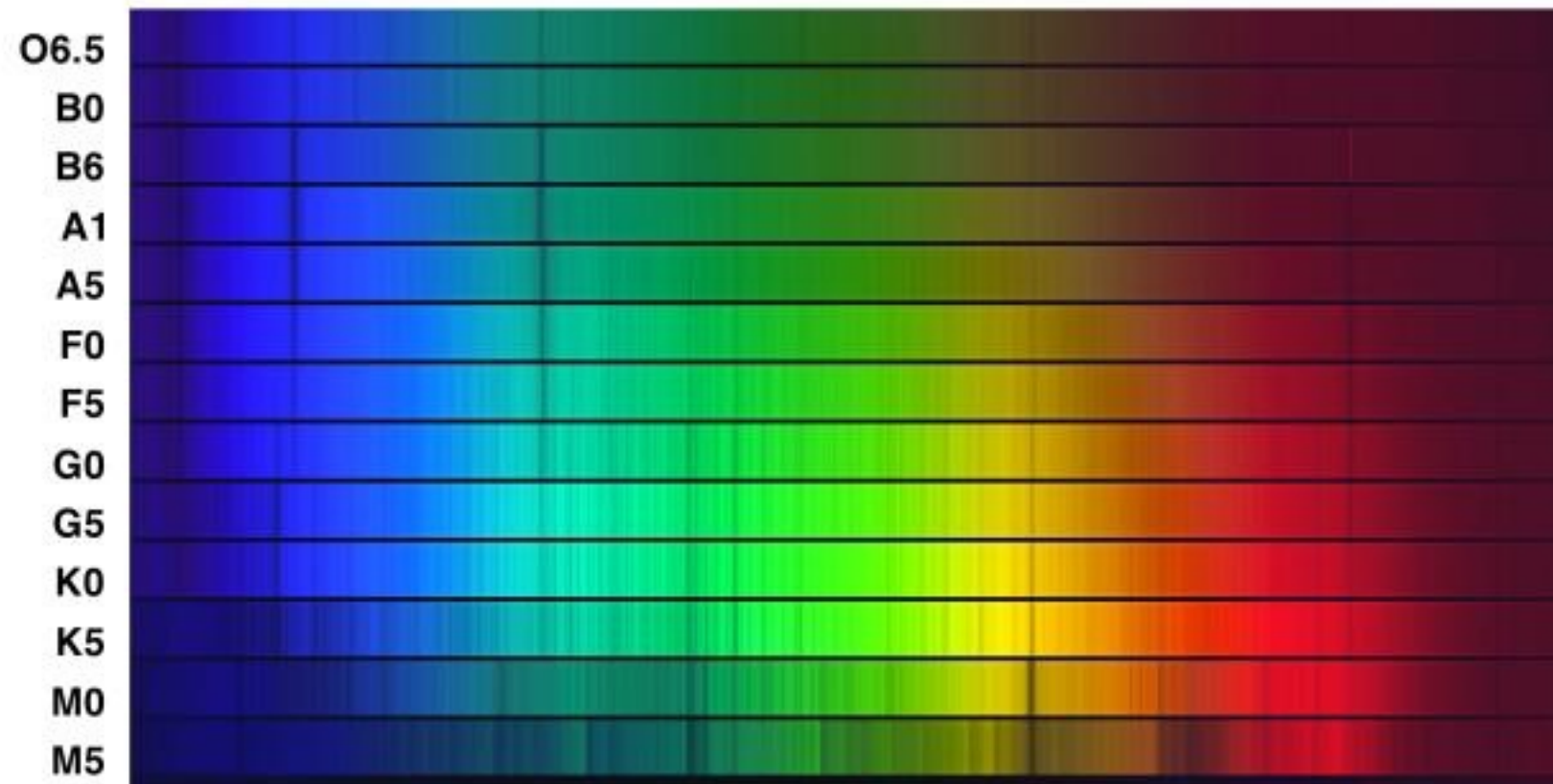
*The Milky Way
(our neighborhood)*

**Telescopes
(+ spectrographs)**

Earth
(1)

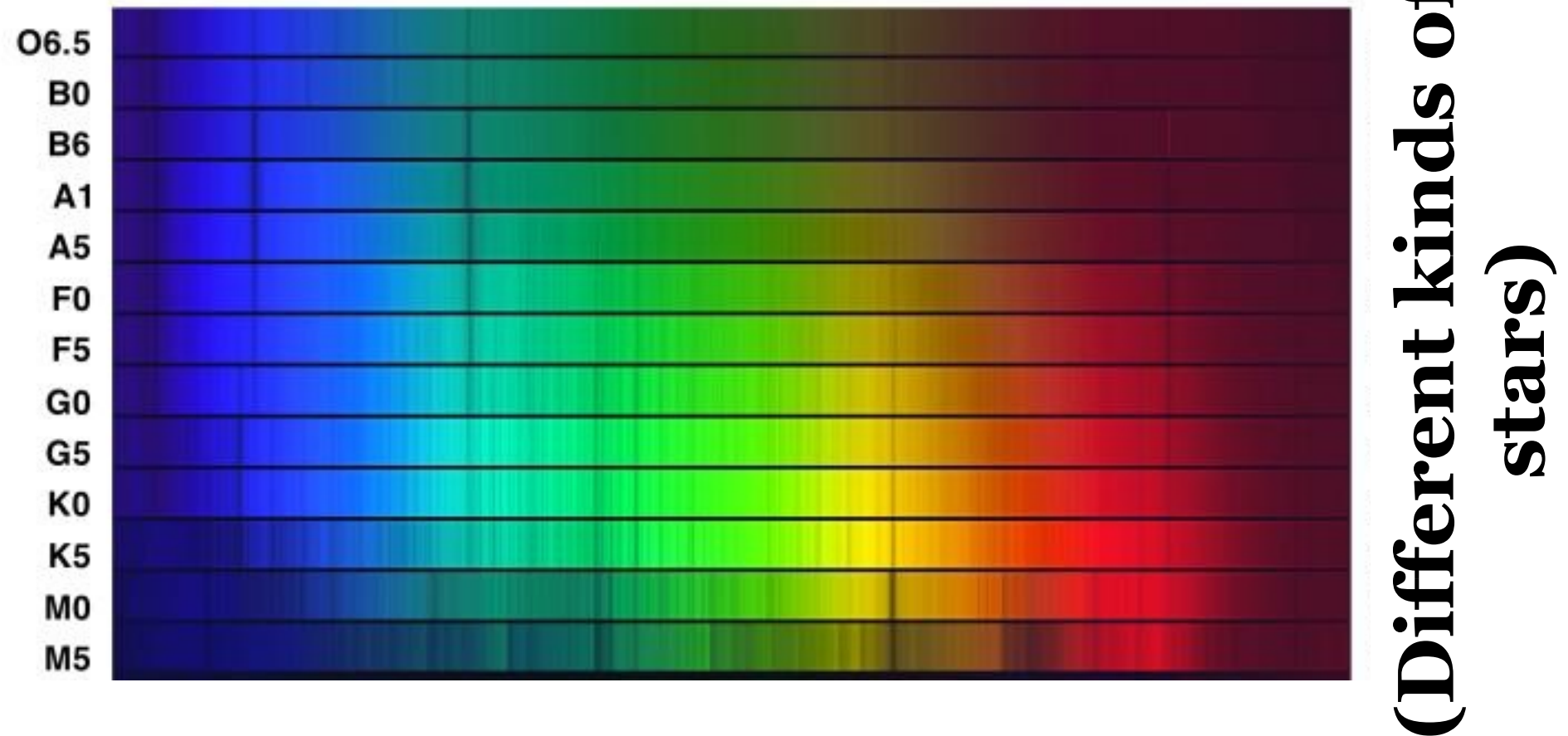


Looks like just a bunch of lines ...



(Different kinds of
stars)

**Looks like just
a bunch of lines ...**



...but...

When stars die, they eject heavy elements (Carbon, Oxygen, etc) into the interstellar space. These elements later form new stars with planets that can potentially host life!

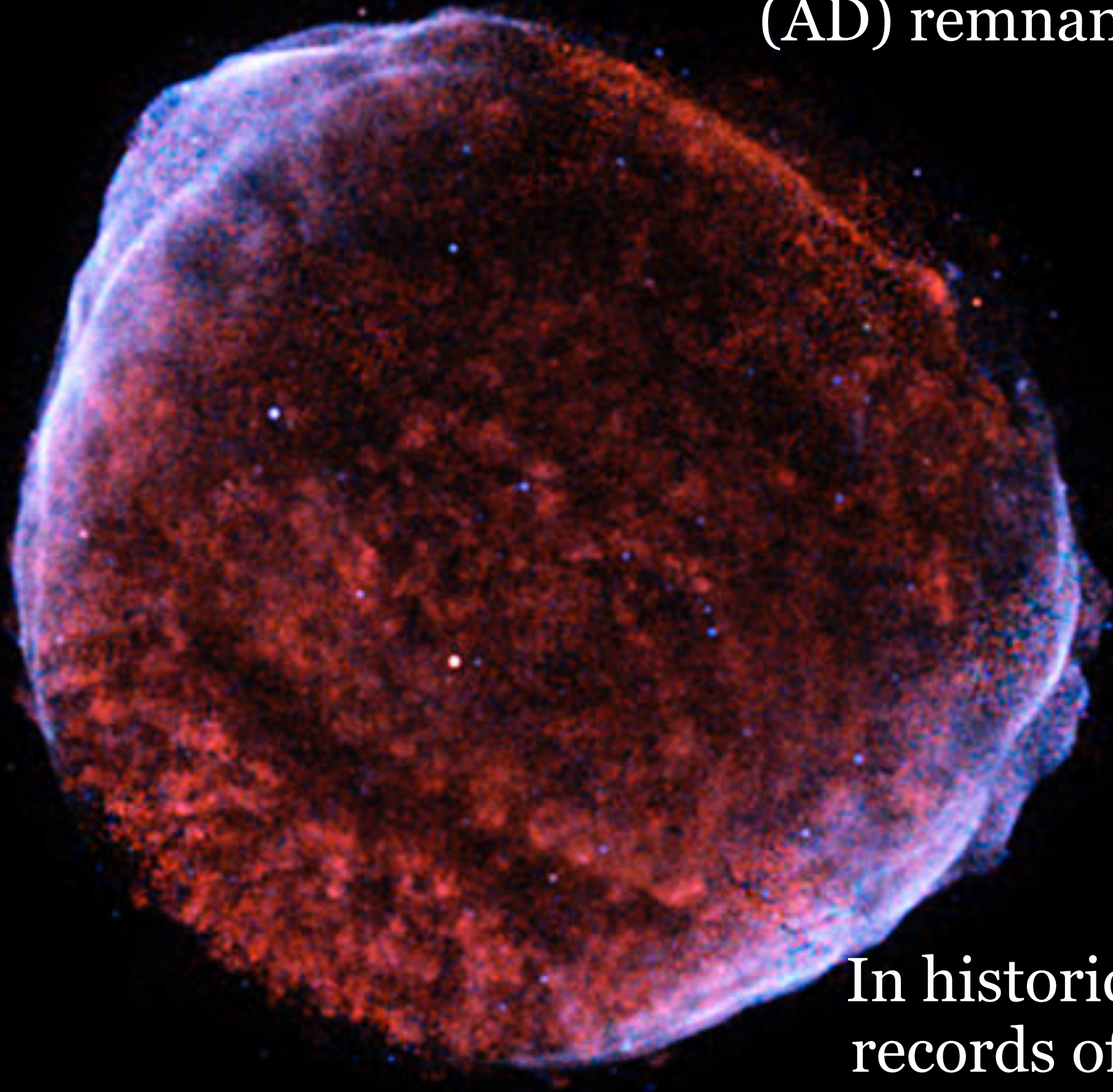
This stuff is in us! →

The Cat's Eye Planetary Nebula



The Helix Planetary Nebula

Supernova 1006 (AD) remnant



In historical
records of 3
continents!

Supernova 1987 in Large Magellanic Cloud

