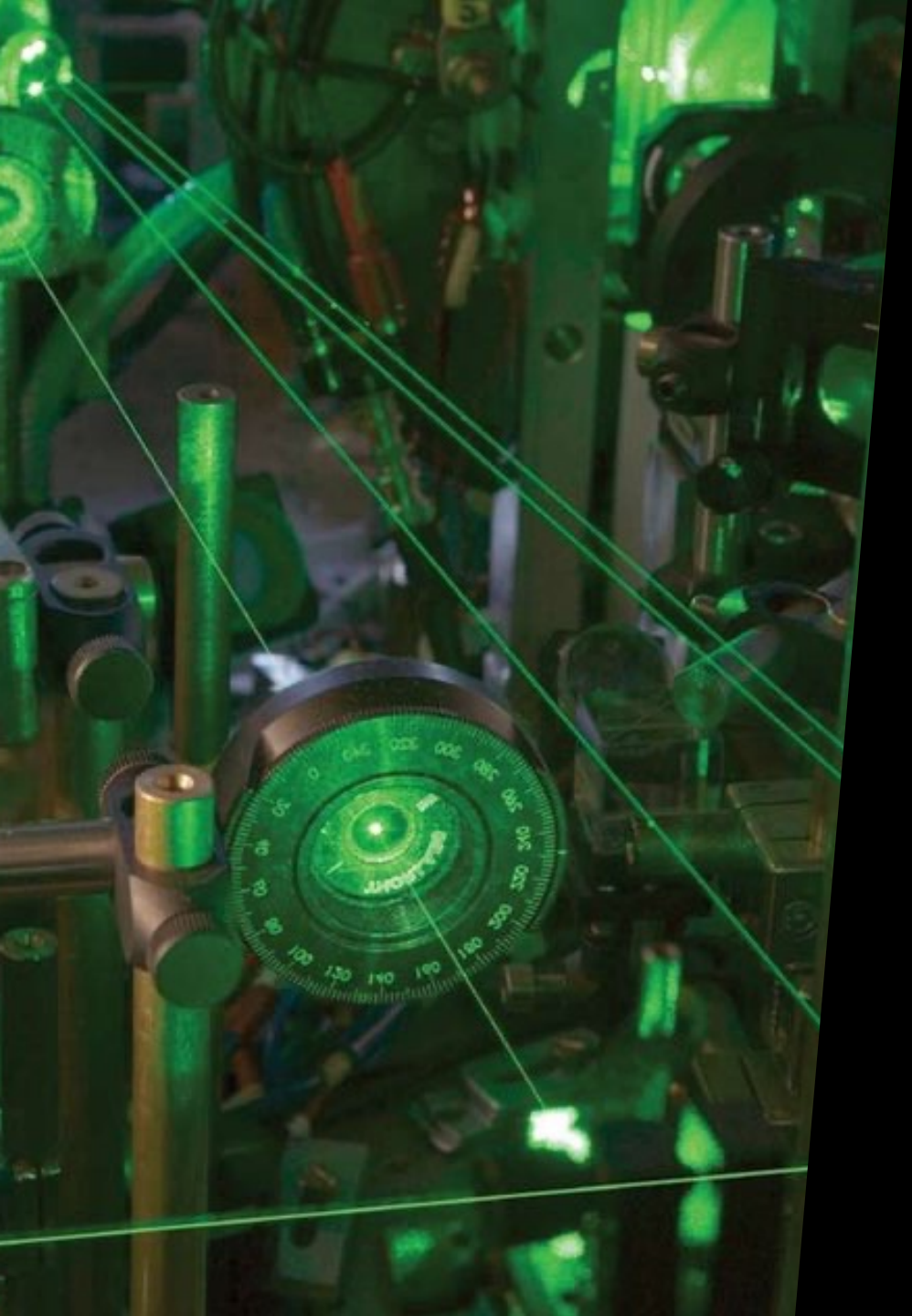
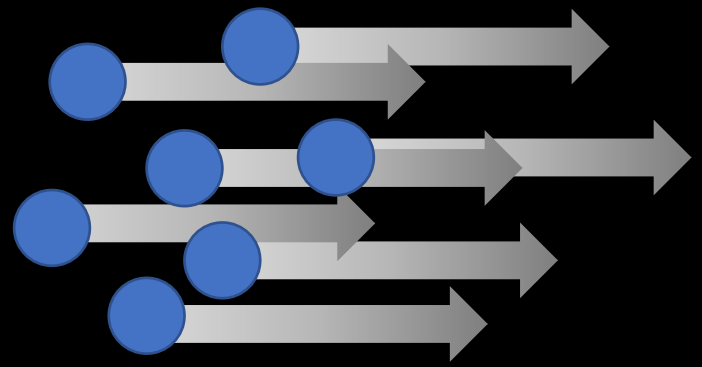


Zero Temperature Ultracold Matter

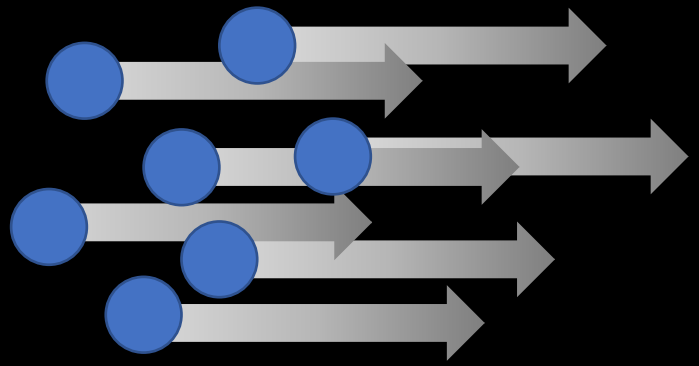
Alexander Rothkopf (University of Stavanger)
@rothkopfAK, www.alexrothkopf.de

Image from American Scientist – Image credit: Pascal Goetgheluck
For a report on cooling atoms with lasers: https://bit.ly/3MibNrY

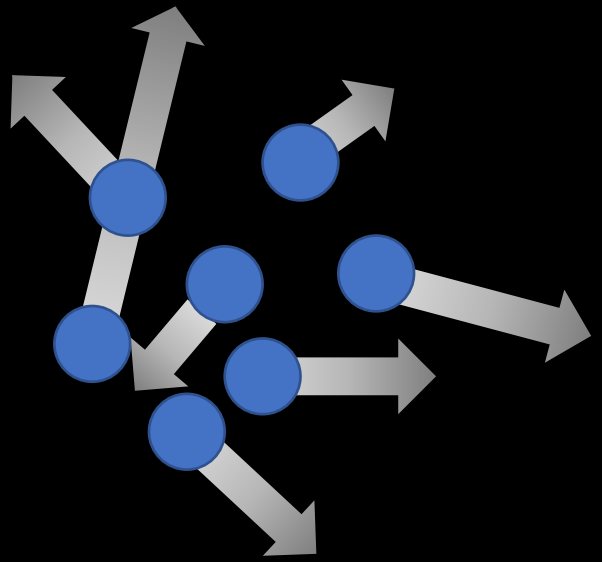
What is Temperature?



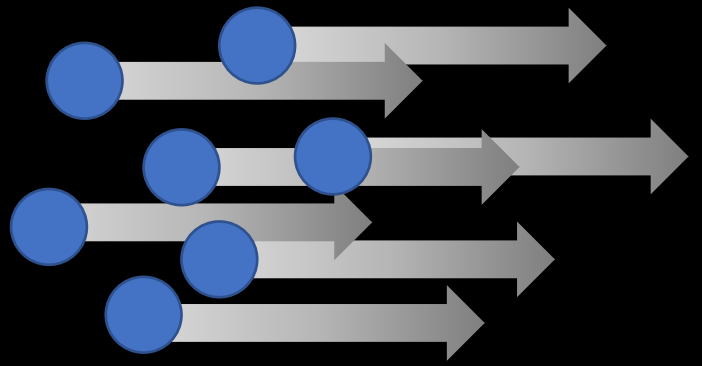
directed kinetic energy



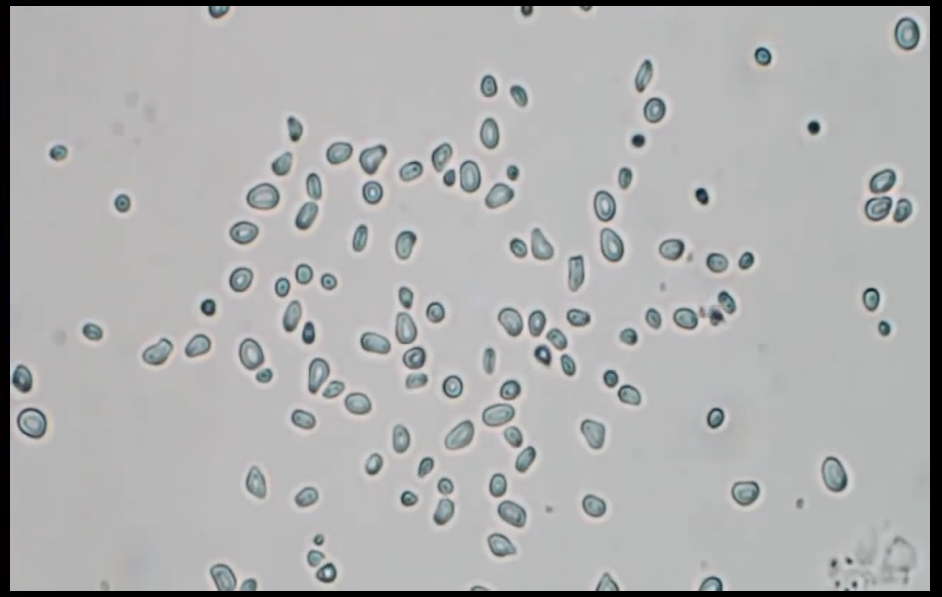
directed kinetic energy



undirected kinetic energy



directed kinetic energy



undirected kinetic energy

Movie by Koshu Endo

Low temperature =

less random motion

Low temperature =

less random motion

0 °Celsius

Water freezes

Low temperature =

less random motion

0 °Celsius
Water freezes

0 °Fahrenheit
Brine (water&salt)
freezes

Low temperature =

less random motion

0 °Celsius
Water freezes

0 °Fahrenheit
Brine (water&salt) freezes

0 ° Kelvin
Absence of any motion

The coldest place in the universe?

Antarctica

−89.2 °C
-128.6 °F
180 °K

bit.ly/3MUKGnd
Image credit: New Scientist

Antarctica

-89.2 °C
-128.6 °F
180 °K

bit.ly/3MUKGnd
Image credit: New Scientist

Boomerang Nebula

-272 °C
-522 °F
1.15 °K

https://bit.ly/3MmeWqP
Image credit: Space.com

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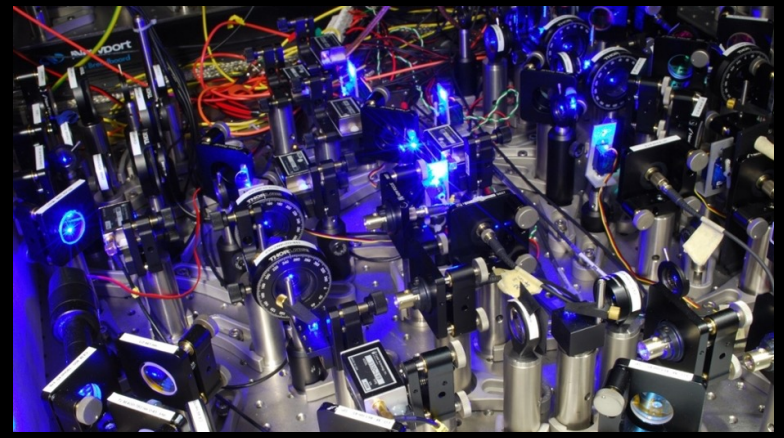
Image credit: Space.com

Physics Laboratory



-273.149999 °C
-459.669999 °F
0.000000001 °K

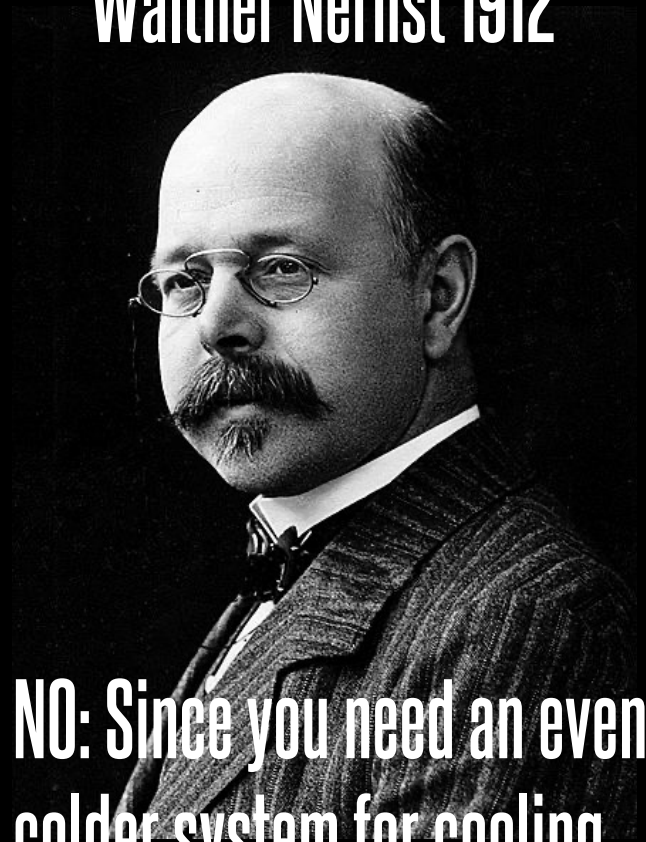
https://bit.ly/44O7D2l
Image credit: University of Amsterdam

Can one reach zero Kelvin?

Images: Wikipedia

Can one reach zero Kelvin?

Walther Nernst 1912

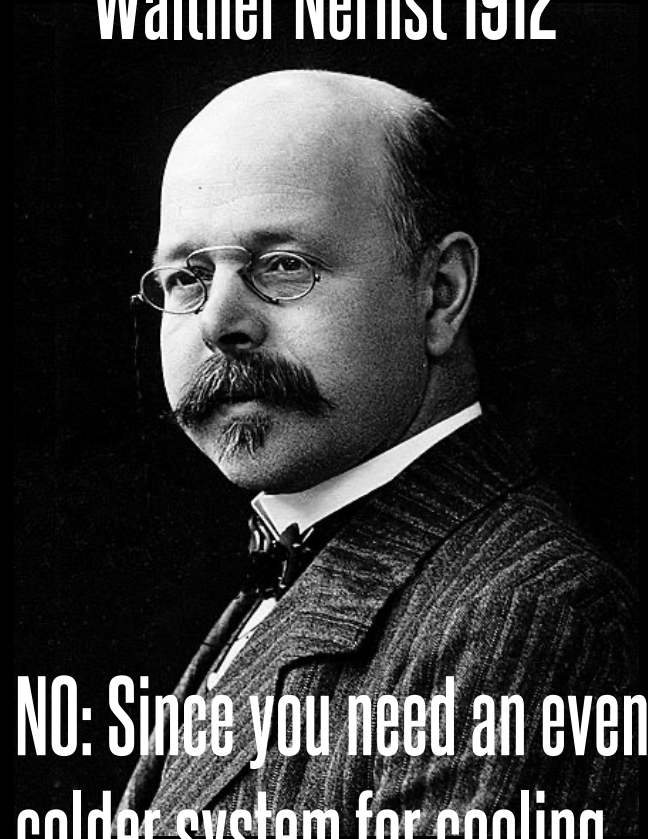


NO: Since you need an even colder system for cooling

Images: Wikipedia

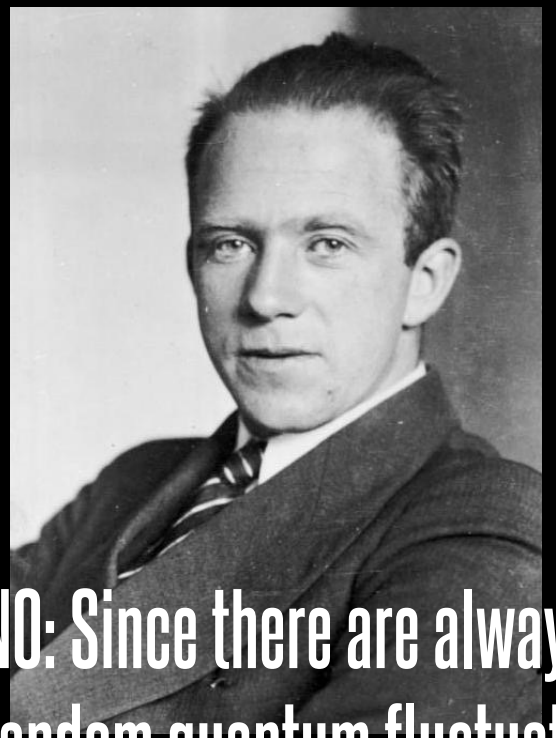
Can one reach zero Kelvin?

Walther Nernst 1912



NO: Since you need an even colder system for cooling

Werner Heisenberg 1927

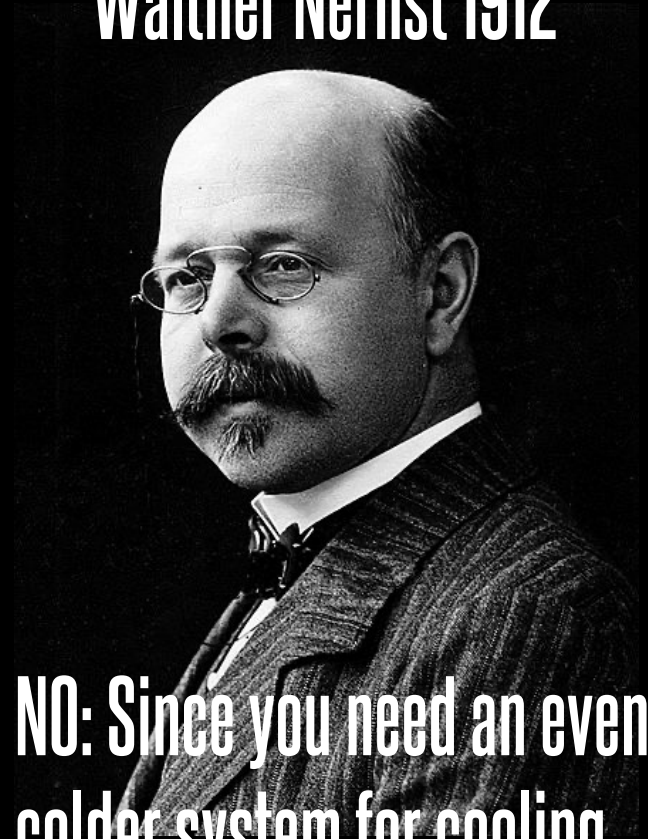


NO: Since there are always random quantum fluctuations

Images: Wikipedia

Can one reach zero Kelvin?

Walther Nernst 1912



NO: Since you need an even colder system for cooling

Werner Heisenberg 1927

NO: Since there are always random quantum fluctuations

Images: Wikipedia

A journey towards Zero Kelvin

Cryogenics challenge

Find out more about Cryogenics: https://bit.ly/41zIZzB

Cryogenics challenge

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How to cool?

Cleverly compress and expand gasses < 1/100K

He (4.2K) N(77.4K)

Cryogenics challenge

Find out more about Cryogenics: https://bit.ly/41zIZzB

How to cool?

Cleverly compress and expand gasses < 1/100K

He (4.2K) N(77.4K)

How to check?

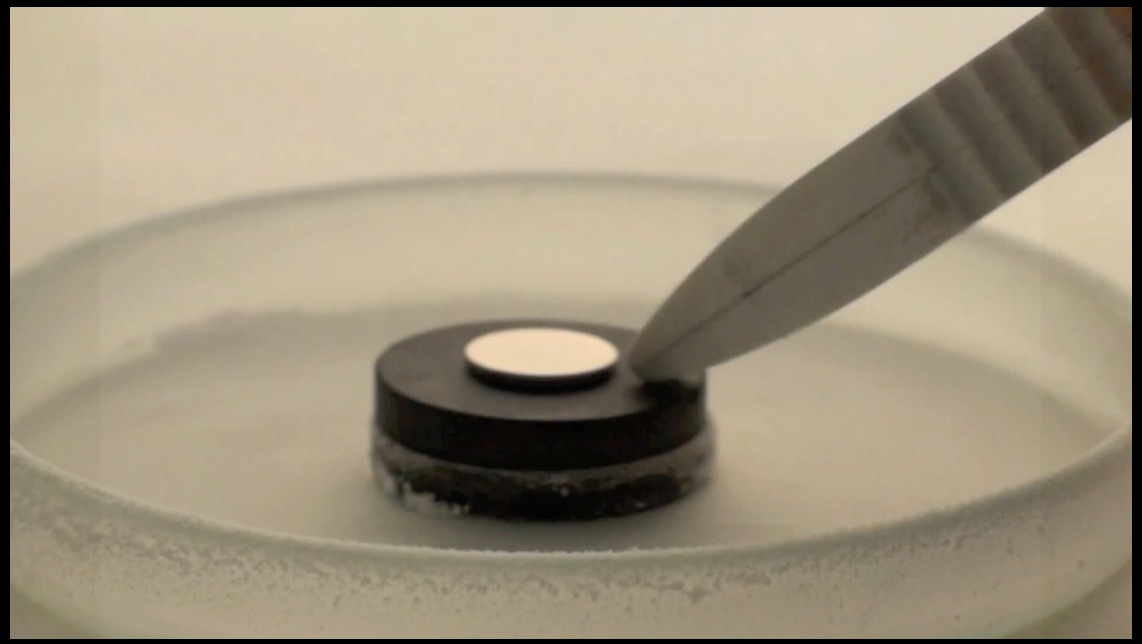
Measure how materials conduct electricity

Superconductivity & Superfluidity

Videos: Wikipedia & Pint of Science FR

Superconductivity & Superfluidity

Currents without resistance



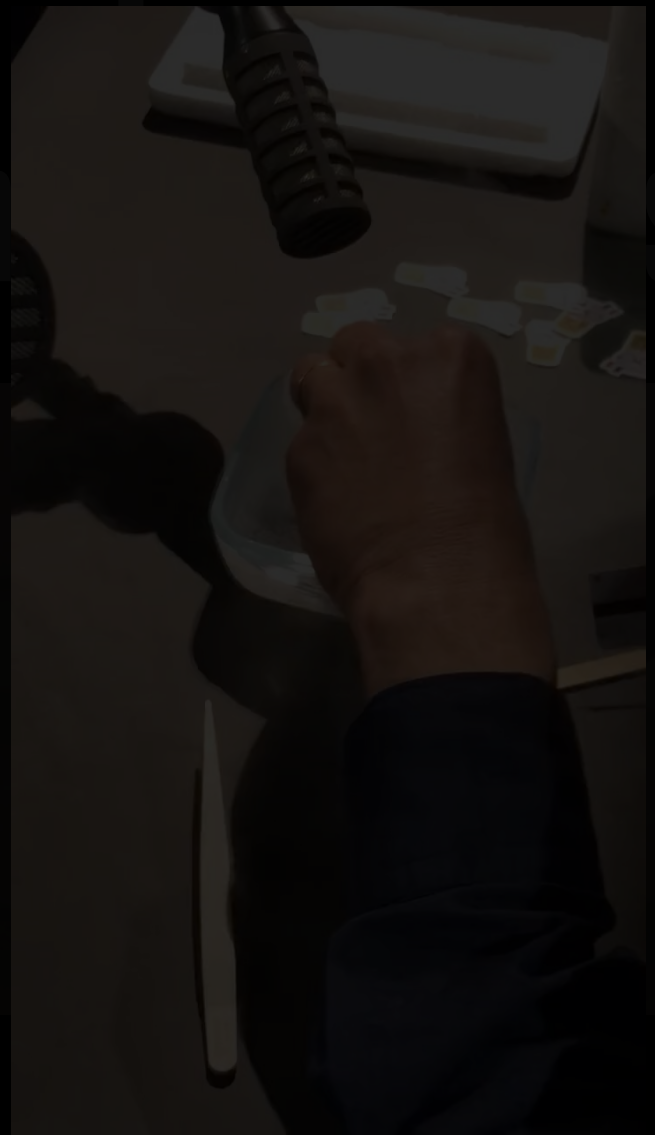
Videos: Wikipedia & Pint of Science FR

Superconductivity & Superfluidity

Curren stance

Videos: Wikipedia & Pint of Science FR

Superconductivity & Superfluidity

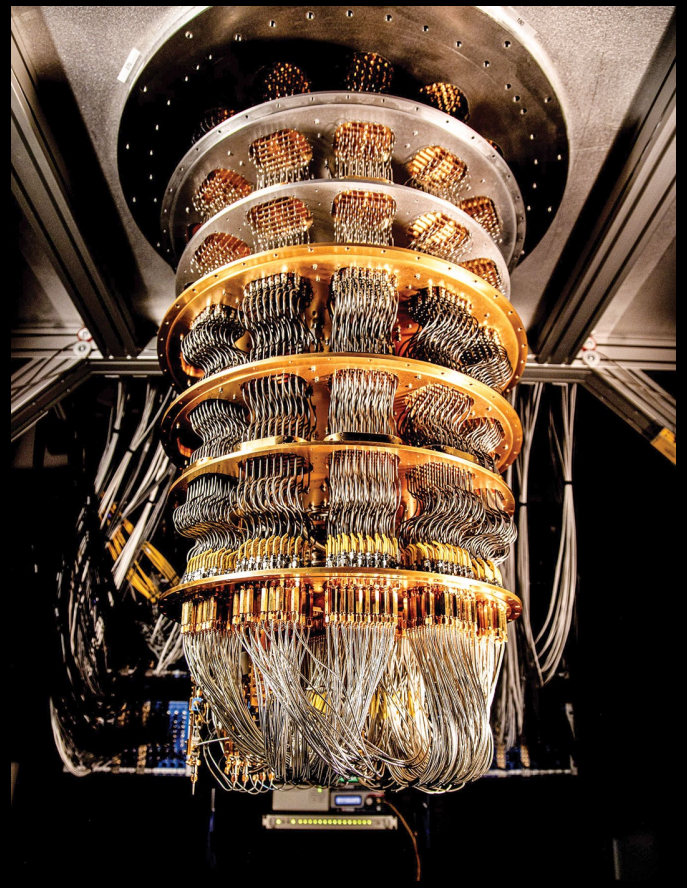


Flow without resistance

Videos: Wikipedia & Pint of Science FR

Why go towards zero Kelvin?

Superconductors used to build strongest magnets



Quantum properties of matter persist

Images: Wikipedia & Google

Ultracold Matter

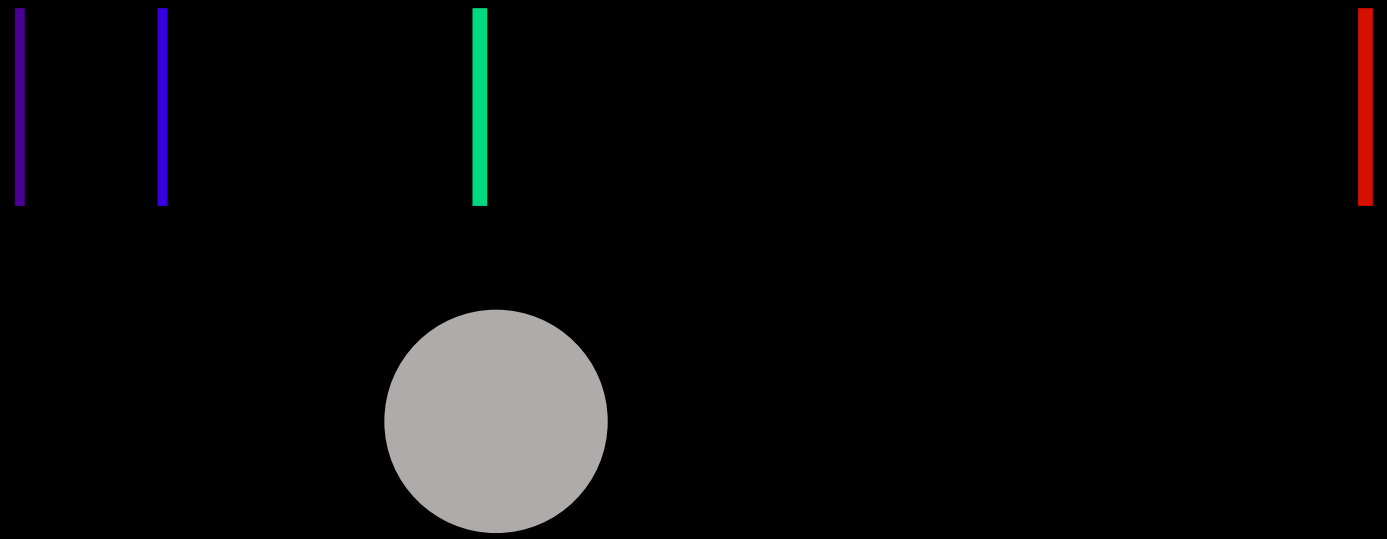
Coldest place in universe on earth

Challenging journey to Zero Kelvin

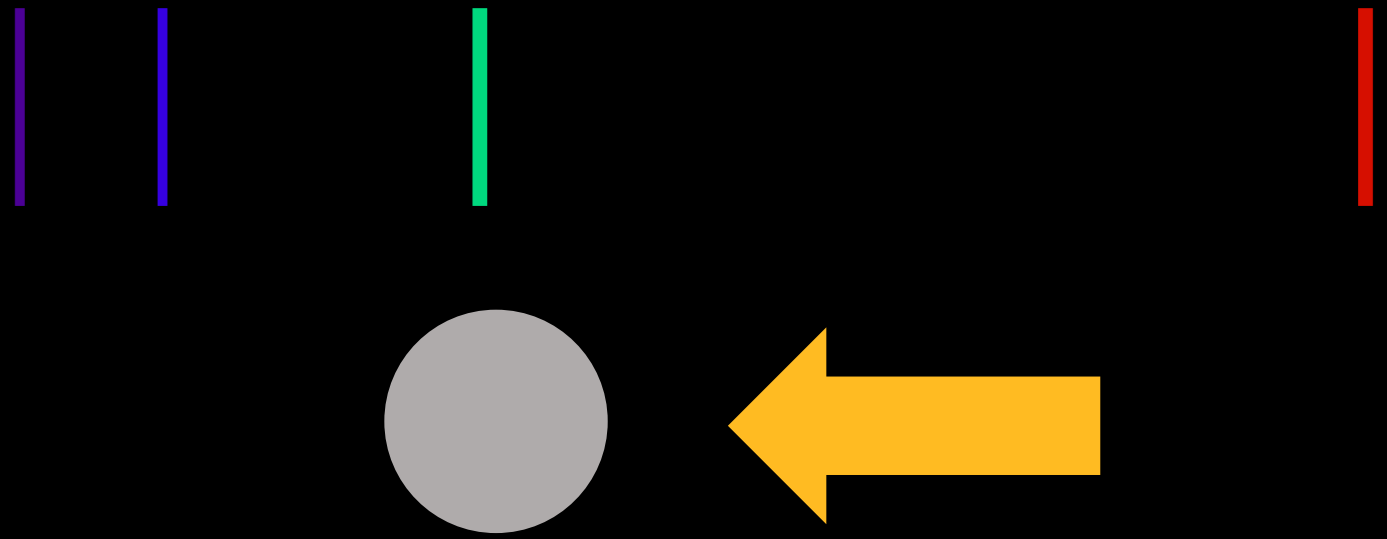
Novel phenomena close to 0°K

Just one more thing: LASERs!

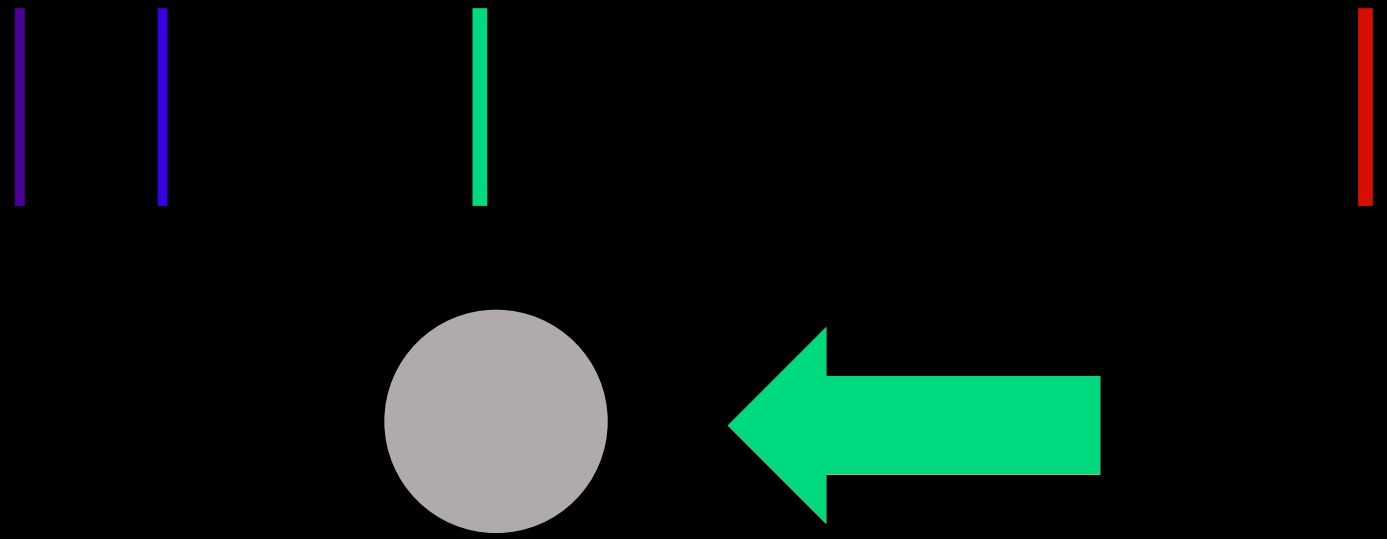
Absorbing light



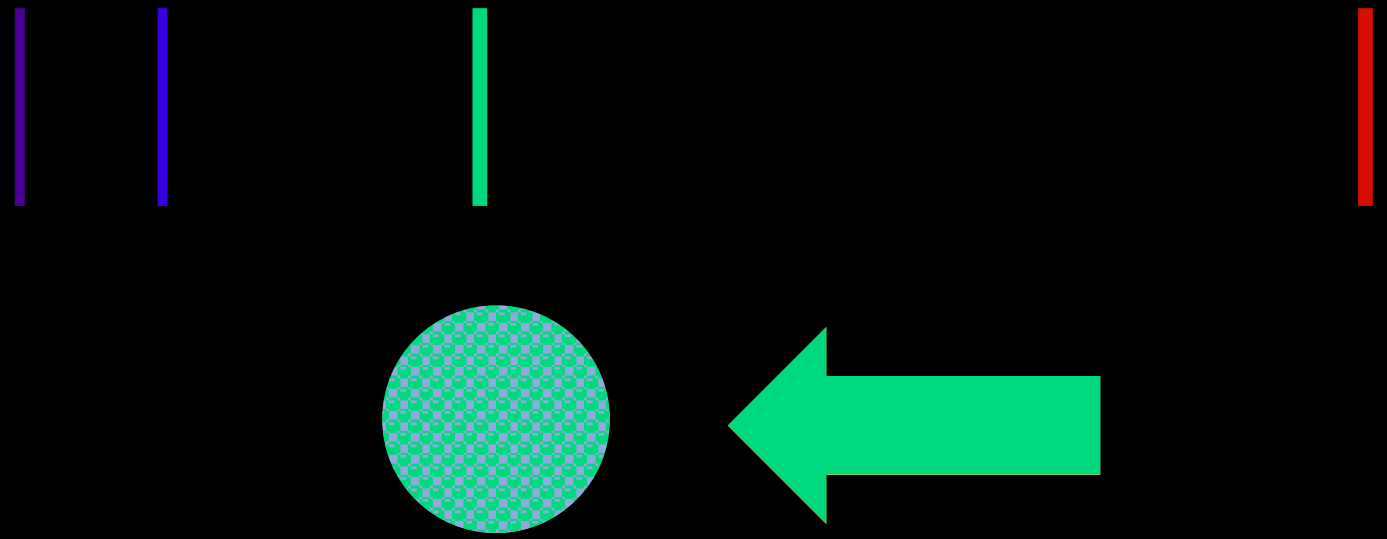
Absorbing light



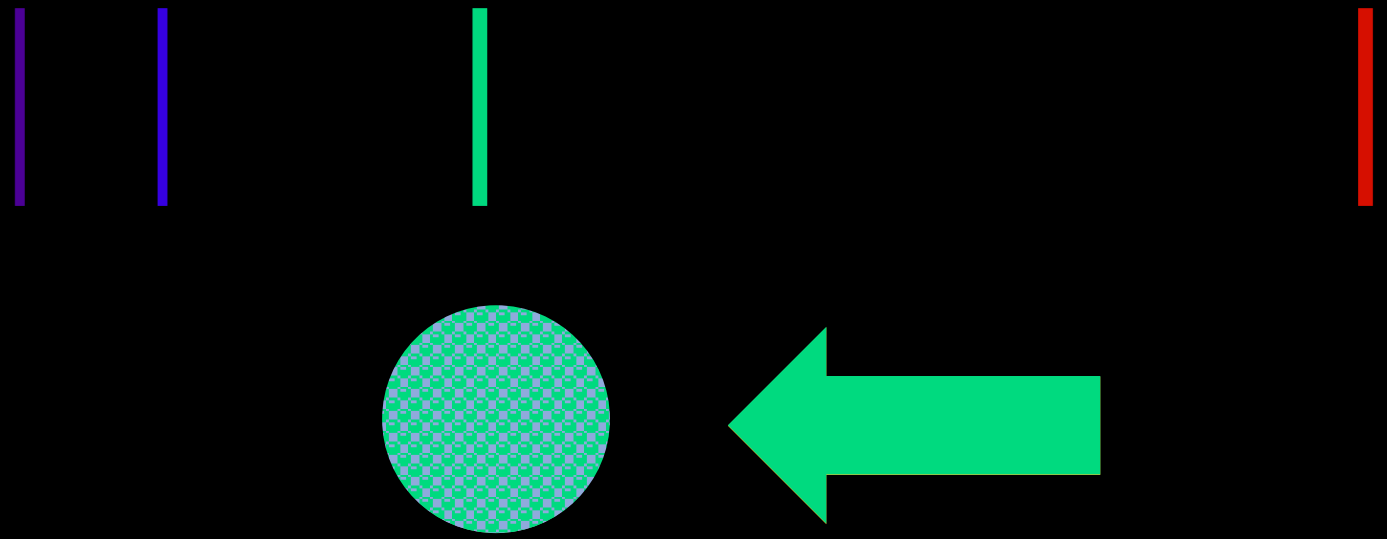
Absorbing light



Absorbing light



Absorbing light



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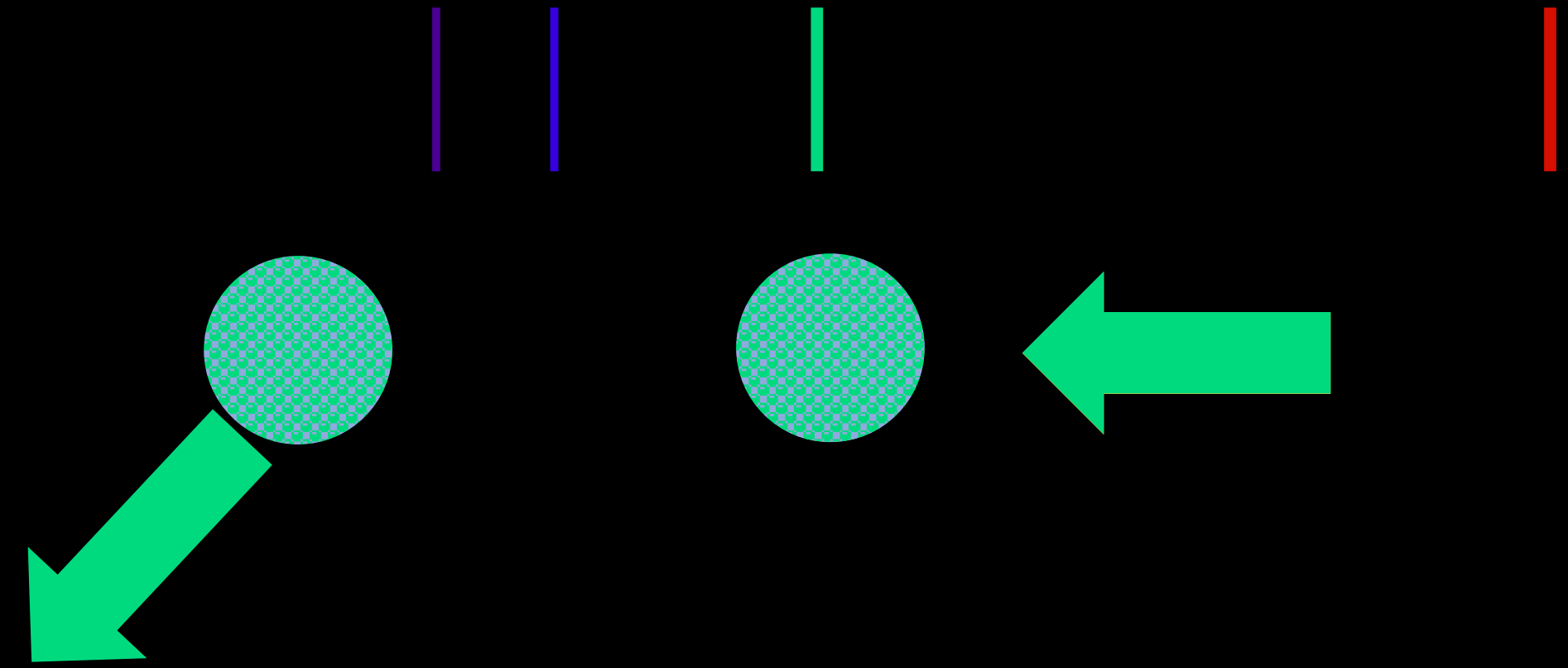
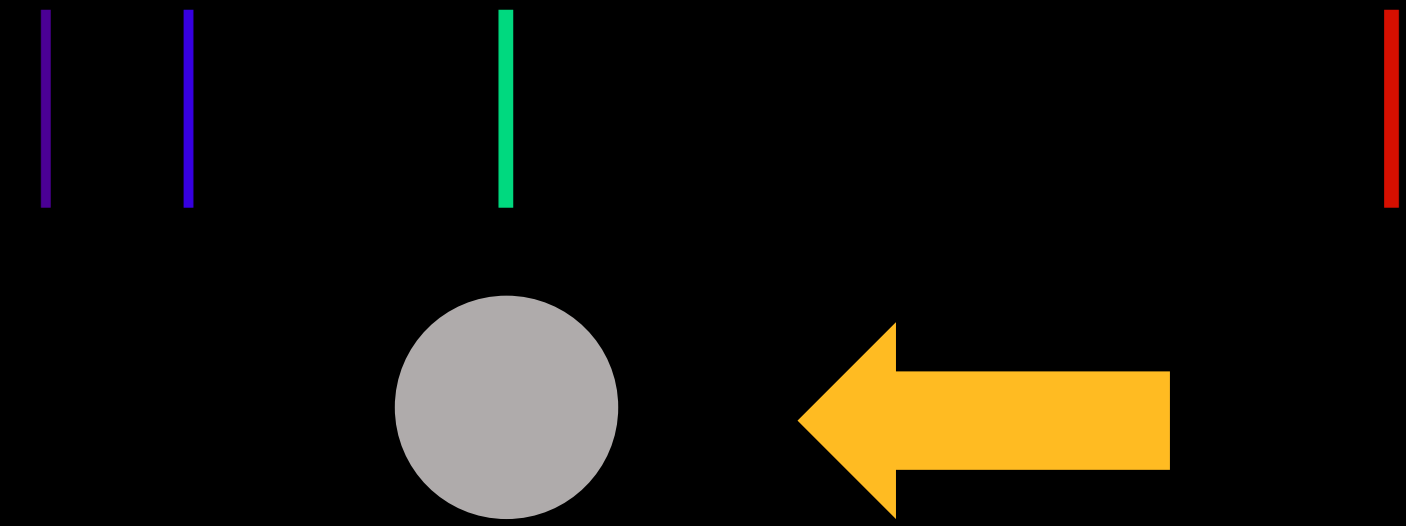


Can you hear the ambulance?



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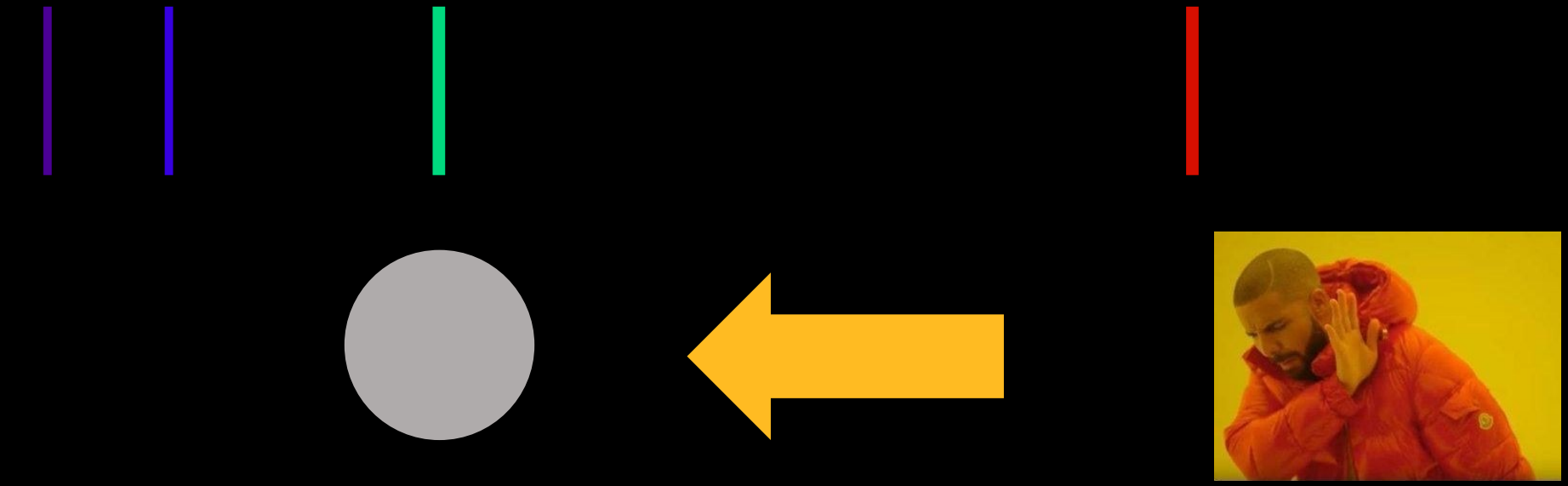
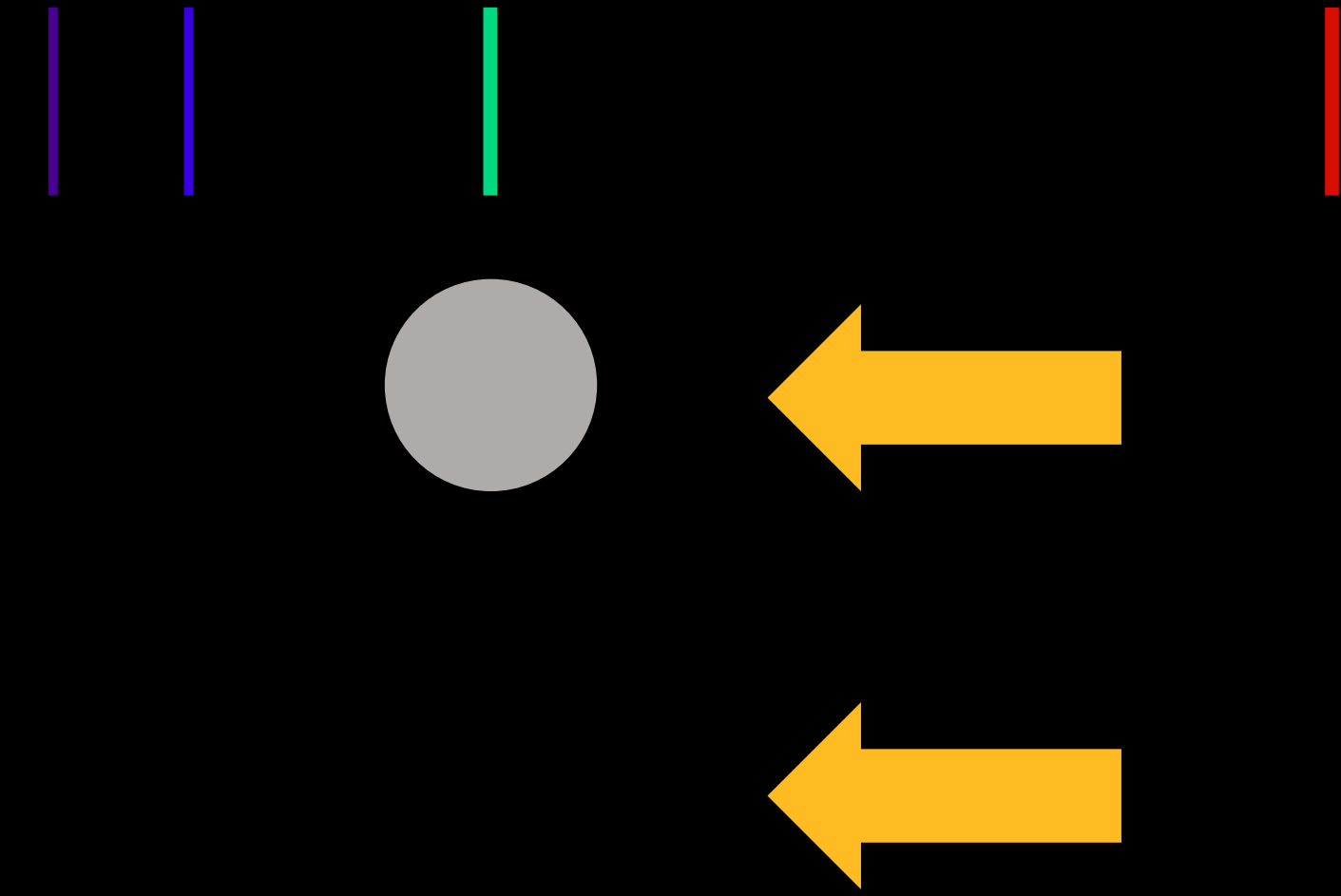


Can you hear the ambulance?



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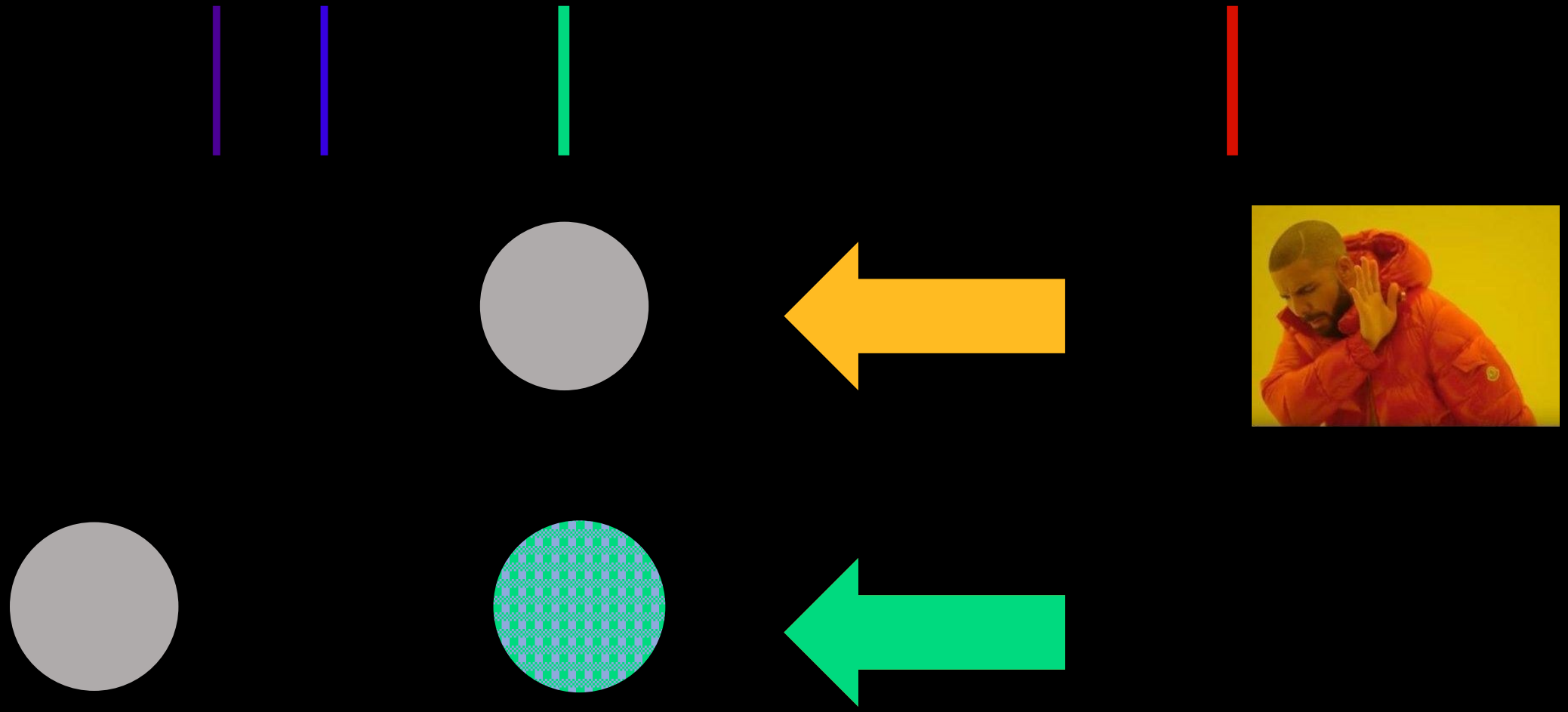

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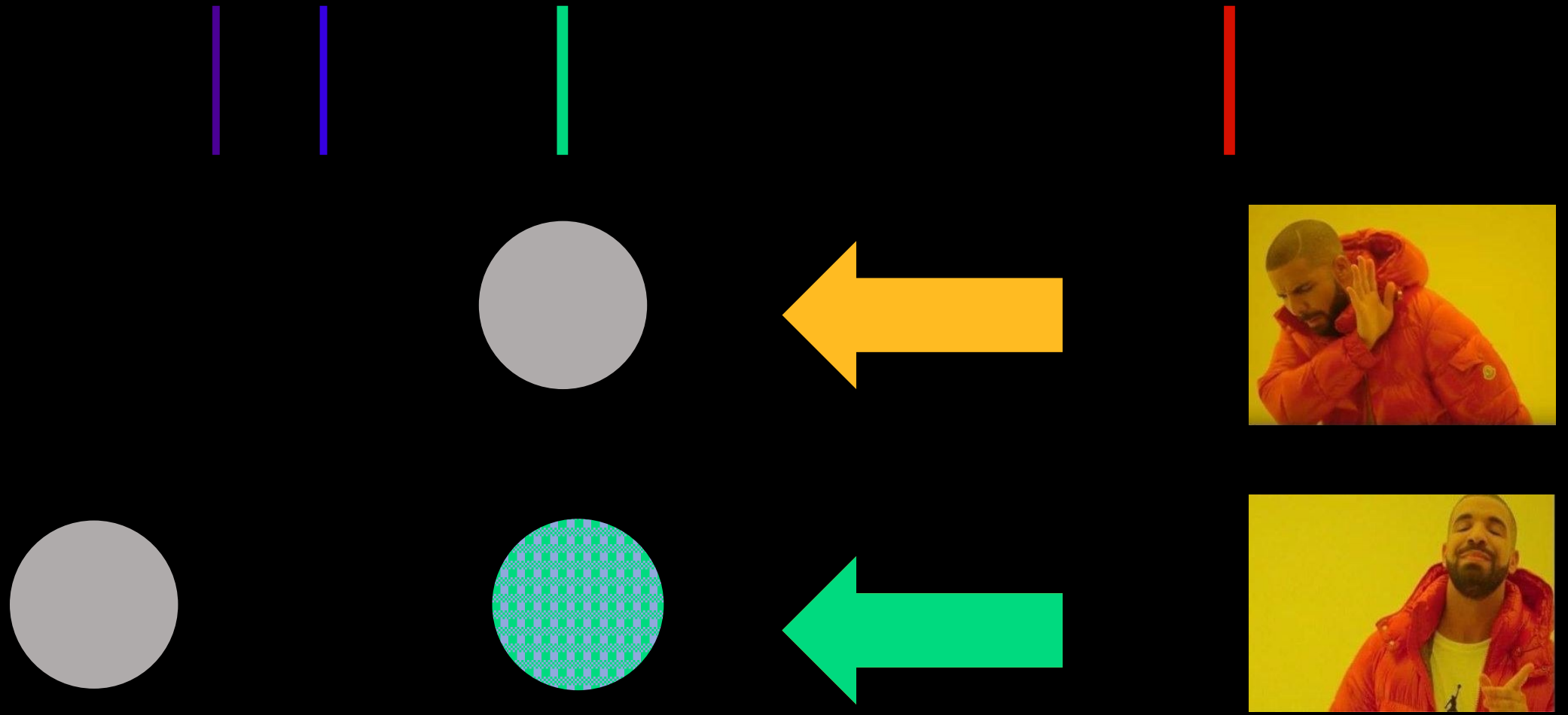
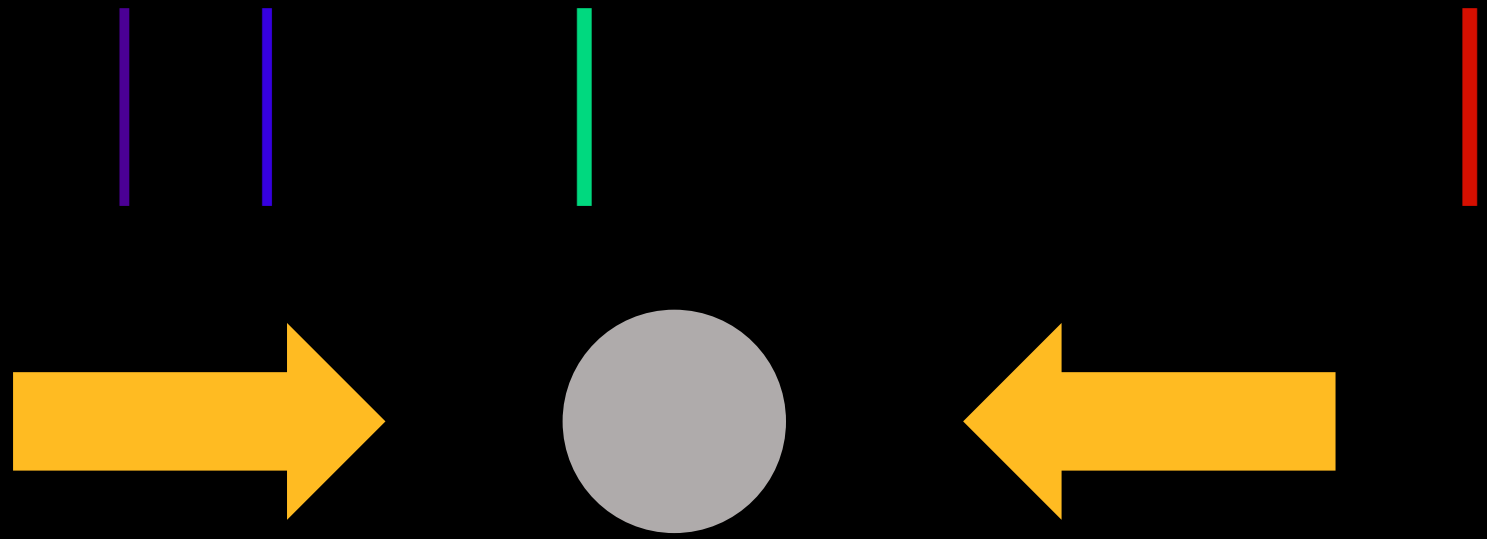


Doppler effect at work!

Cooling with lasers

Cools down gases to a fraction of a thousand of a Kelvin!

Cooling with lasers



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