History
of the Universe
(a current view)

spice
secondary teachers' enrichment program

The University of Western Australia
Achieving International Excellence

Government of Western Australia
Department of Education

The Big Bang theory

- Discoveries in astronomy and physics suggest that the Universe had a definite beginning.
- The Big Bang theory is the prevailing theory that describes the origin and evolution of the Universe.
- It is considered to be our best theory of cosmology because it explains most experimental observations.

What was the Big Bang?

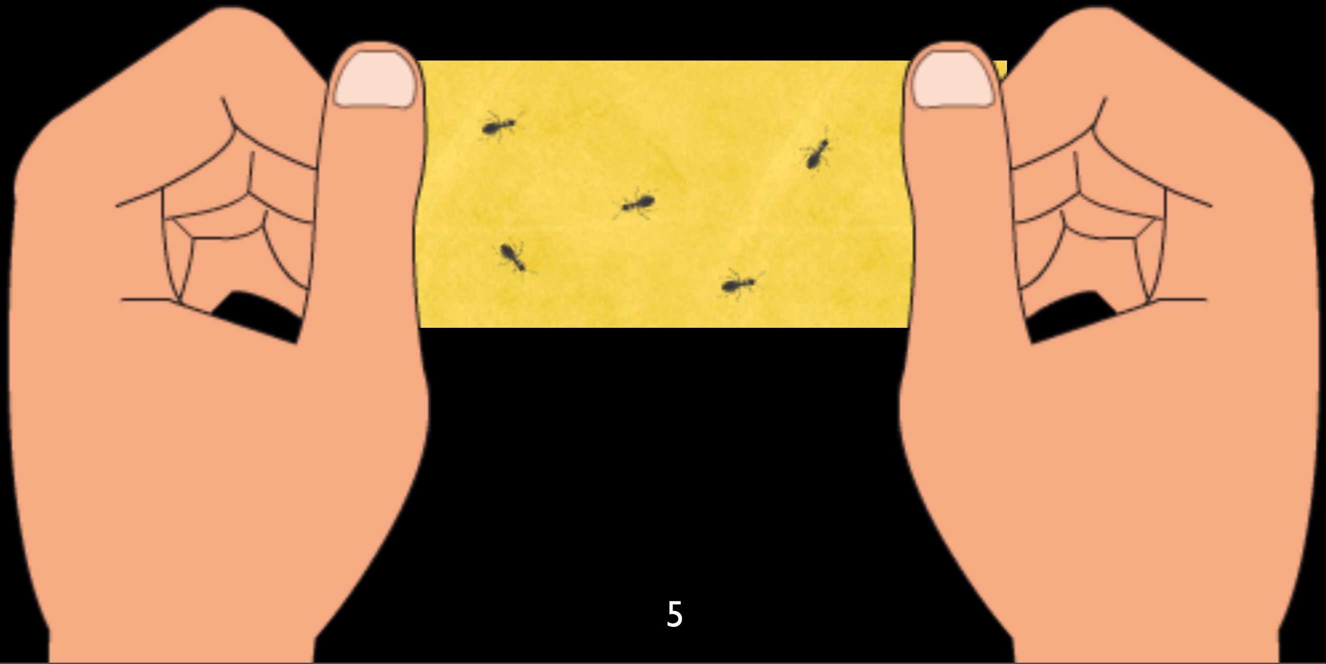
- About 13.7 billion years ago, the entire Universe was compressed into a singularity – a place with zero volume and infinite density.
- Matter, energy, space and time all began inside the singularity.
- At the moment of the Big Bang, the Universe started to expand, cool and become less dense.
- The Universe is still expanding today.

What the Big Bang wasn't

- The Big Bang wasn't an explosion that happened somewhere in space.
- The Universe didn't appear somewhere in space.
- The Big Bang created space and time.

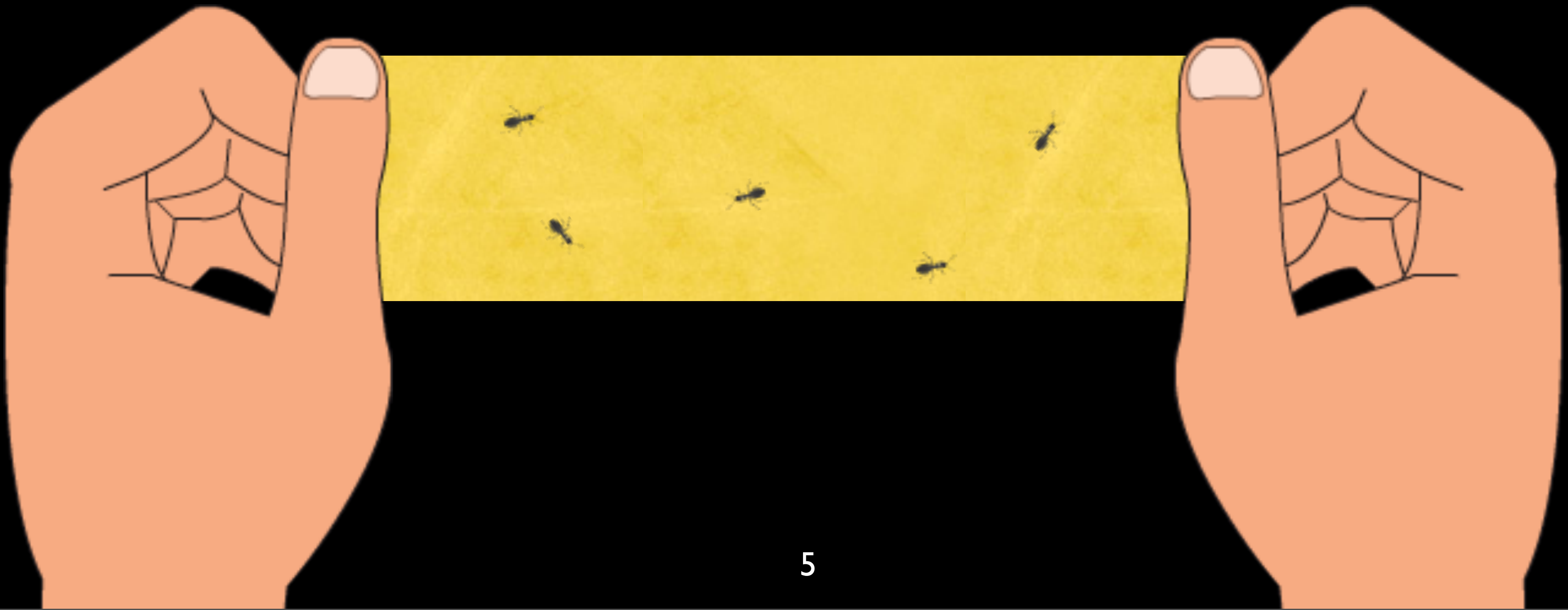
What is an expanding Universe?

- Galaxies move apart because space itself is expanding.
- They are not moving apart because of some past explosion.

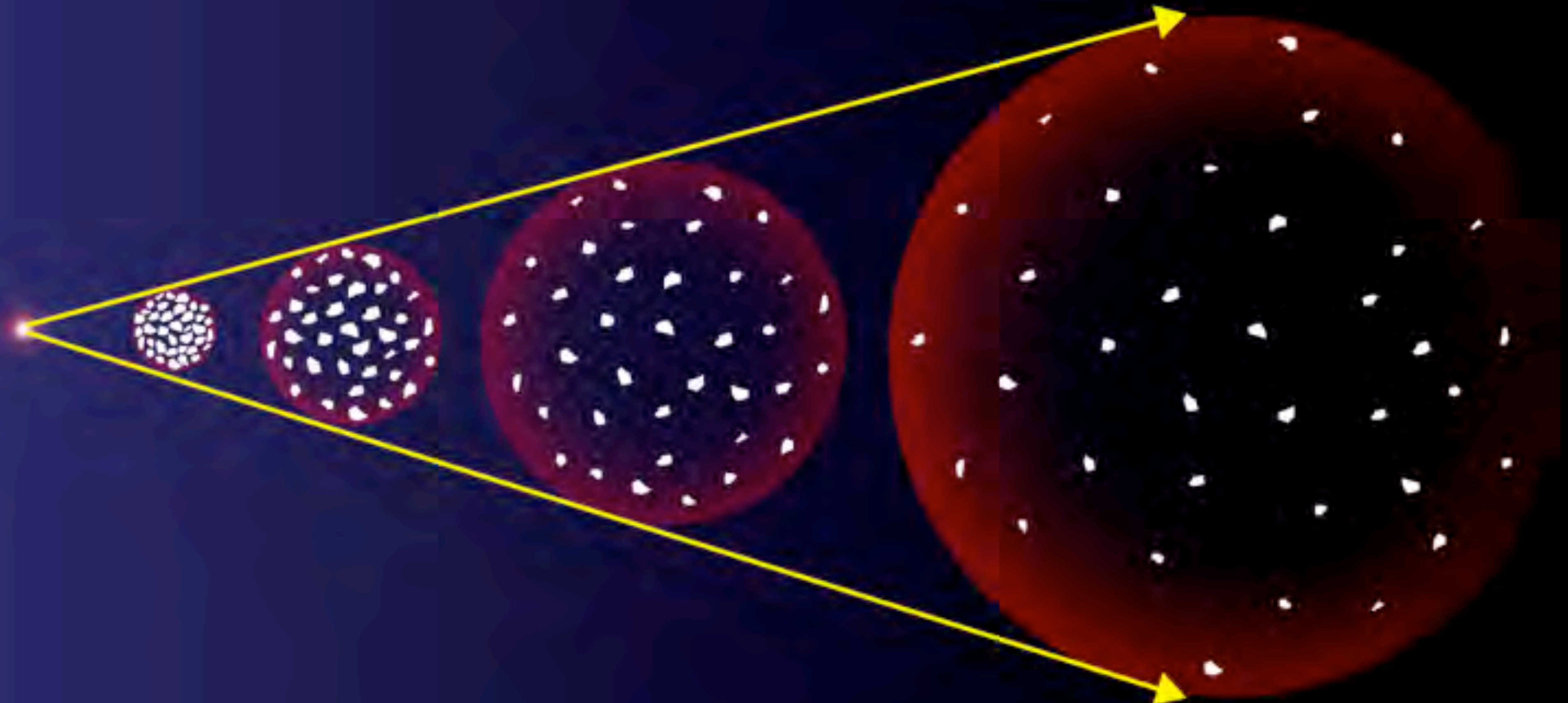


What is an expanding Universe?

- Galaxies move apart because space itself is expanding.
- They are not moving apart because of some past explosion.



Expansion of the Universe



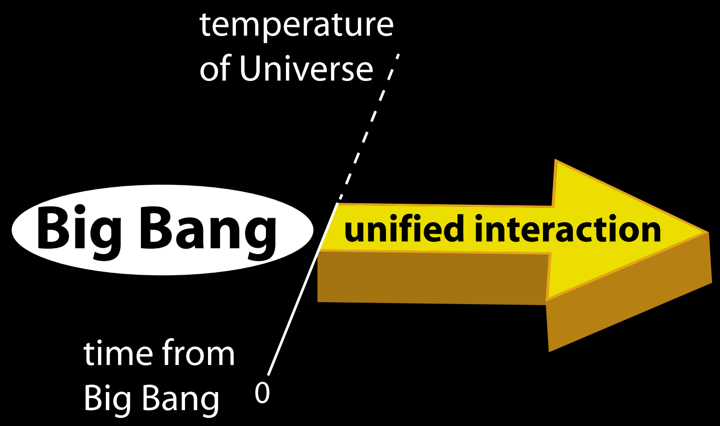
Galaxies move apart as the Universe expands.

The beginning of the Universe

- Big Bang theory doesn't attempt to explain why the Universe was created, or what (if anything) might have existed before it.
- Our ideas about the very early Universe are, at best, speculative.
- The first 10^{-43} seconds of the Universe is called the Planck era. Conditions were so extreme that we suspect quantum behaviour was dominant, including quantum gravity.
- We don't yet have a theory of quantum gravity, but we do have theories that explain what happened from this time on.

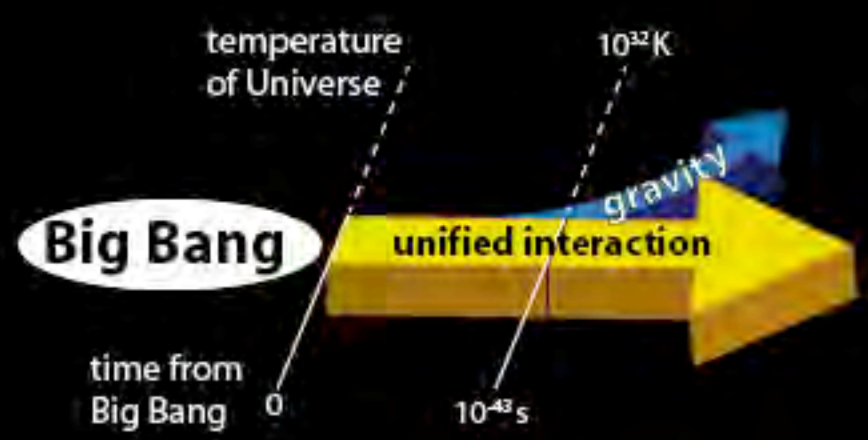
Fundamental interactions

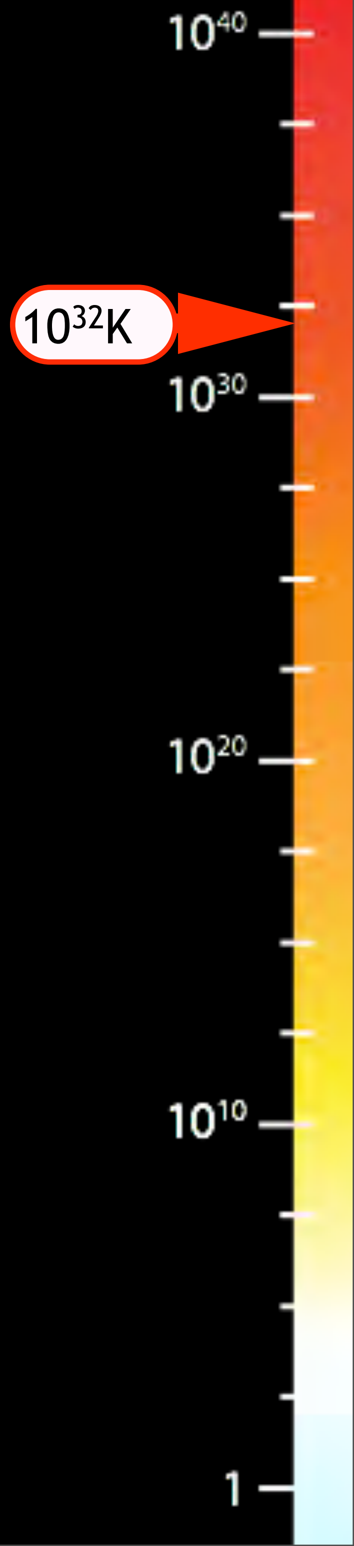
- All forces in the Universe can be attributed to four fundamental interactions between particles.
- Physicists believe that all known interactions were unified at the moment of the Big Bang.
- Shortly after the Big Bang, this unified interaction began to separate into gravitational, strong, weak and electromagnetic interactions.



Fundamental interactions

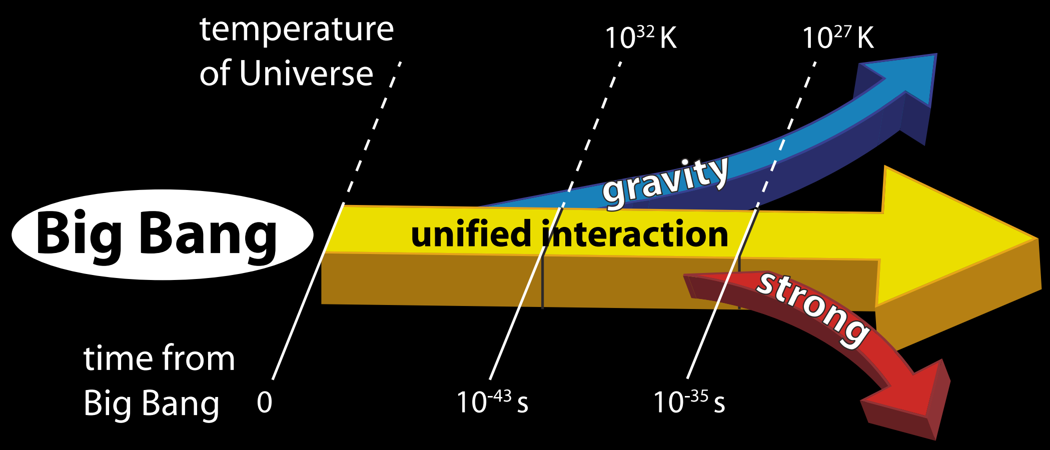
- 10^{-43} seconds after the Big Bang, gravity separated from the unified interaction.

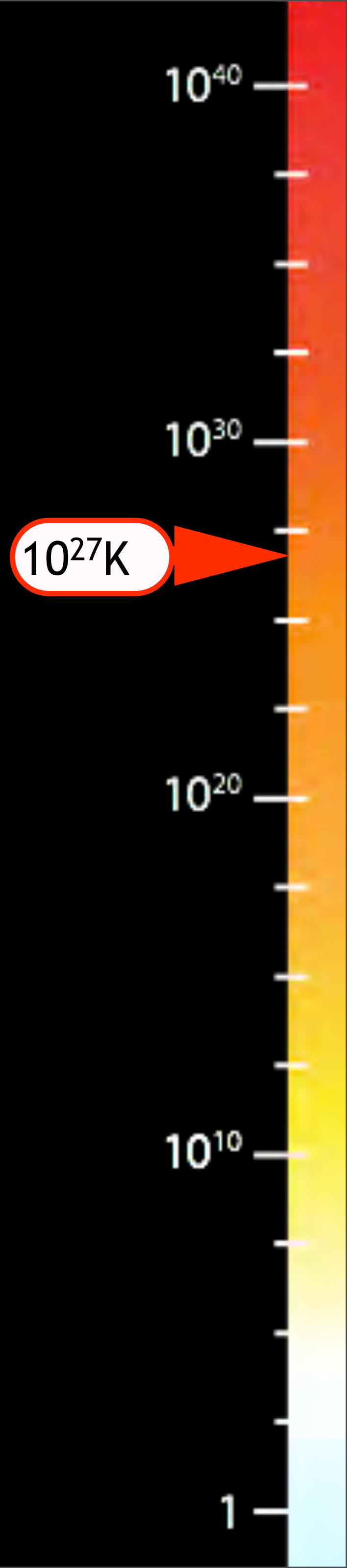




Fundamental interactions

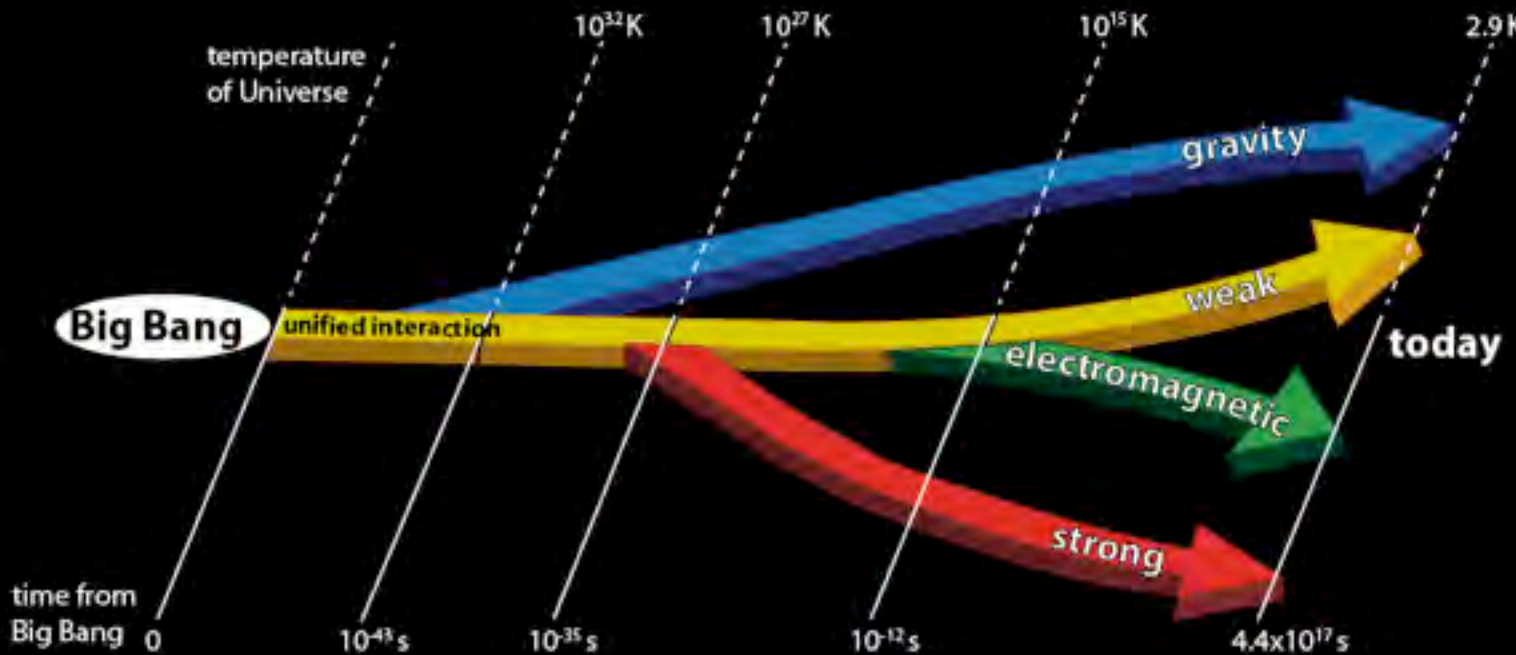
- 10^{-35} seconds after the Big Bang, the strong interaction separated.
- This released a vast amount of energy, making the Universe expand at an extraordinary rate.

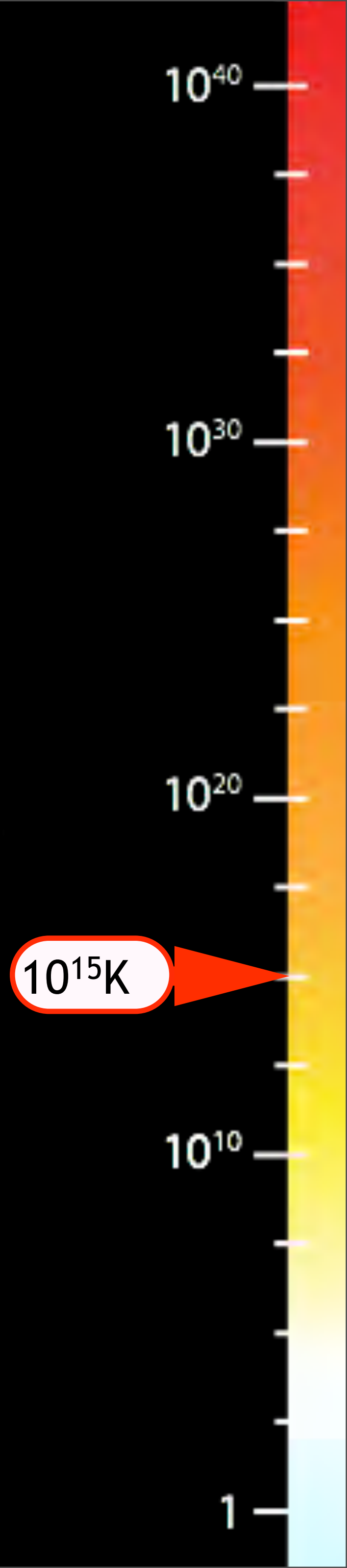




Fundamental interactions

- 10^{-12} seconds after the Big Bang, the electromagnetic and the weak interactions separated. The four fundamental interactions were now distinct, as they remain to this day.



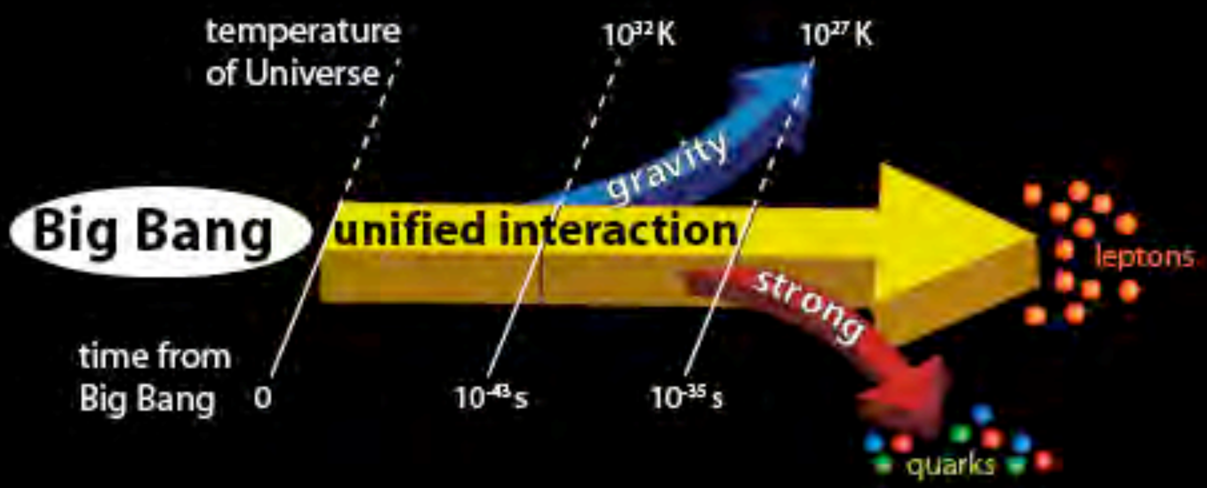


The evolution of matter

quark era	10^{-12} – 10^{-6} seconds after the Big Bang
hadron era	10^{-6} – 1 second after the Big Bang
lepton era	1 sec – 10 seconds after the Big Bang
radiation era	10 sec – 300 000 years after the Big Bang

The quark era (10^{-12} – 10^{-6} s)

- When the strong interaction separated from the unified interaction, matter separated into quarks and leptons.
- Quarks 'feel' the strong interaction , but leptons don't.
- The temperature of the Universe was too high for quarks to combine.



The hadron era (10^{-6} – 1 s)

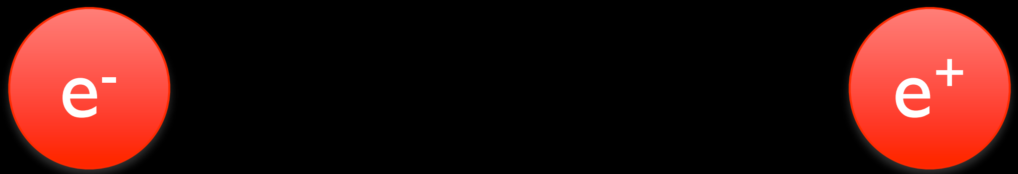
- As the temperature of the Universe fell, quarks combined to form hadrons: protons, neutrons and their antiparticles.
- Almost equal quantities of particles and antiparticles were created.
- As the temperature fell further, most particles annihilated their antiparticles.
- A small excess of particles was left, which accounts for all hadrons in the Universe today.

proton

neutron

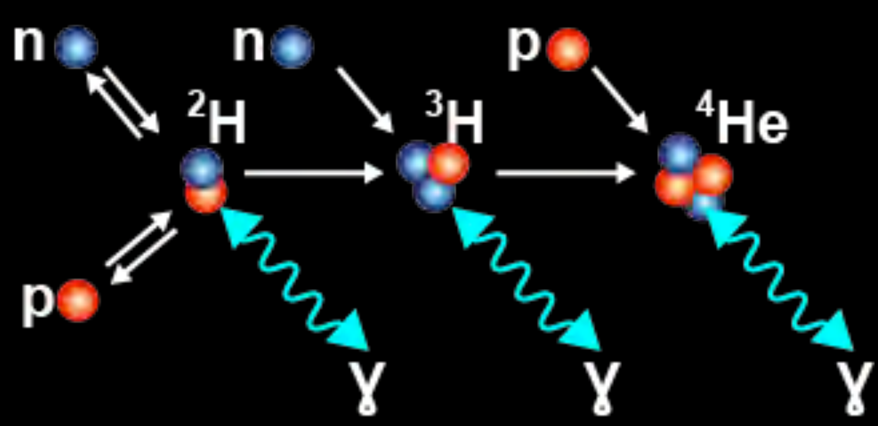
The lepton era (1 s – 10 s)

- Once most hadrons had been annihilated, leptons became the dominant form of matter: electrons, neutrinos and their antiparticles.
- As the Universe continued to cool, most leptons and antileptons annihilated each other.
- A small excess of leptons was left, which accounts for all the leptons in the Universe today.



The radiation era (from 10 s)

- Particle-antiparticle interactions left the Universe full of radiation (photons).
- Protons and neutrons combined to form hydrogen and helium nuclei in a process called nucleosynthesis.
- Photons were continually absorbed and emitted by particles, so the Universe was opaque to radiation.

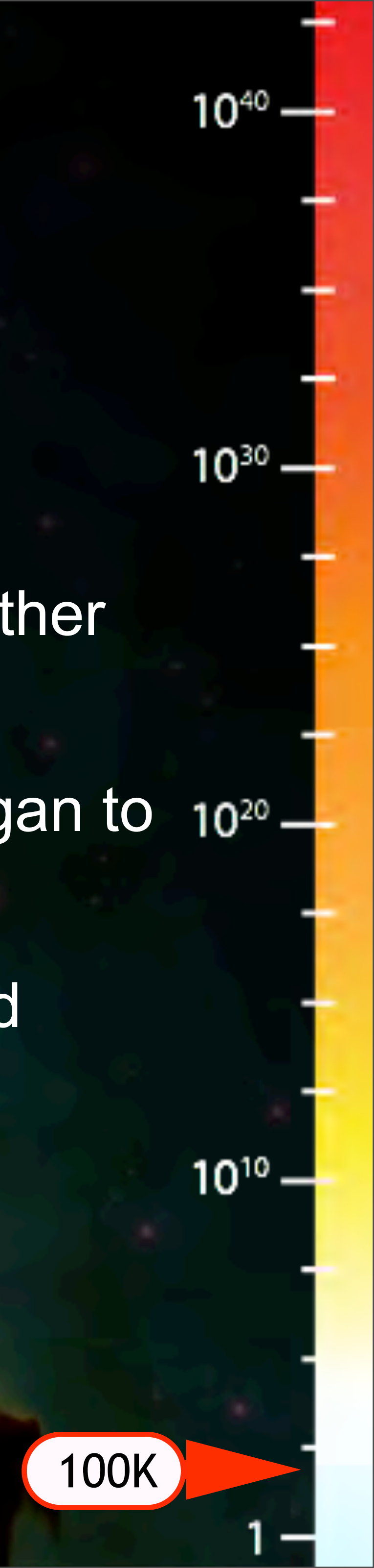


The radiation era

- Towards the end of the radiation era, 300 000 years after the Big Bang, hydrogen and helium nuclei started to capture electrons to form stable atoms.
- The density of the Universe continued to decrease as it expanded.
- The Universe became transparent to light about 370 000 years after the Big Bang.

The formation of stars

- Over the next 100 million years or so, the Universe continued to expand and cool.
- Gravitational variations caused matter to clump together and become hotter and denser.
- 100–200 million years after the Big Bang, matter began to coalesce and form stars.
- Fusion of light elements in stars released energy and formed elements from carbon to iron.



‘Eagle nebula pillars’ from NASA/ESA
http://commons.wikimedia.org/wiki/File:Eagle_nebula_pillars_complete.jpg

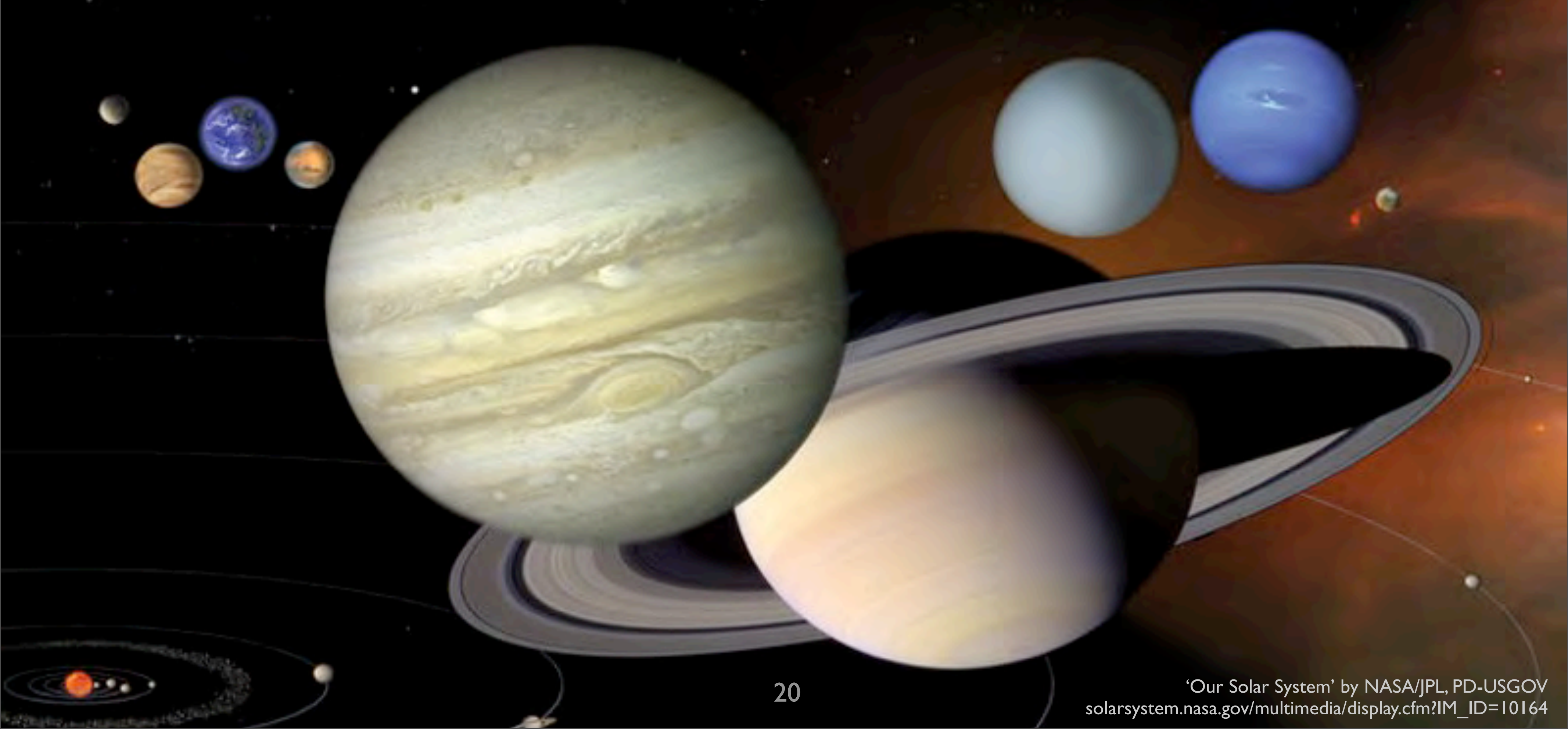
The formation of galaxies

- A billion years after the Big Bang, stars grouped to form galaxies.
- Galaxies formed clusters.

NGC 4414, a typical spiral galaxy in the constellation Coma Berenices.
NASA/ESA, http://en.wikipedia.org/wiki/File:NGC_4414_%28NASA-med%29.jpg

Formation of the Solar System

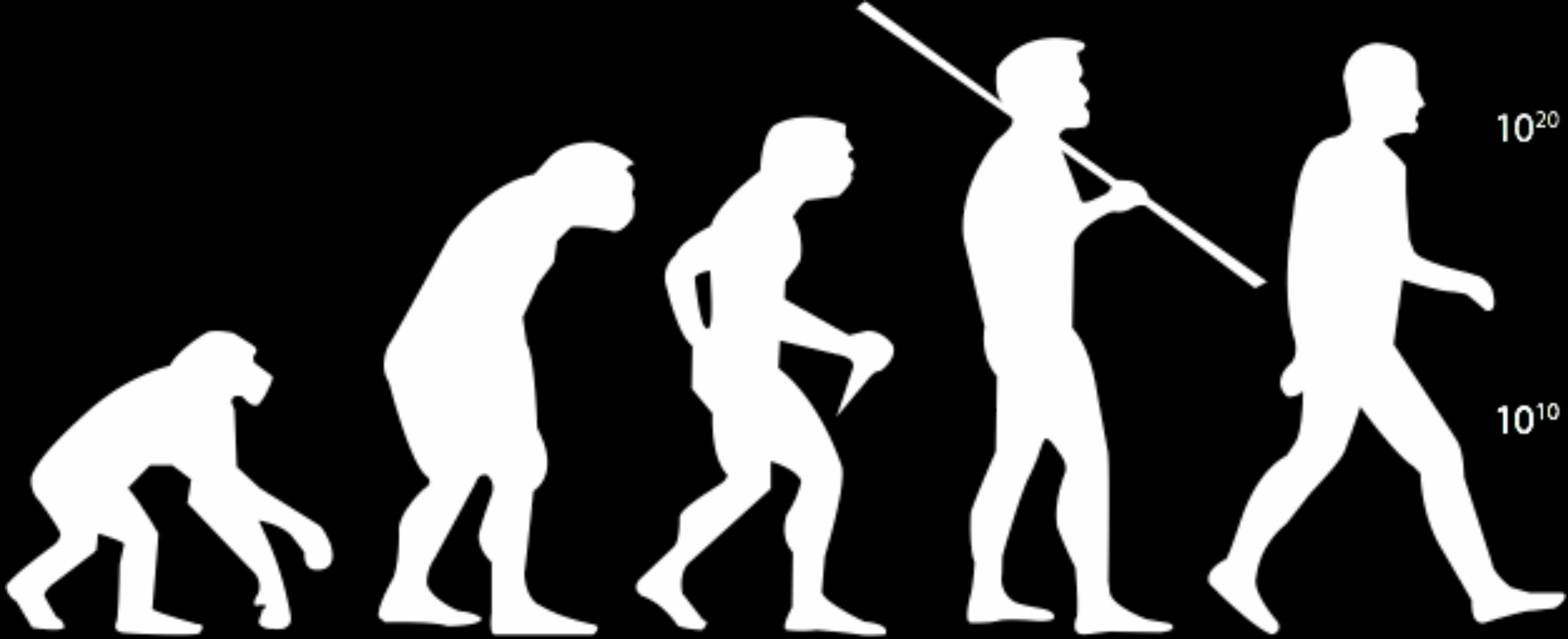
- 8.4 billion years after the Big Bang (4.5 billion years ago), the Solar System began to form from the collapse of a giant gas cloud.

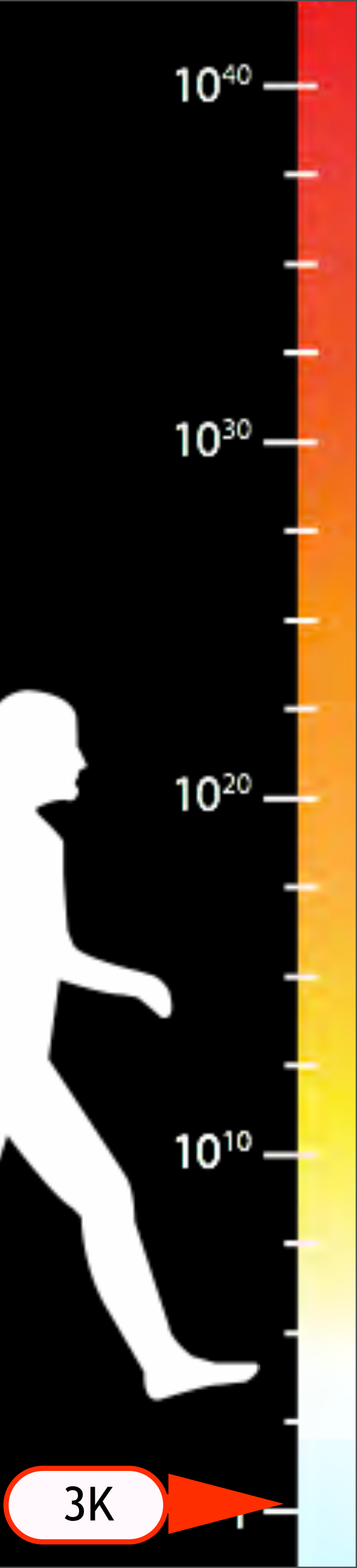


'Our Solar System' by NASA/JPL, PD-USGOV
solarsystem.nasa.gov/multimedia/display.cfm?IM_ID=10164

Humans appear on Earth

- 13.7 billion years after the Big Bang, human life began on Earth.





"The most incomprehensible thing about the Universe is that it is comprehensible."

Albert Einstein, 1935

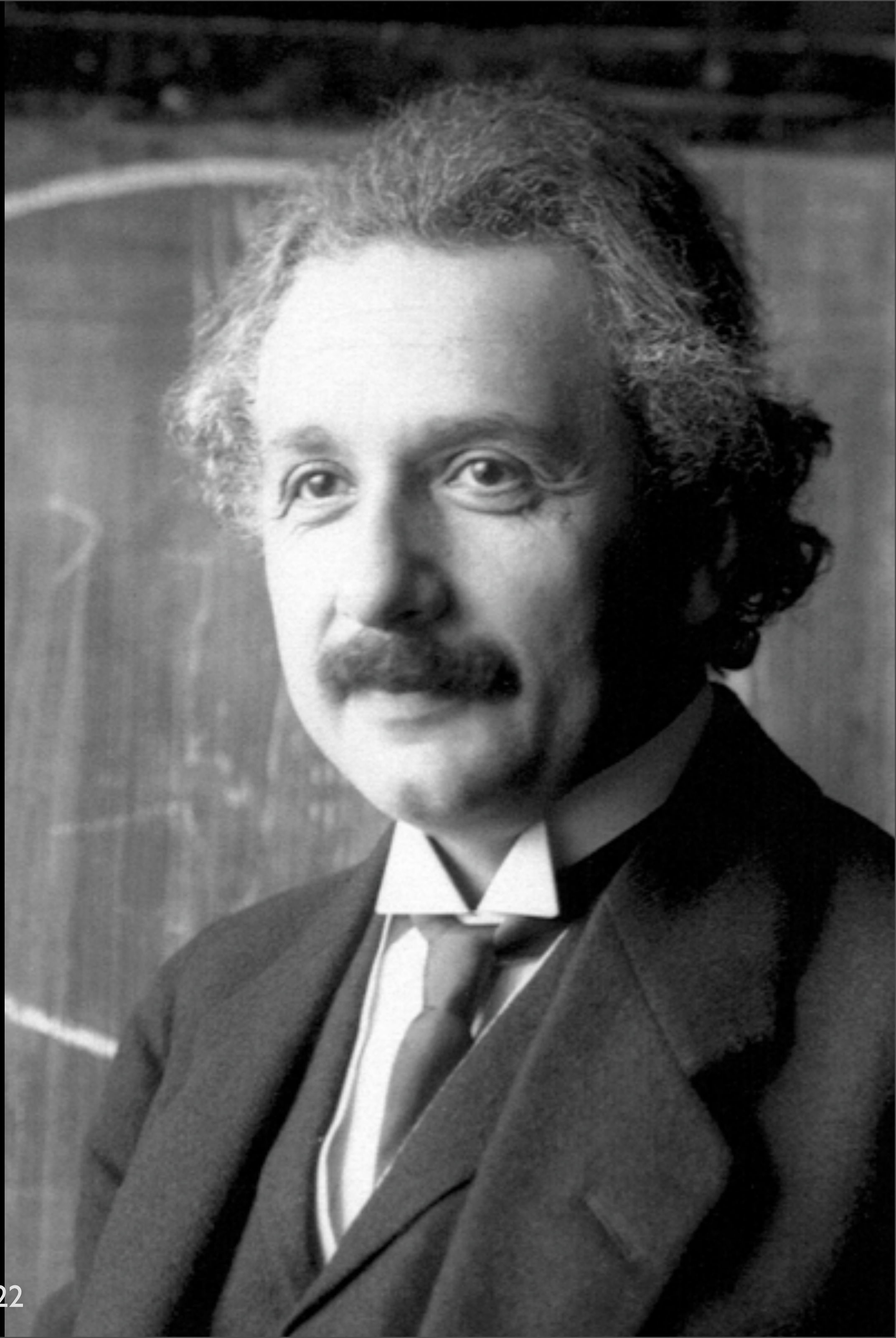


photo by Ferdinand Schmutzer,
commons.wikipedia.org/
wikiFile:Einstein1921_by_F_Schmutzer_2.jpg