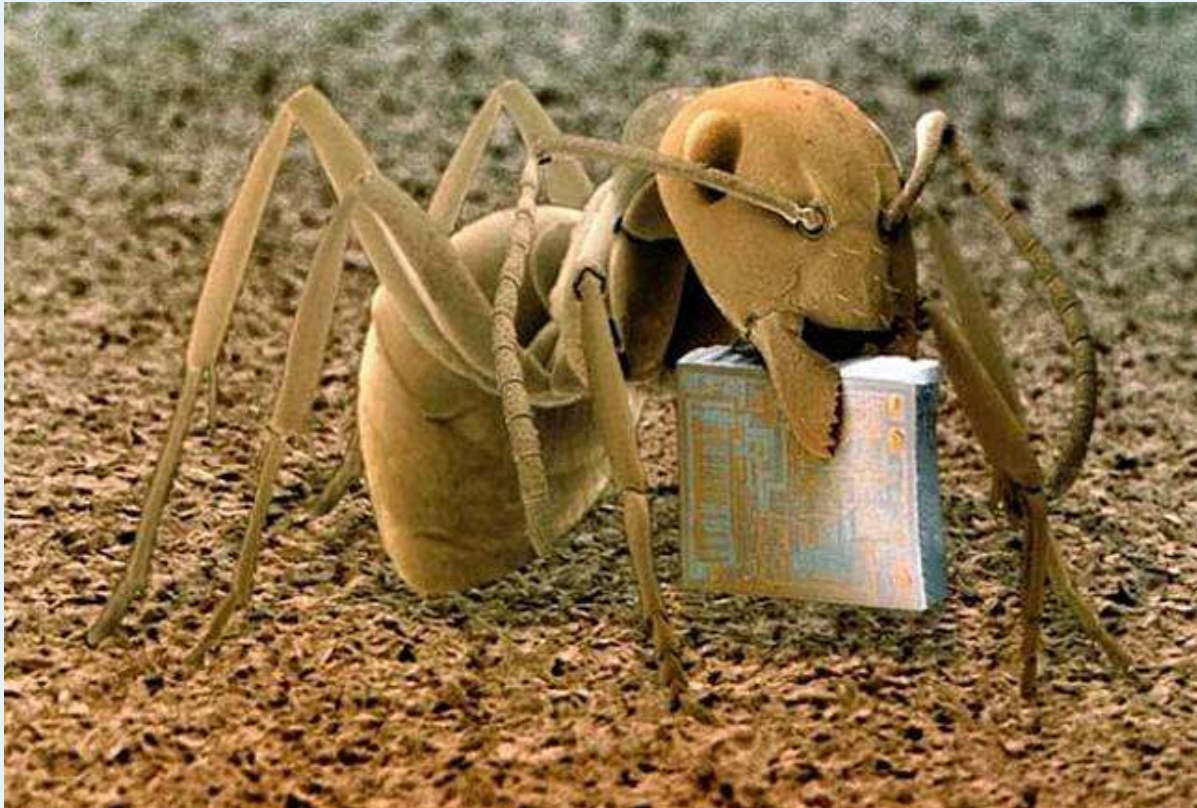


What is the smallest thing in the Universe?



Alexander Lenz

Durham University

Typical sizes

- Typical height of Year 6 kids: 1.34 m

Larger scales

- Typical length of a car: 5 m
- Height of Durham Cathedral: 66 m
- Distance: St. Godric's School to Durham Cathedral: $2.5\text{ mls} = 4023\text{ m}$

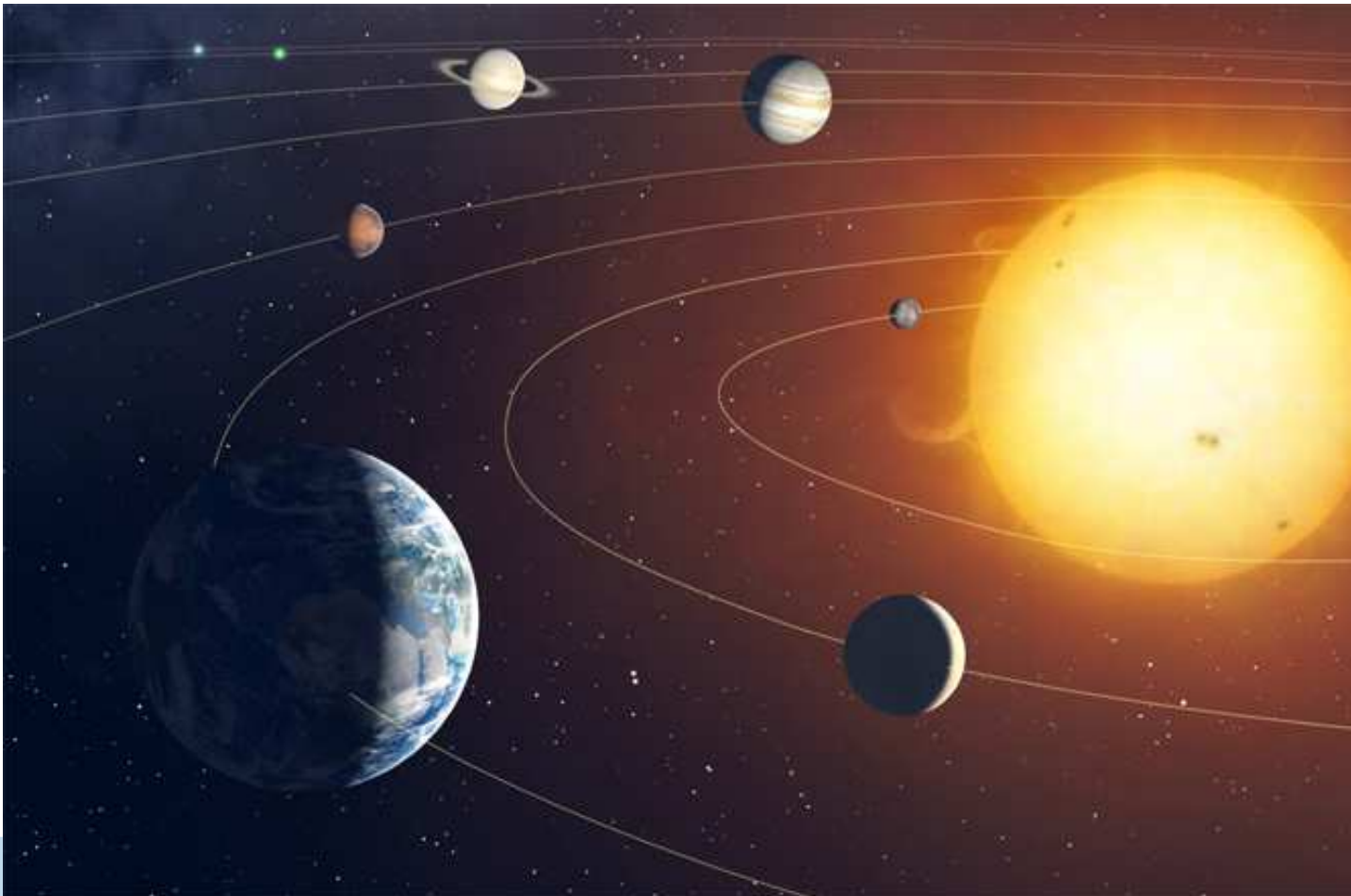
Shorter scales

- Typical length of a pencil: $15\text{ cm} = 0.15\text{ m}$
- Length of an ant: $0.2 - 2.5\text{ cm} = 0.002 - 0.025\text{ m}$
- Diameter of human hair: $0.017 - 0.180\text{ mm} = 0.000017 - 0.000180\text{ m}$



Very large sizes

- The highest mountain: Mount Everest: 8848 m
- Perimeter of the Earth: $40074\text{ km} = 40074000\text{ m}$
- Distance: Earth - Moon: $385000\text{ km} = 385000000\text{ m}$
- Distance: Earth - Sun: $149.6\text{ million km} = 149600000000\text{ m}$



Examples for very large distances

Distance to the next star *Proxima Centauri*: 4.24 light-years = $4.0 \cdot 10^{16} m$

1 Light-year = $299792,458 km/s \cdot 3600 s \cdot 24 \cdot 365.25 = 9.46 \cdot 10^{15} m$

Distance to the next galaxy *Andromeda*: 2.5 Million light years = $2.4 \cdot 10^{22} m$



Andromeda Galaxy — NASA, Hubble Telescope

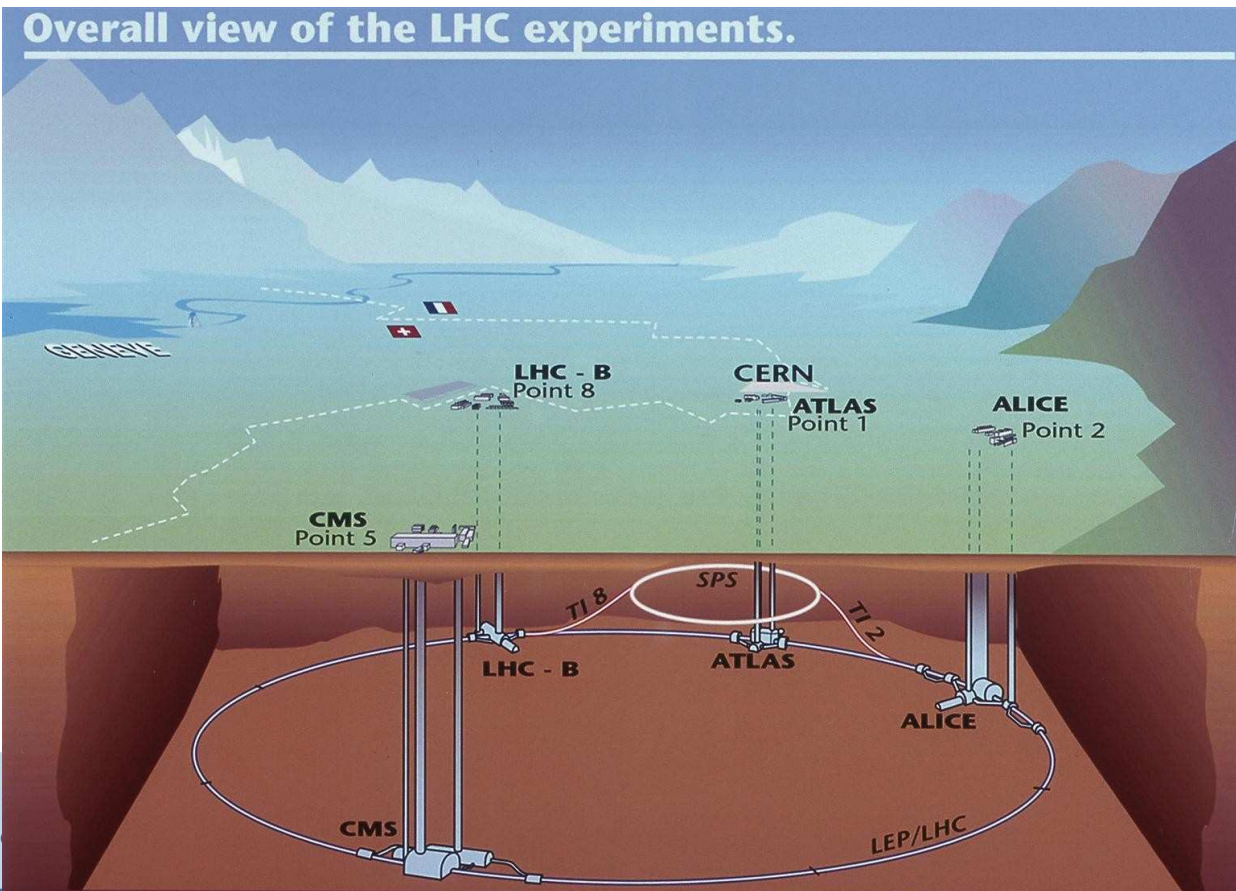
Very small sizes

- Human cell: $0.00003 - 0.000001 \text{ m}$
- Bacteria: $0.000005 - 0.0000005 \text{ m}$
- Virus: $0.0000005 - 0.00000001 \text{ m}$
- Structures in computer chips: $0.000001 - 0.000000001 \text{ m}$
- Atom: 0.0000000001 m



How to measure very short distances

- down to $10^{-7} m$: Microscope
- down to $10^{-10} m$: Electron microscope
- down to $10^{-19} m$: Particle Accelerators



The Large Hadron Collider 1

- Located close to Geneva, Switzerland at CERN
- The biggest machine ever built by humans
 - ◆ 27km Circumference
 - ◆ between 60 and 100 m beneath the earth



What did we learn from all our telescopes?

All matter is made of **molecules**

Molecules are made out of **atoms**

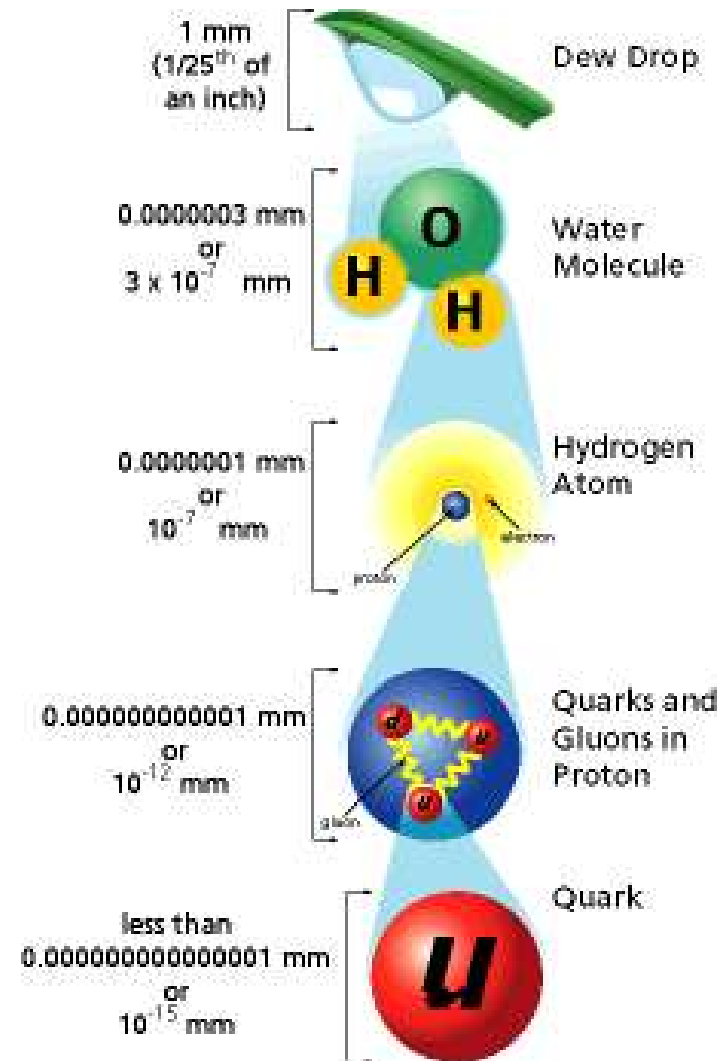
Water molecule = 2 Hydrogen atoms and 1 oxygen atom

Atoms are made of **nuclei** and **electrons** spinning around the nuclei

Nuclei are made of **protons** and **neutrons**

Protons and neutrons are made of **quarks**

Quarks are made off ???



What did we learn from all our telescopes?

- **Protons** can be seen in our microscopes as extended objects
They have a radius of about $0.000000000000001 \text{ m} = 10^{-15} \text{ m}$
- **Quarks** and **electrons** look like points in our best telescopes
Our best telescopes have a resolution of 10^{-19} m
So we only know that quarks and electrons are smaller than 10^{-19} m
But we do not know if they are points or extended
- **LHC** was just restarting in June 2015, with a higher resolution (energy), so maybe we know soon, whether these particles are extended or points

