

The largest, the smallest, and us

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Mumbai Local, Junoon
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The largest, the smallest, and us

- 1 The two extremes
 - How large is large ?
 - How small is small ?

- 2 How they meet: three stories
 - Why did the apple fall ?
 - How does the Sun shine ?
 - Where did all the gold come from ?

- 3 My personal junoon with science

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In my office: about $1\text{ m} \times 1\text{ m}$



zoom-out 1: $10m \times 10m$

10^1 meters

10 meters



zoom-out 2: $100m \times 100m$

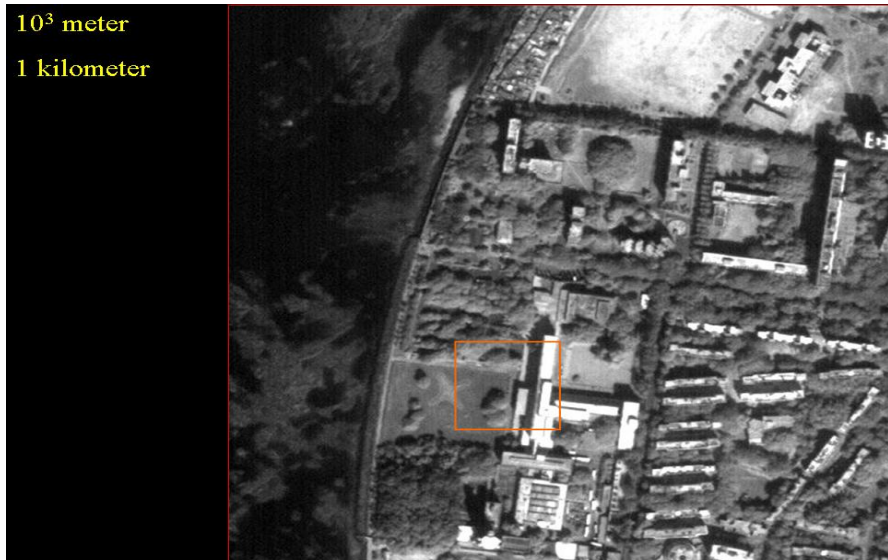
10^2 meters

100 meters



zoom-out 3: $1\text{ km} \times 1\text{ km}$: Navy Nagar

10^3 meter
1 kilometer



zoom-out 4: Our beloved city

10^4 meters

10 km



zoom-out 5: Mumbai and Thane districts

10⁵ meters

100 km



zoom-out 6: From Goa to Karachi

10^6 meters

1000 km



zoom-out 7: Almost the entire Earth

10^7 meters

10000 km



zoom-out 8: The earth and nothing else

10^8 meters

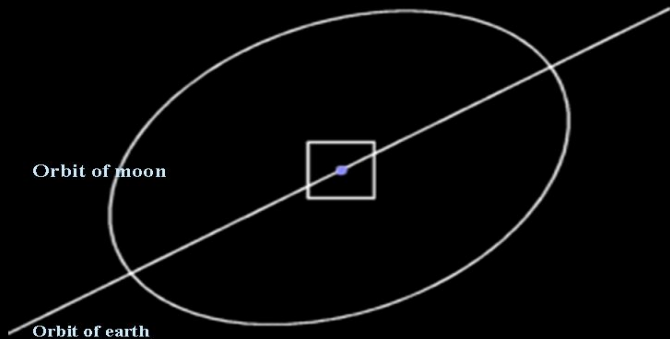
100,000 km



zoom-out 9: The orbit of the moon

10^9 meters

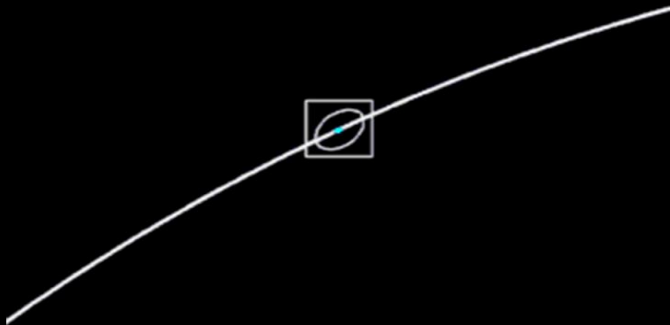
1 million km



zoom-out 10: Nobody but the two of us

10^{10} meters

10 million km

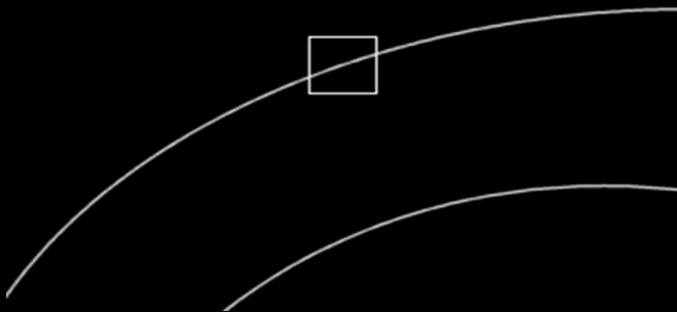


zoom-out 11: Venus and mars: neighbouring planets

10^{11} meters

100 million km

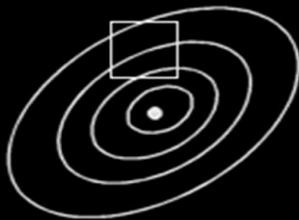
0.7 Astronomical Units



zoom-out 12: The inner planets

10^{12} meters

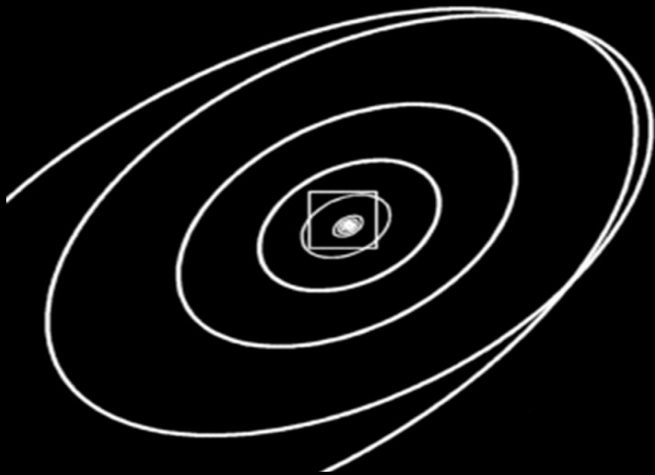
7 Astronomical Units



zoom-out 13: The solar system

10^{13} meters

70 AU



zoom-out 14: The solar system, and nothing..

10^{14} meters

700 AU



zoom-out 15: More nothingness: is anybody there ?

10^{15} meters

7,000 AU



zoom-out 16: How alone we are....

10^{16} meters

1 Light year



zoom-out 17: Finally, some neighbouring stars...

10^{17} meters ●

10 light years Altair

3.1 parsecs

Fomalhaut

Centauri

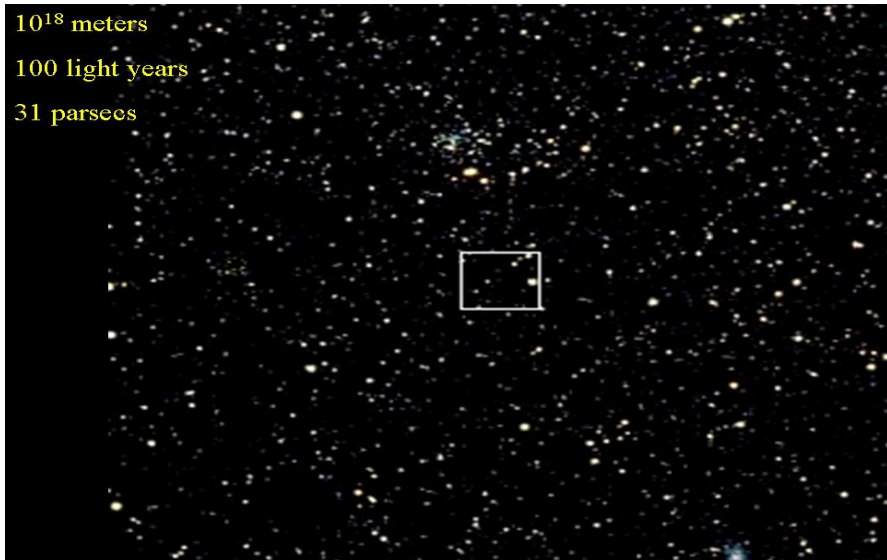
Sirius ●

zoom-out 18: Our local star colony

10^{18} meters

100 light years

31 parsecs

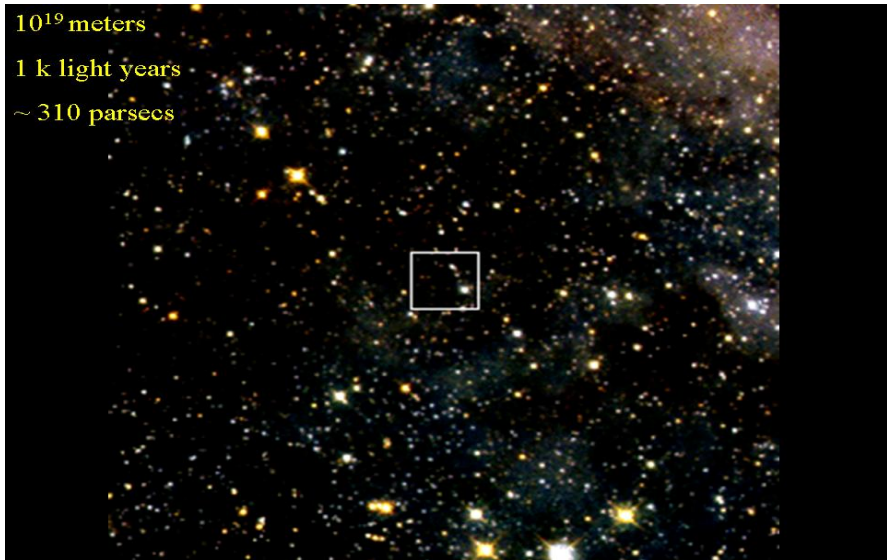


zoom-out 19: A corner of the Milky Way

10^{19} meters

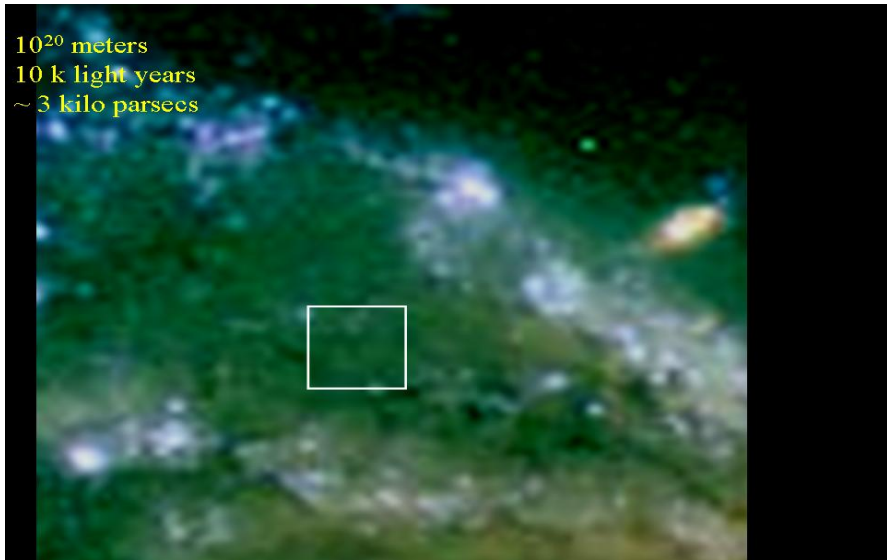
1 k light years

~ 310 parsecs



zoom-out 20: It's not the whole galaxy yet...

10^{20} meters
10 k light years
~ 3 kilo parsecs

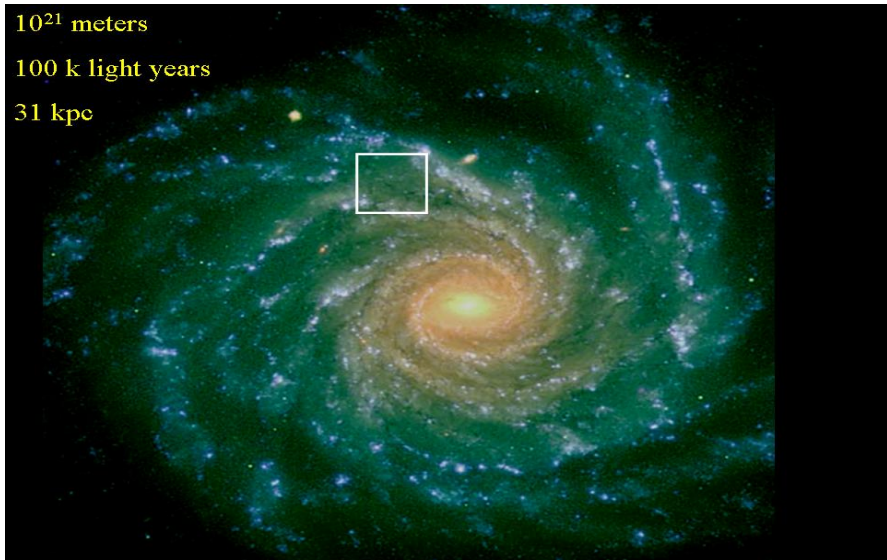


zoom-out 21: Finally, the Milky Way galaxy !

10^{21} meters

100 k light years

31 kpc



zoom-out 22: Some nearby neighbours

10^{22} meters

1 Mega Light years

310 kpc

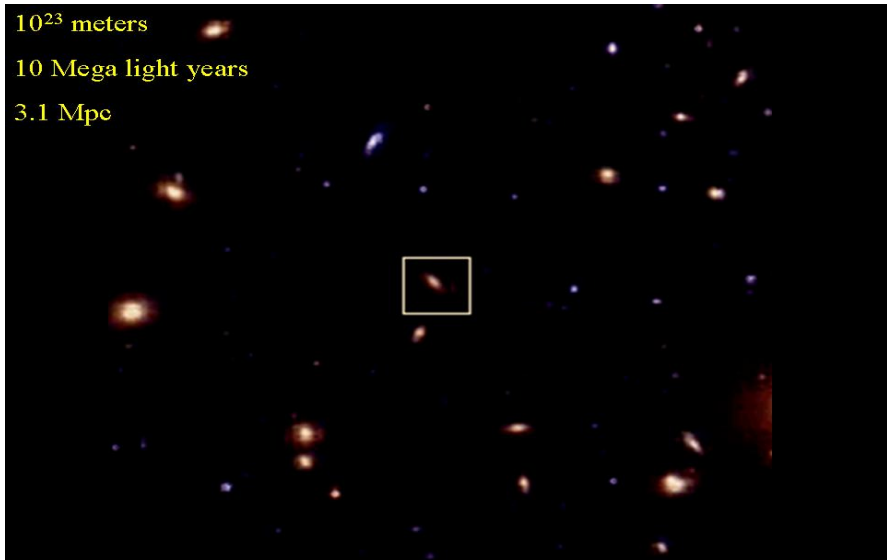


zoom-out 23: Our galaxy cluster

10^{23} meters

10 Mega light years

3.1 Mpc

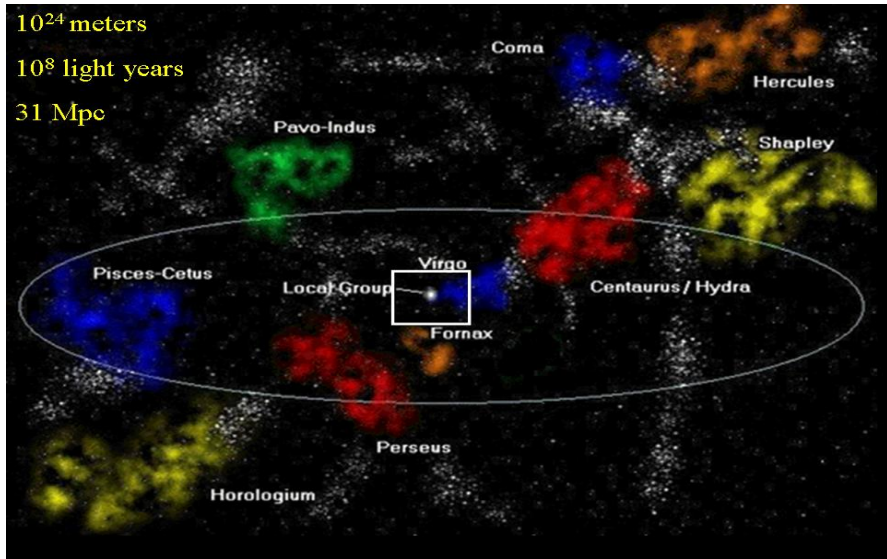


zoom-out 24: Light takes 10 crore years to cross this

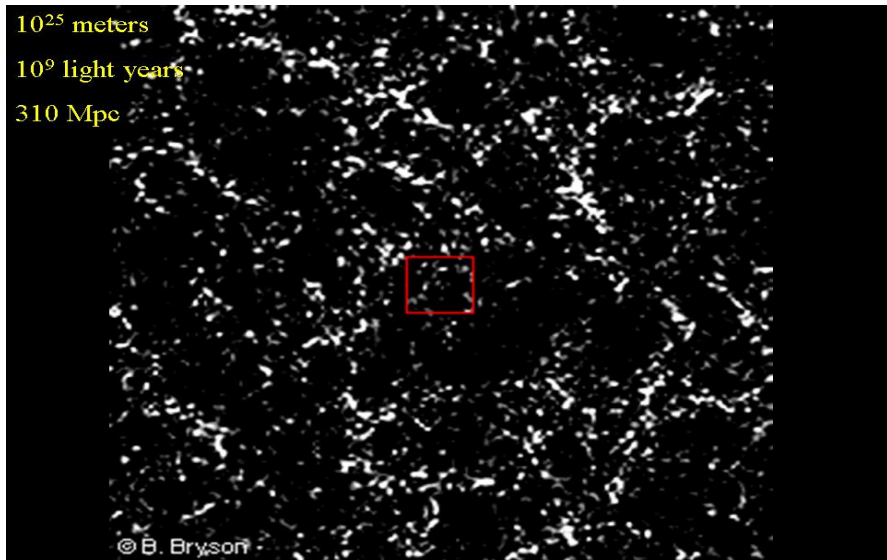
10^{24} meters

10^8 light years

31 Mpc

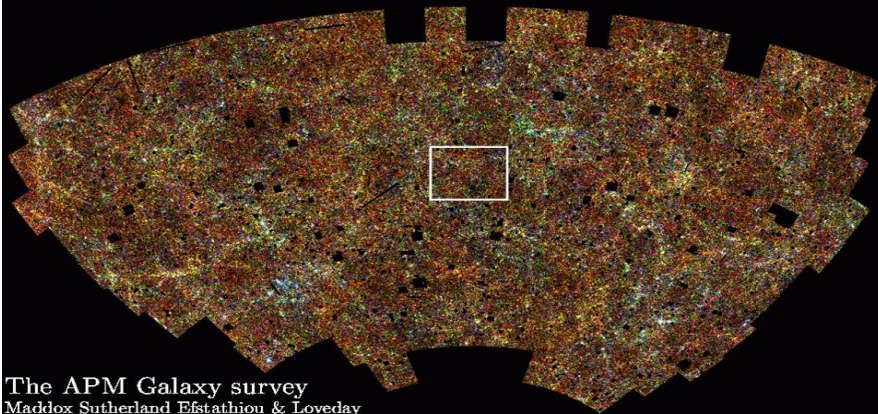


zoom-out 25: ... and 100 crore years to cross this !



zoom-out 26: That's all the universe we see...

10^{26} meters
 10^{10} light years
3100 Mpc



The APM Galaxy survey
Maddox Sutherland Efstathiou & Loveday

Accelerating Universe

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Back to the Earth: $1\text{ m} \times 1\text{ m}$



zoom-in 1: 10cm × 10cm

10⁻¹ meters

0.1 meters

10 cm



zoom-in 2: $1\text{ cm} \times 1\text{ cm}$

10^{-2} meters

1 centimeter

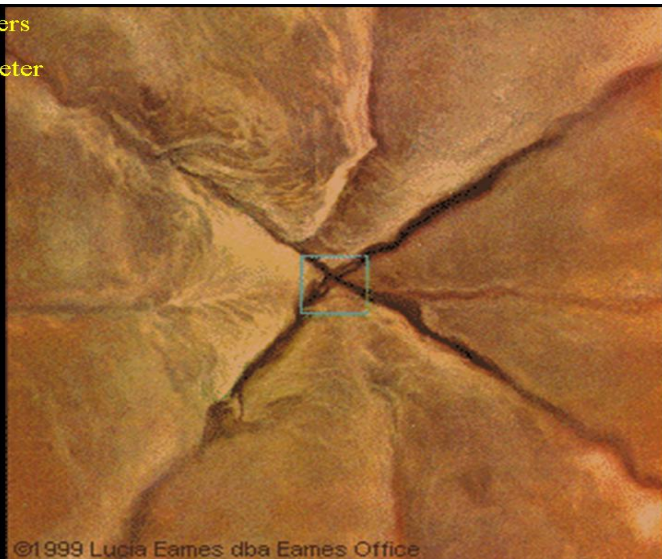


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zoom-in 3: $1\text{ mm} \times 1\text{ mm}$

10^{-3} meters

1 millimeter

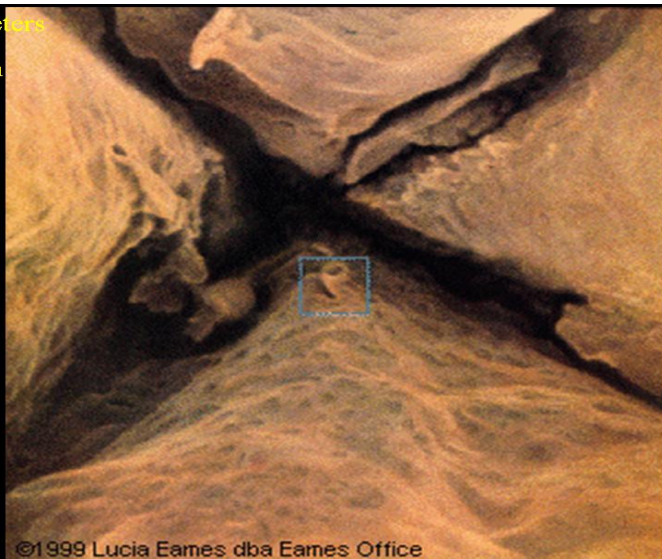


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zoom-in 4: Blood vessel

10⁻⁴ meters

0.1 mm



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zoom-in 5: White blood cell

10^{-5} meters

0.01 mm

10 microns



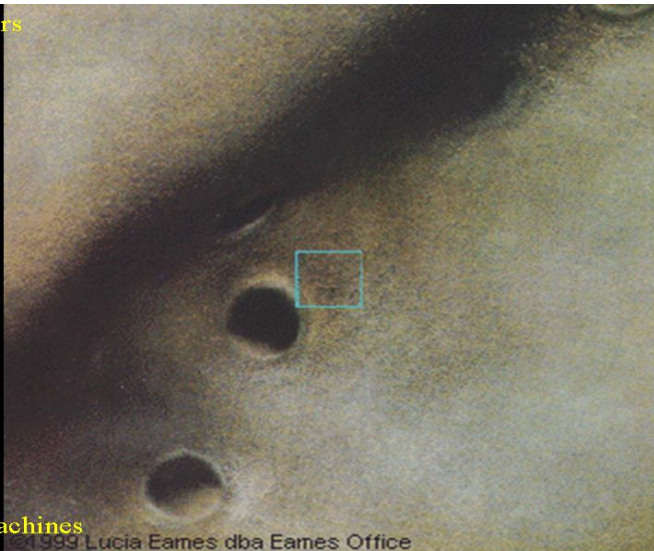
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zoom-in 6: Cell membrane (also: light wavelength)

10^{-6} meters

1 micron

Micro-machines



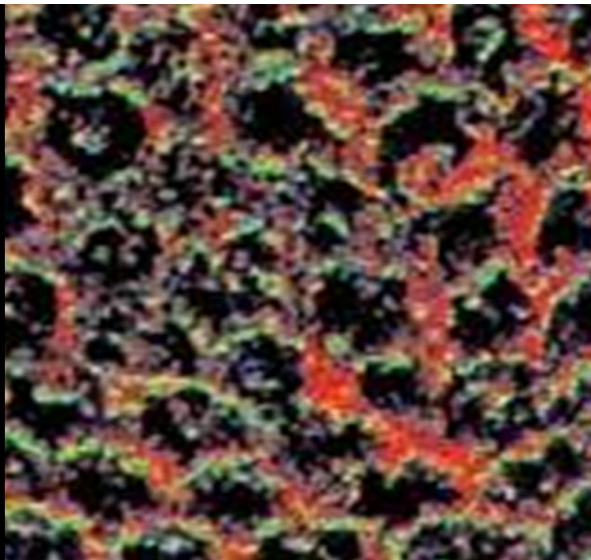
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zoom-in 7: Inside the cell

10^{-7} meters

0.1 micron

100 nm



zoom-in 8: Chromosomes and DNA

10^{-8} meters

0.01 microns

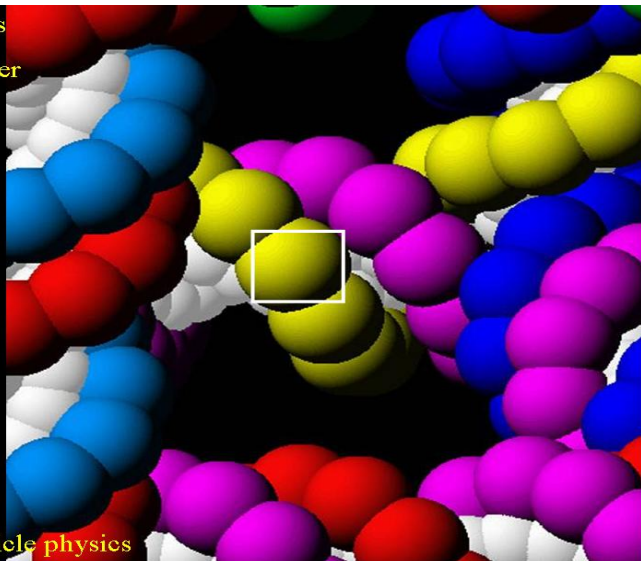
10 nm



zoom-in 9: Amino acids, nanoparticles

10^{-9} meters

1 nanometer



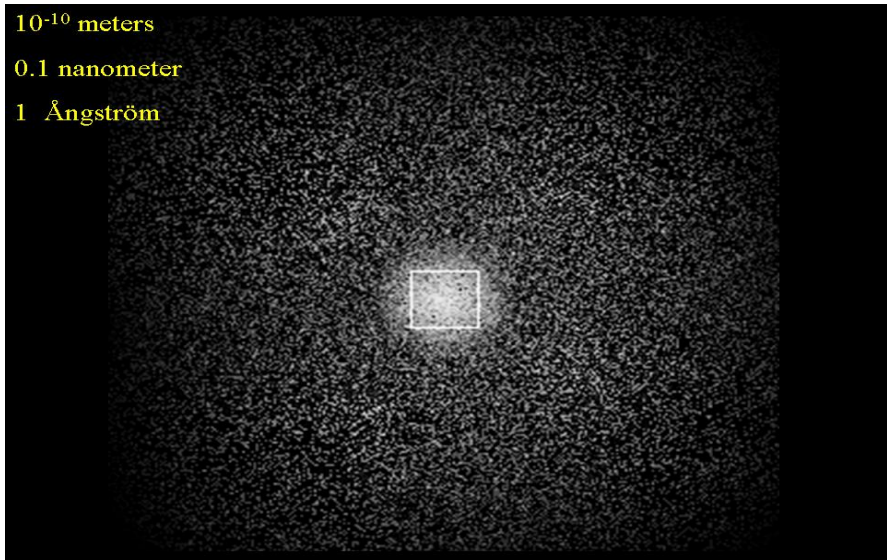
Nano-particle physics

zoom-in 10: An Atom

10^{-10} meters

0.1 nanometer

1 Ångström



zoom-in 11: Within the electron cloud

10^{-11} meters

0.1 Ångström



Note: It is force that is central to Physics

zoom-in 12: Nucleus and nothingness

10^{-12} meters

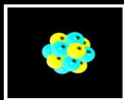
1 picometer



zoom-in 13: Protons and Neutrons

10^{-13} meters

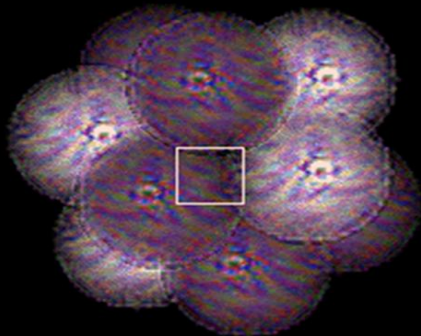
100 femtometers



zoom-in 14: Protons and neutrons have structure

10^{-14} meters

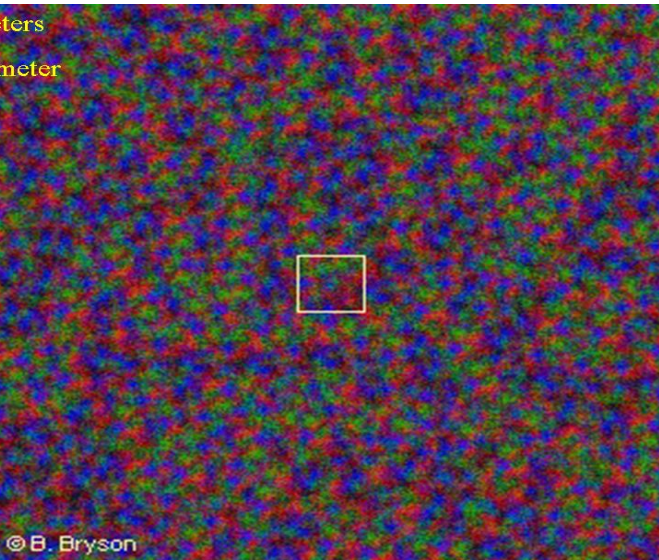
10 femtometers



zoom-in 15: Quarks? gluons? plasma ?

10^{-15} meters

1 femtometer



zoom-in 16: The picture is still unclear...

10^{-16} meters

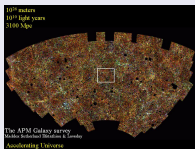
0.1 femtometer



© B. Bryson

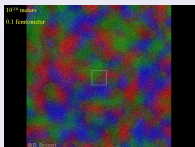
The two extremes

The largest scale



⇒ 100 000 000 000 000 000 000 000 000 000 m

The smallest scale



⇒ 0. 000 000 000 000 000 000 1 m

Shall the twain ever meet ?

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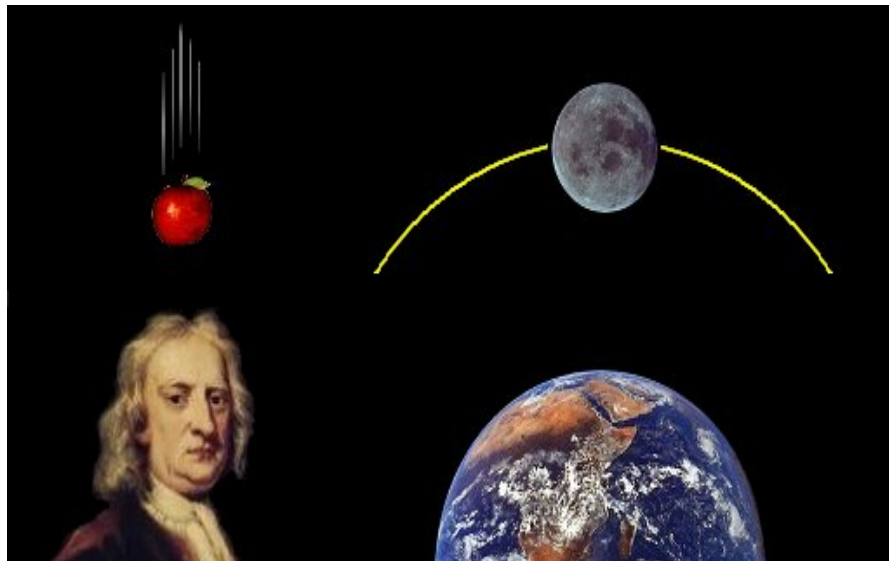
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The falling apple



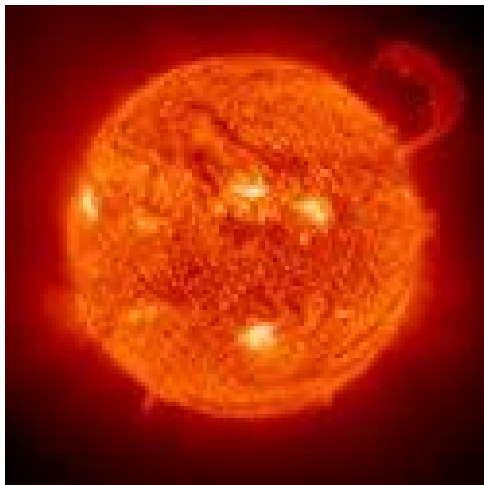
The universal gravitation



The largest, the smallest, and us

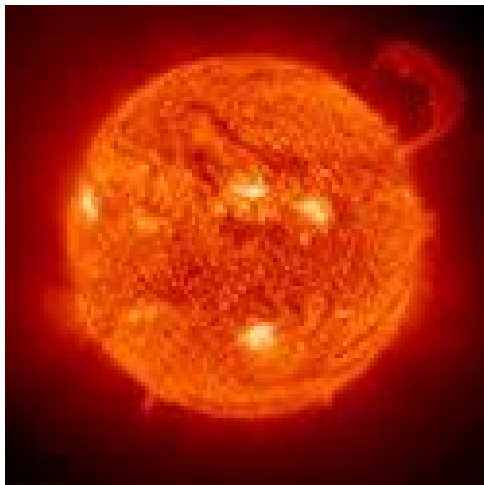
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Burning ball of fire ?



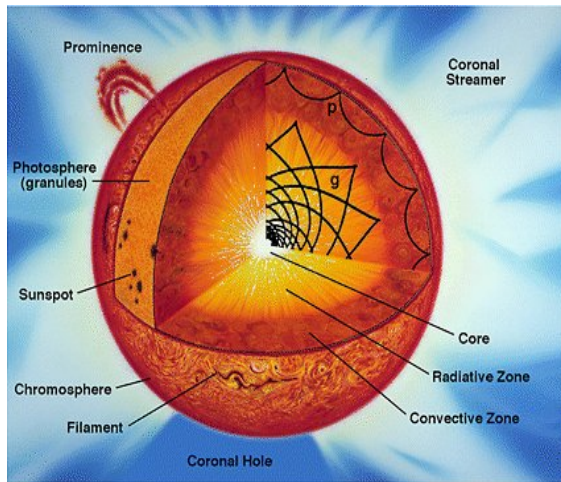
- Would have burnt out in a few thousand years
- But has been around for many more !!

Burning ball of fire ?



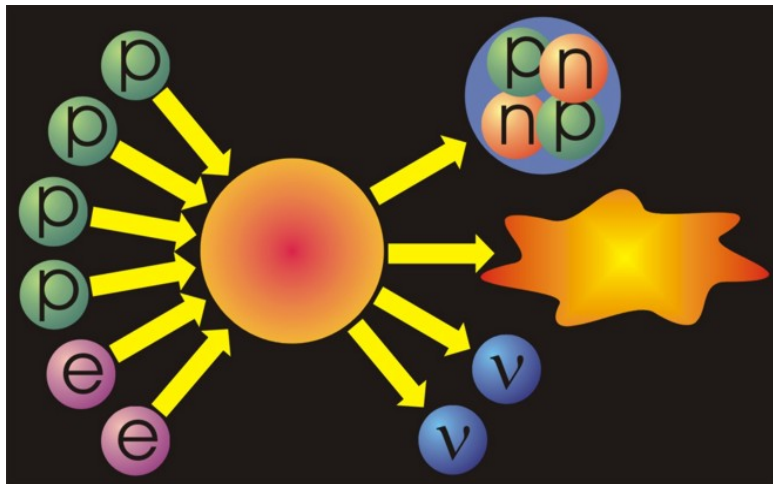
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The structure of the Sun



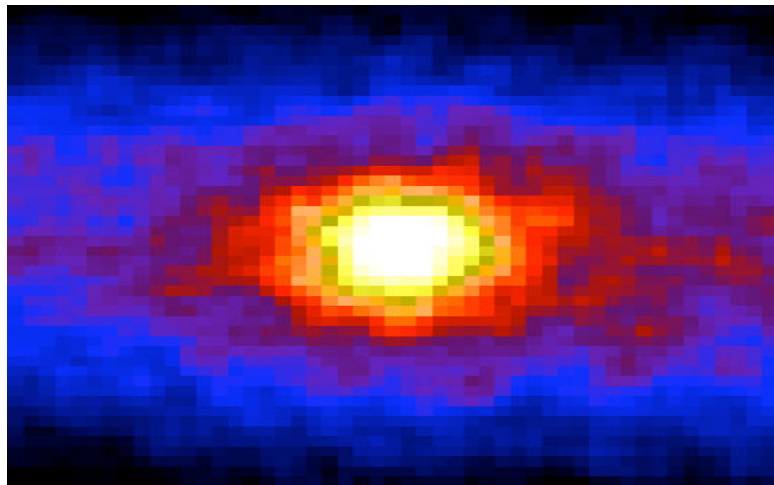
It is a nuclear reactor !

The nuclear reactions



How do we know this ? Can we see some evidence ?

Neutrinos from the Sun: tiny point particles



- Can indeed see neutrinos from the Sun now !
- Around 1 000 000 000 000 neutrinos pass through each of us every second !

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Many forms of gold: origin ?

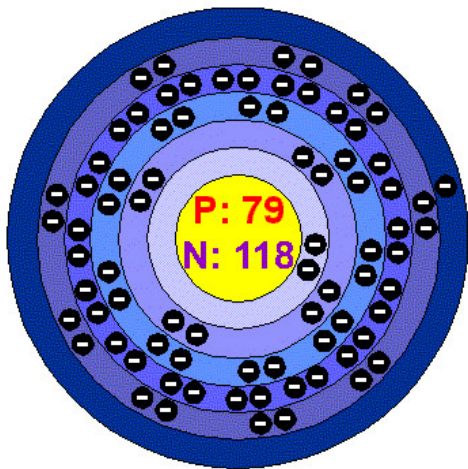


The gold mine



But where did the gold in the mines come from ?

The essence of gold



Why is it a big deal to make gold ?

- Elements have to be made, starting from hydrogen, by nuclear fusion inside stars
- Even the intense temperature and pressure inside stars cannot make elements heavier than iron (26 protons, 30 neutrons)
- Gold has 79 protons and 118 neutrons. How is this possible ?
- There is just one phenomenon we know in nature that can do this...

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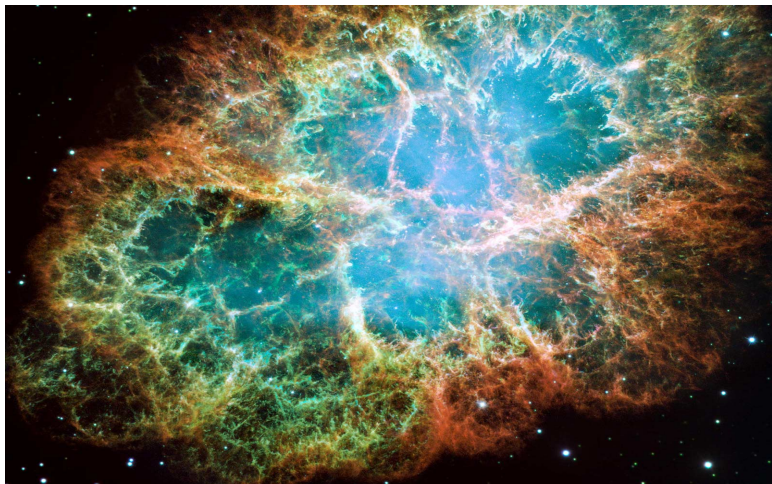
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A supernova !



Crab nebula, Supernova seen exploding in 1054

So that's the story...

- Once upon a time, there was a big star, which exploded (supernova)
- The exploded material travelled far and wide in the galaxies
- It is from this material that the solar system was made.
- We are, literally, "Stardust"

The story of gold has become the story of our origin,
through our knowledge of elementary particles !

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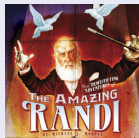
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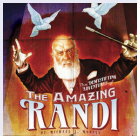
What attracted me to science

Magic tricks (science is unraveling nature's magic tricks)



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Science fiction



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Magic tricks (science is unraveling nature's magic tricks)



Science fiction



An impression that scientists get to travel a lot

What science means to me

Science is...

- A combined global effort to understand how Nature works
- The only reliable way we have to get at objective truth
- An exciting and fulfilling quest

What do I get from being a scientist

- Satisfaction of understanding how nature works
- A different / enhanced(?) appreciation of beauty
- Excitement at new discoveries (even if by others)
- Ecstasy of being the first to know about something new

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The process and the by-product

The enjoyable process

Q and A with nature: each experiment is a question to nature

The by-product

- Learn to ask questions
- Learn to accept answers
- Learn to separate wheat from chaff (pseudoscience)

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The modus operandi of a theorist

- Look for ideas that excite you
- Focus on testable ideas: suggest experiments
- Talk to people about their own research, in any field
- Develop frameworks where many things can be explained together
- Test ideas and throw away the ones that do not fit the data

A creative process, tempered by the way nature works

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How the largest, the smallest, and we come together

- Compared to the vastness of the Universe, we are insignificant: **very humbling**
- Even then, we can understand a lot about how the world functions: **very audacious**
- We can do this by studying properties of tiny particles in the laboratory: **very ingenious**
- In the process, we learn more and more about the nature, and about ourselves...

That's my junoon !

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