Scale of the Universe

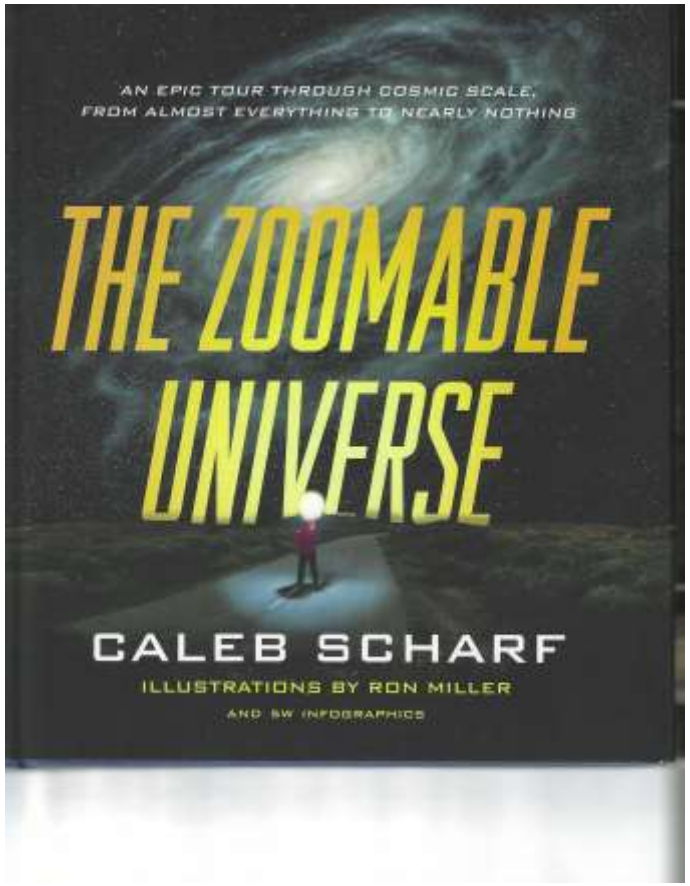
Rick Marra
Pretend physicist; real Chemical Engineer

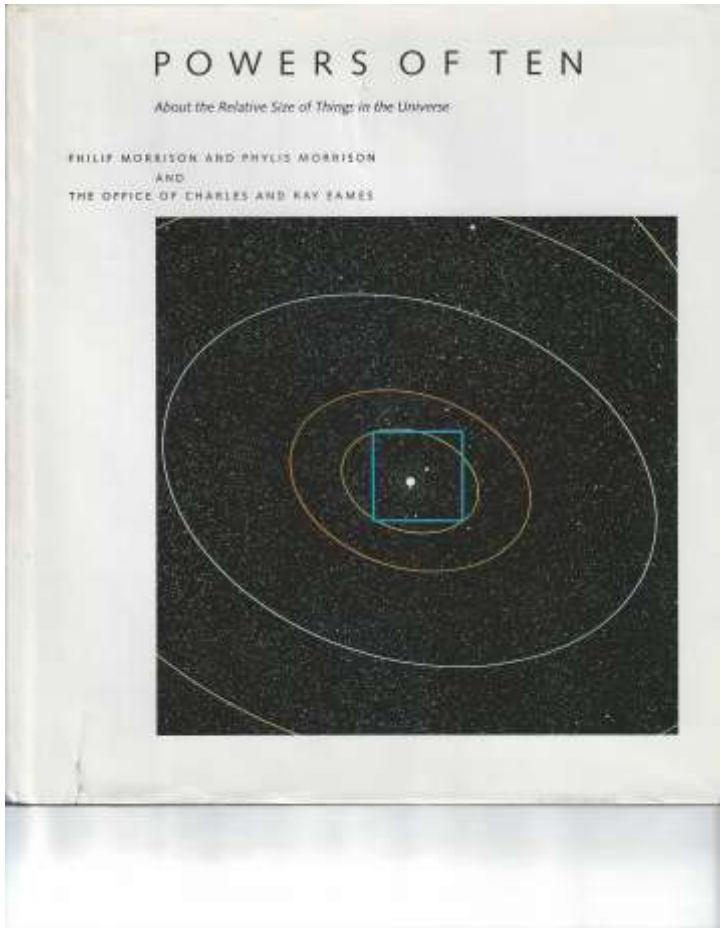
I get fascinated with a new book and try to share with my OLLI friends.

The Scale of the Universe will “Blow Your Mind”.

No objective here; just a fun romp through the wonders of our world.

(I actually look better than this!!)


AN EPIC TOUR THROUGH COSMIC SCALE,
FROM ALMOST EVERYTHING TO NEARLY NOTHING
THE ZOOMABLE UNIVERSE
CALEB SCHARF
ILLUSTRATIONS BY RON MILLER
AND SW INFOGRAPHICS


POWERS OF TEN
About the Relative Size of Things in the Universe
PHILIP MORRISON AND PHYLIS MORRISON
AND
THE OFFICE OF CHARLES AND RAY EAMES

This is NOT Science Fiction or Mere Speculation

- Everything I'm going to cover has a scientific basis and is considered possible by the "Cosmological Community".

- (Great Courses a good reference)

The Limitations of “Human Scale”

- Inch/ foot/ yard/ mile
- Mile 1000 Roman Paces (5280ft/1000 = 5ft per pace - big guy!)
- A mile can walk in (a young person) about 20 minutes
- 10 miles about 3 hours
- 100 miles (Columbus) 5 days (a young person)
- 1000 miles (Denver) Appalachian Trail – 2-3 months Wagon Train - 6 months Auto 2-3 days
- 2000 miles (California) 4 hours in a plane (doesn’t count) 3 days in a car
- 10,000 miles (around the world) Magellan – 3 years
-
- <u>This is about IT. I can’t grasp anything more.</u>
- Planes don’t count. No perspective.

Human Scale

- The moon - 250,000 miles (1.28 light seconds)
- 500 days in a car
-
- The sun - 93,000,000 miles (8 light minutes)
- 186,000 days in a car
- 500 years in a car

Similar on the downside

- Distance (How small can we perceive?)
- A centimeter
- A millimeter
- The width of a human hair
- A chigger
- ???

Time is Similar

- Second minute hour day month year decade century millennium

- One generation (20 years) my parents
- Two generations (40 years) my grandparents
- Three Generations (60 years) my great grandparents
- Four Generations (80 years) ?
- Five Generations (100 years) ?
- Six Generations (120 years) ?
- Seven Generations (140 years) ?
- Eight Generations (160 years) old photos

- My human limit is about 200 years

Small Times

- A second
- A tenth of a second – baseball
- A hundredth of a second – hocky puck
- A thousands of a second - ????

The Human Condition

So, we are heavily biased by the “human condition”.

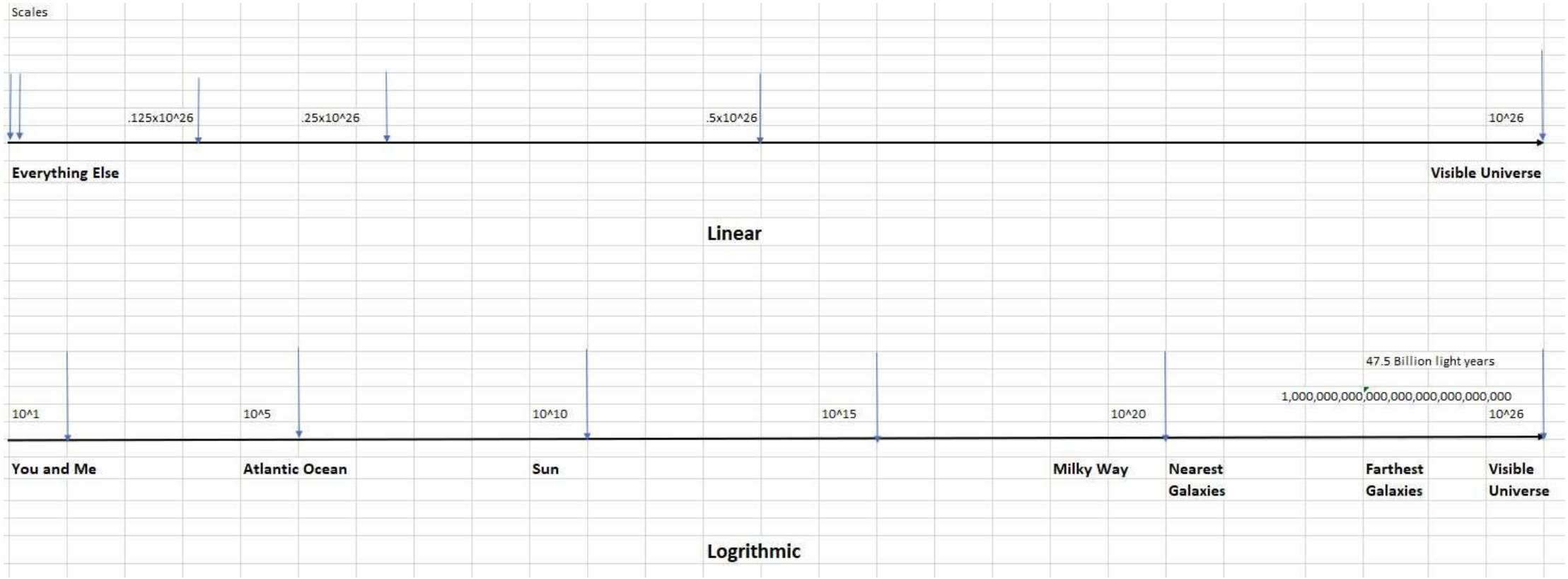
(bacteria and protozoans are not “crazy”.)

Because the scales are so huge

We need a new math to describe the situation

- Linear not practical Consider a Yardstick
- We would need a sheet of paper that would stretch to the moon
- Or, a mile of paper and our solar system would be an atom. Doesn’t work

Linear versus Logarithmic Scales



Exponents were created

- 10^0 1
- 10^1 10
- 10^2 100
- 10^3 1,000
- 10^4 10,000
- 10^5 100,000
- 10^6 million
- 10^9 billion
- 10^12 trillion

Plus

10^4 x 10^5 = 10^9

Exponents add in multiplication

10^8 is NOT twice as big as 10^4

10^8 is 10 x10 x10 x10 or 10,000 times bigger than 10^4

Distance Measurements Big

A meter (about 1 yard)

A “Light Year”

about 10^15 meter

a million (10^6) x a million (10^6) x a thousand (10^3)

Astronomical Unit earth to sun distance

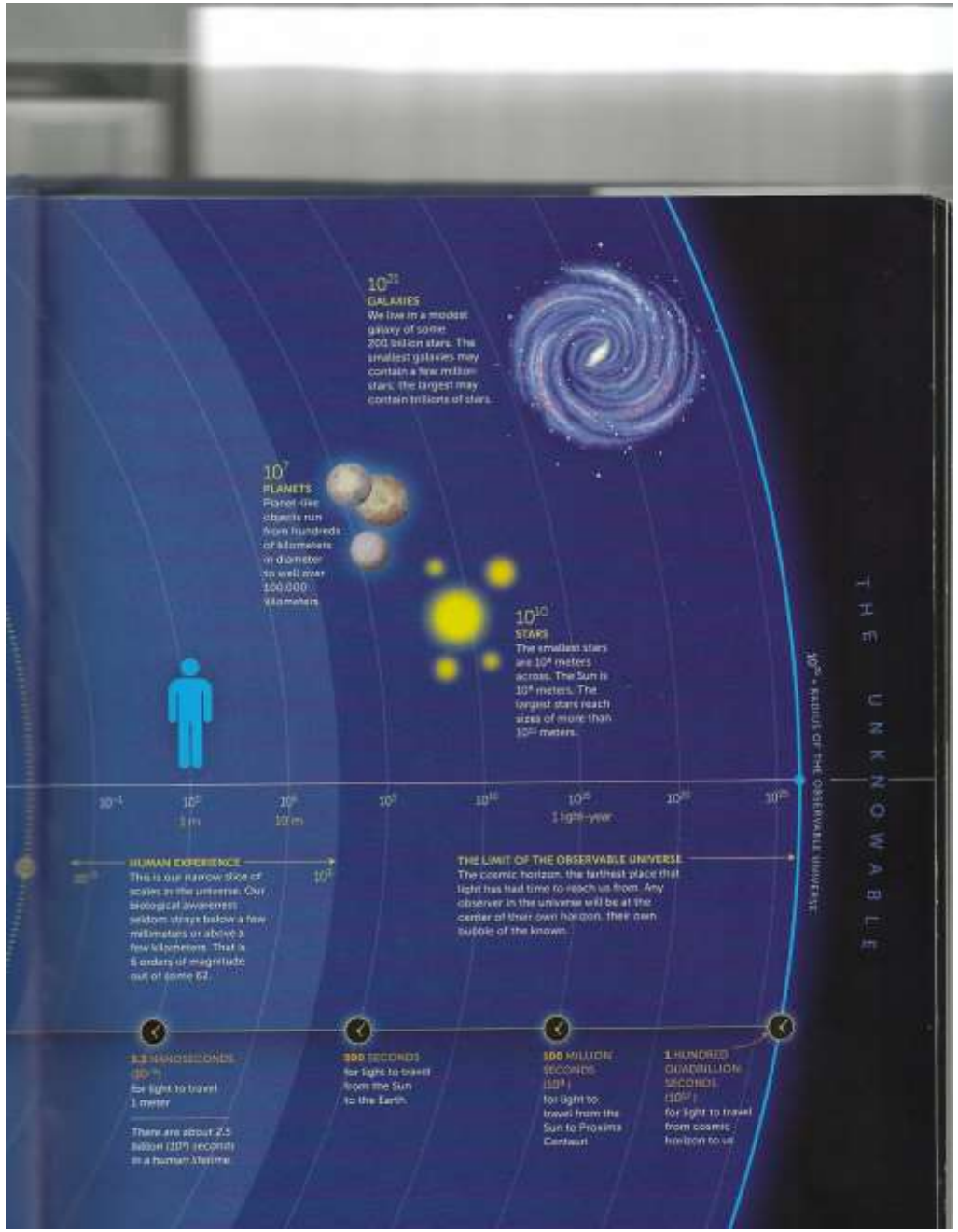
A “Light Year” about 63,000 AU

Distance Measurements Small

A meter (about 1 yard)		10^0 meter
A millimeter	1/1000 meter	10^-3 meter
A micrometer (micron)	1/million meter	10^-6 meter
A nanometer	10^-9 meter	
An angstrom	10^-10 meter	
A picometer	10^-12 meter	
A femtometer	10^-15 meter	

“Powers of Ten” Video

Powers of Ten - Bing video



The Observable Universe
10^26 meters away or
46 billion light years but,
The Universe is only 13.8 billion years old

The Universe has been expanding for the 13.8 B years

Stars that emitted light 13.8 B years ago when the universe was 42 million light years away are now 46 Billion light years away.

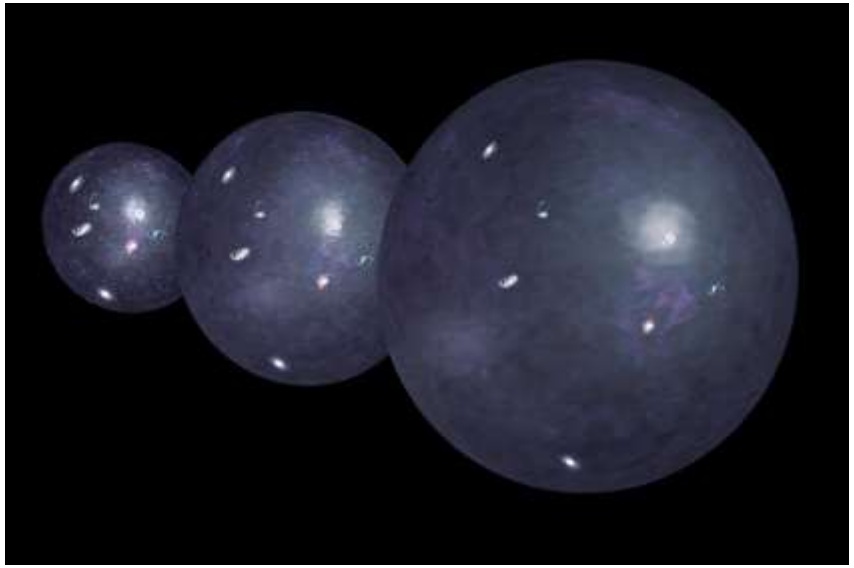
At the present, our observable universe gets bigger every day. However, there will be a time when expansion is faster than the speed of light and we can see NO further, EVER.

What is beyond the “Observable Universe”
at least 250 times bigger
maybe much bigger
infinite ??

A curved universe like an expandable globe. On small scales looks flat. We can’t see any curvature – infinite or very big.

Inflation - 1 meter to 10^1,000,000 meters in a fraction of a second.

Expanding Universe



What is beyond the visible universe ?

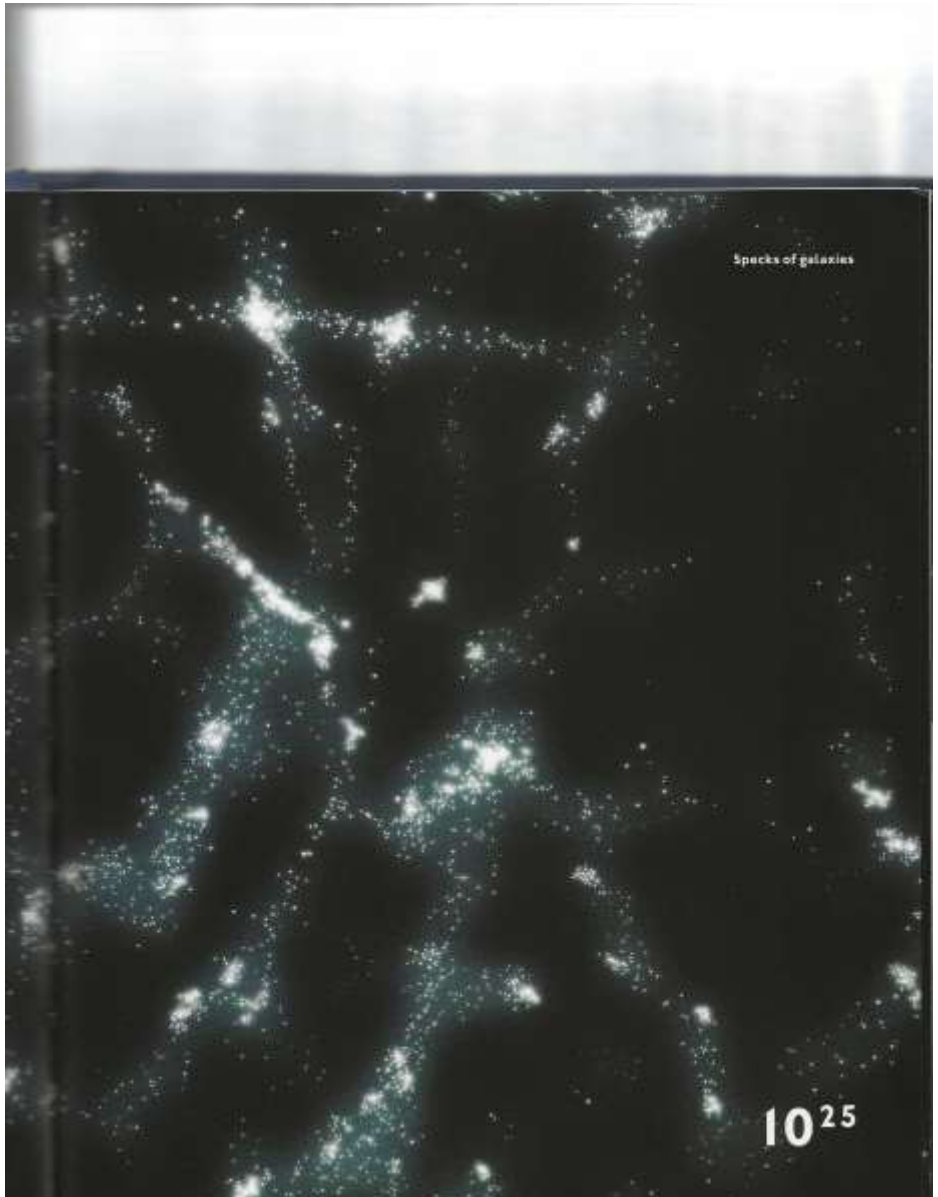
Infinite (flat geometry. Looks flat to us.)
- duplicate universes
- a duplicate “you”

Curved space – finite

Parallel universes
- multi dimensional membranes

Bubble universes

Galactic Clusters 10^25 meters



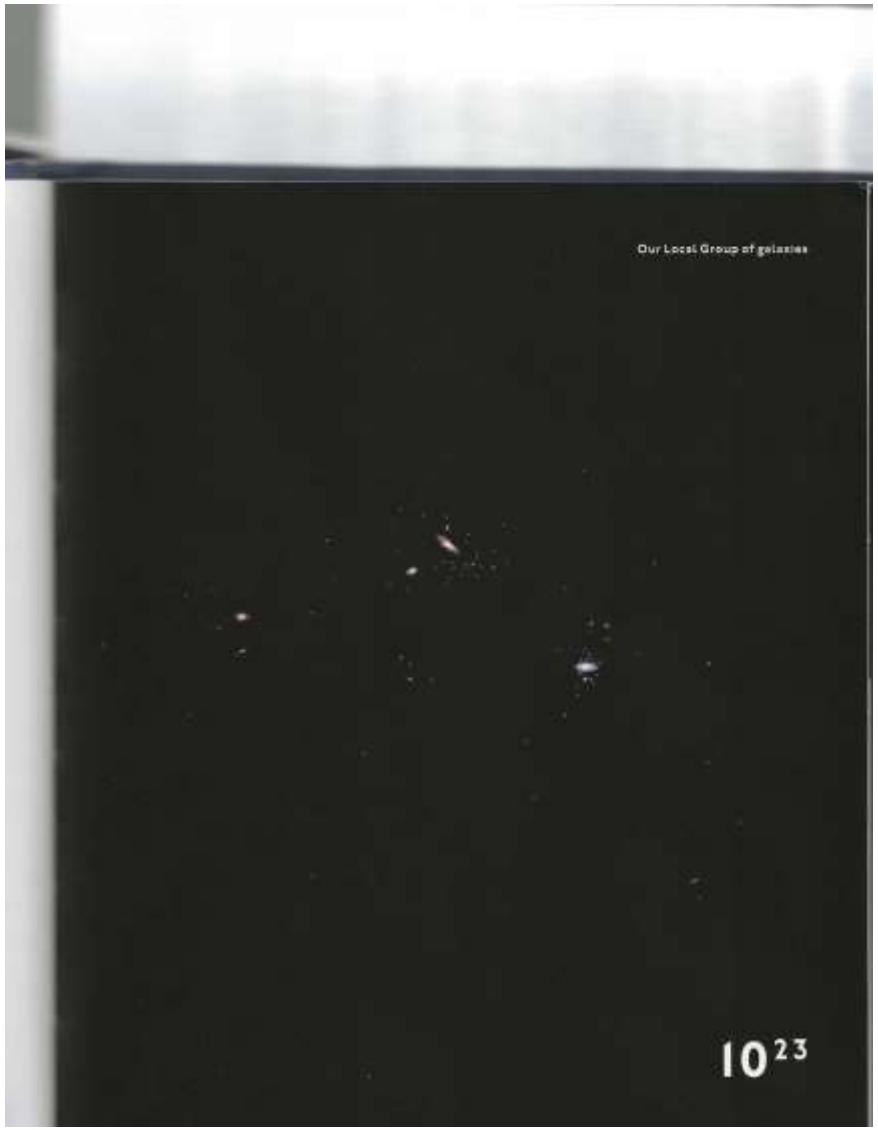
The largest structures in the universe. Galaxies form ribbons and chains.

Models attempt to match these structures by varying the amounts of mater and dark matter at the time of the Big Bang.

The match generates densities that imply a “flat universe” of infinite extent.

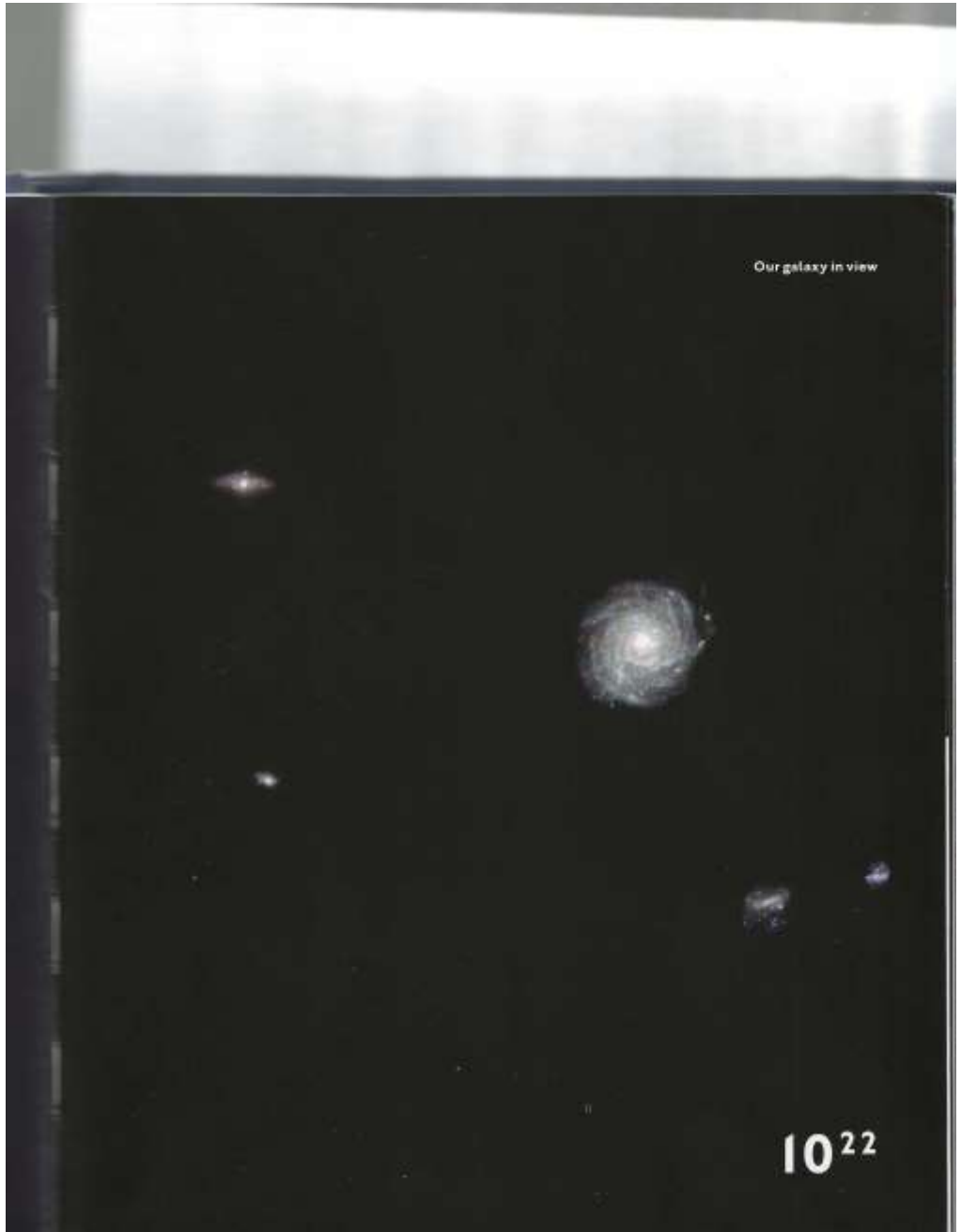
Movement of the clusters seems to indicate that the clusters are being influenced by gravity coming from outside the visible universe, or from another dimension.

Intergalactic Space 10^23 meters



10^26 to 10^23

1000 times smaller

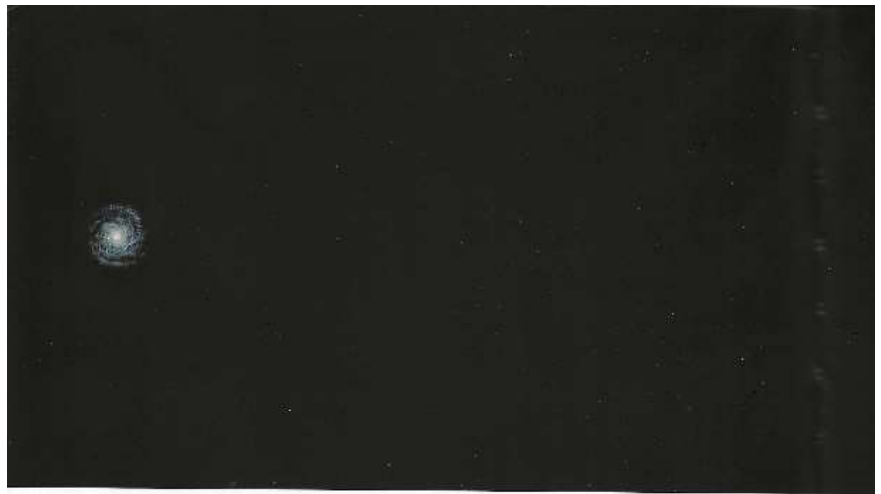


10^22 meters

We can now see our galaxy –

The Milky Way

(10,000 times smaller)



OUR (SLIGHTLY DYSFUNCTIONAL) GALACTIC FAMILY

The typical separation experienced by the brighter clusters and groupings of galaxies themselves is a little less isolating—only about 3 million light-years, or 3×10^{22} meters. For example, from the center of our Milky Way galaxy to the center of the nearest large galaxy, Andromeda (also known as Messier 31, or M31), there is a relatively modest gulf of about 2.5 million light-years, or 2.5×10^{22} meters.

There is also evidence of a tenuous cloud of plasma (a gas of positively charged ions and electrons) surrounding Andromeda out to a distance of about a million light-years (10^{22} meters). It's awfully thin stuff, to our human senses indistinguishable from the harshest of vacuums. But some of the components of this gaseous mixture are at a temperature of nearly a million degrees Kelvin and include carbon and silicon, as well as hydrogen and helium. We don't yet know if the Milky Way has its own similar halo.

The Milky Way (far left) and Andromeda to scale

What we *have* discovered is that the Milky Way plays ringmaster to a swarm of smaller satellite galaxies. The ones with the most stars in them are the familiar Large and Small Magellanic Clouds, a pair of dwarf irregular galaxies containing about thirty billion stars and three billion stars, respectively. But there are at least another thirty dwarf galaxies within about a million and a half light-years, most of which are likely in orbit around the Milky Way.

We've also discovered that this is not an entirely happy family. The orbit of these dwarf galaxies can result in their stars being gravitationally pulled away and stripped out into colossal "tidal streams" that wrap around the Milky Way. These stellar debris fields are clues to understanding galaxy growth. A big galaxy can sometimes put on weight by cannibalizing its smaller associates over billions of years.

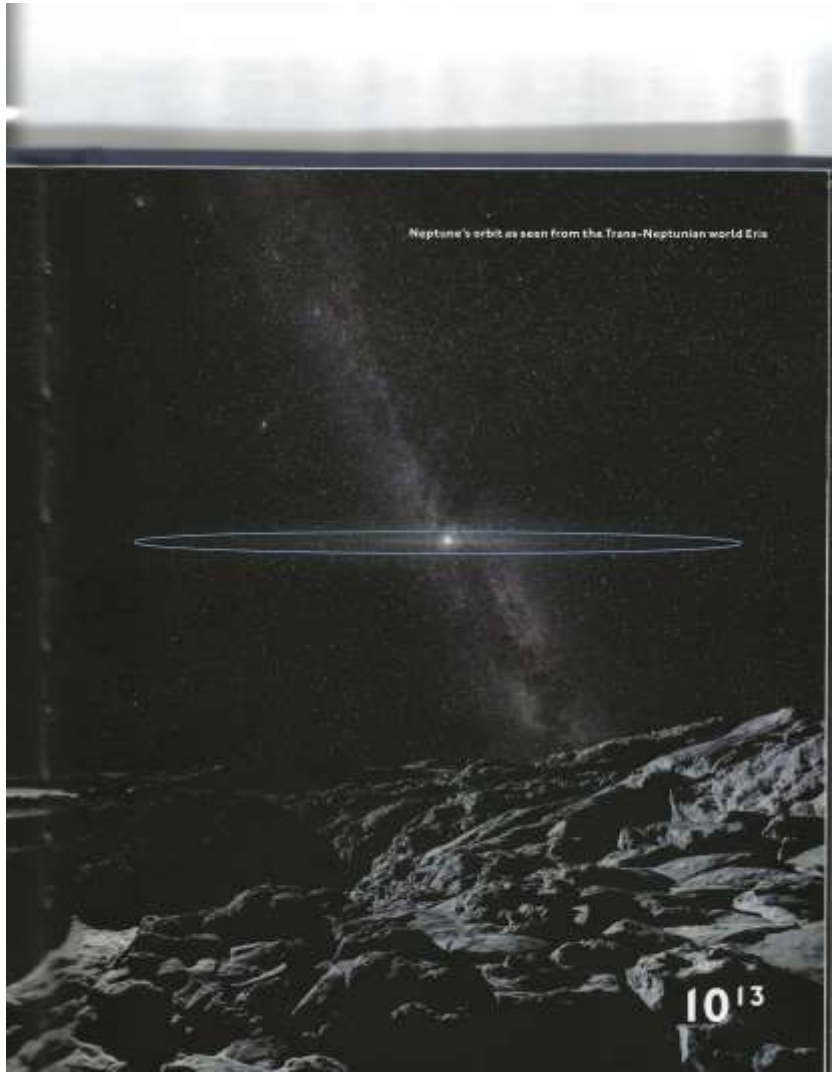
These tidal streams around the Milky Way are extremely faint because they represent only a small number of stars spread across the gulf of intergalactic space. But sensitive telescopic data

Andromeda and the Milky Way to Scale.

2.5 million Light Years separation

Inside the Milky Way 10^20 Meters

The Solar System from Neptune 10^13 Meters

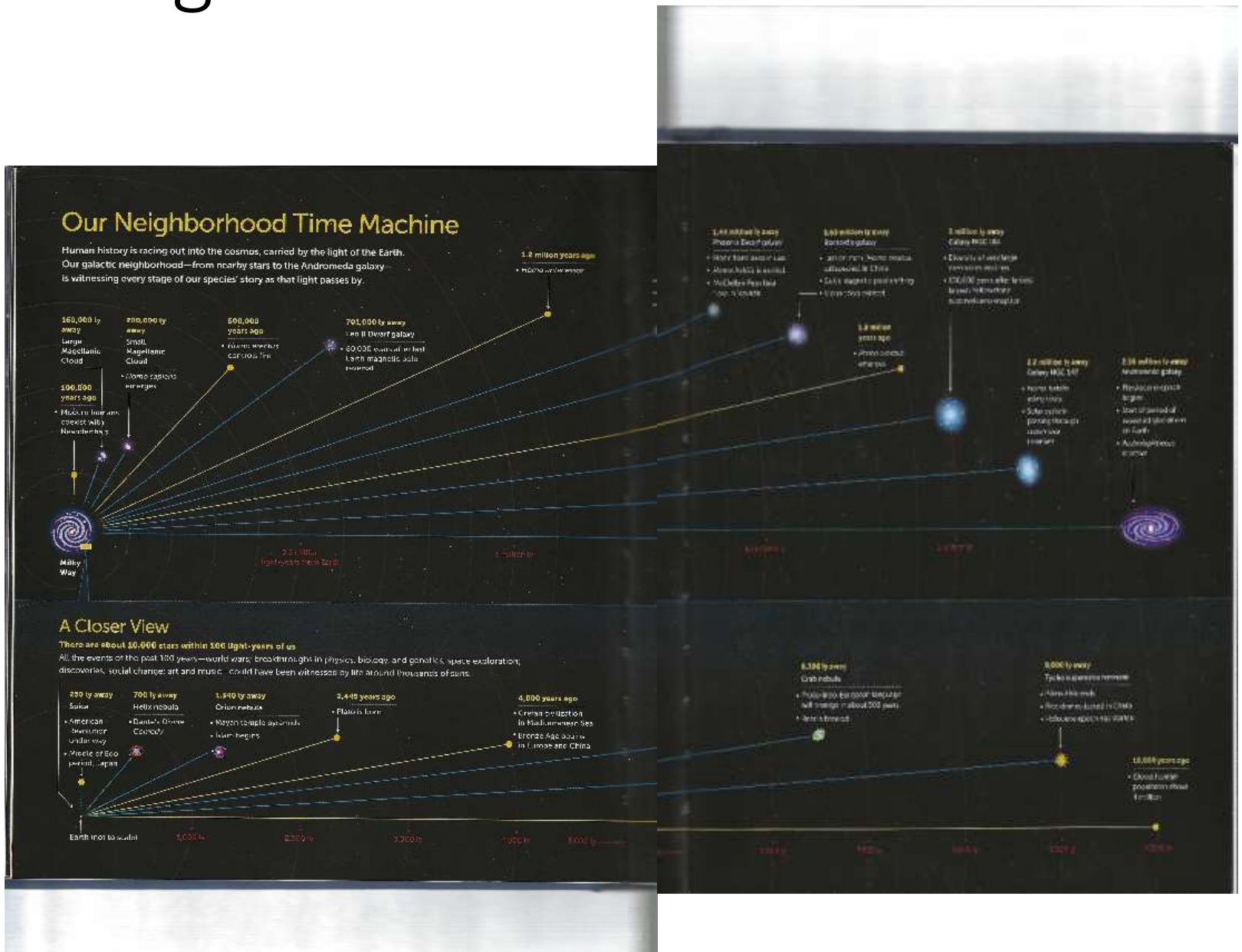


10^26 to 10^13

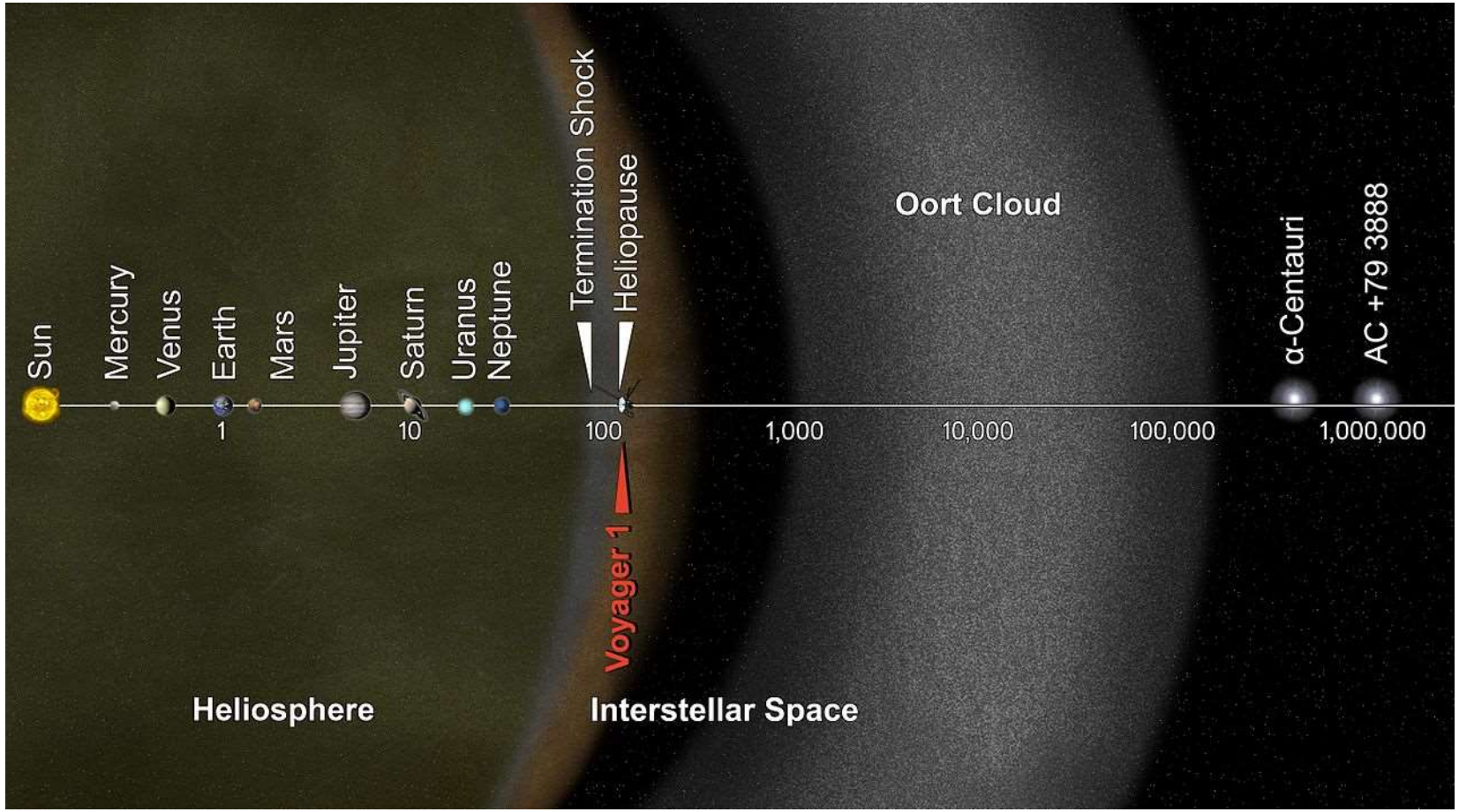
13 orders of magnitude

1 million x 1 million x 10 times smaller

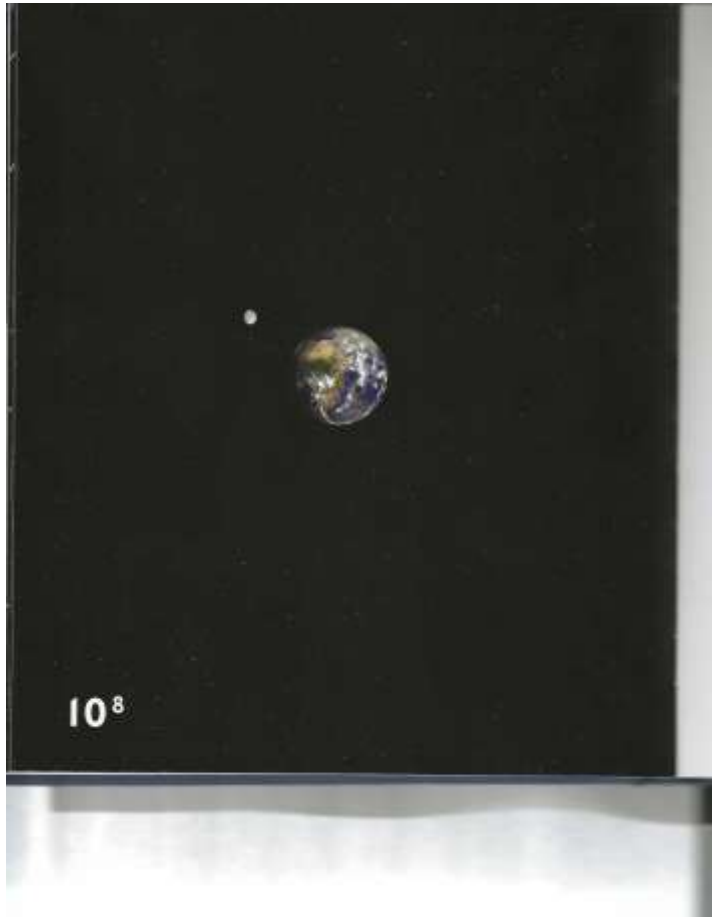
Our Neighborhood



The Extent of our Sun 1.50 10^12 m



Earth and the Moon 10^8 Meters

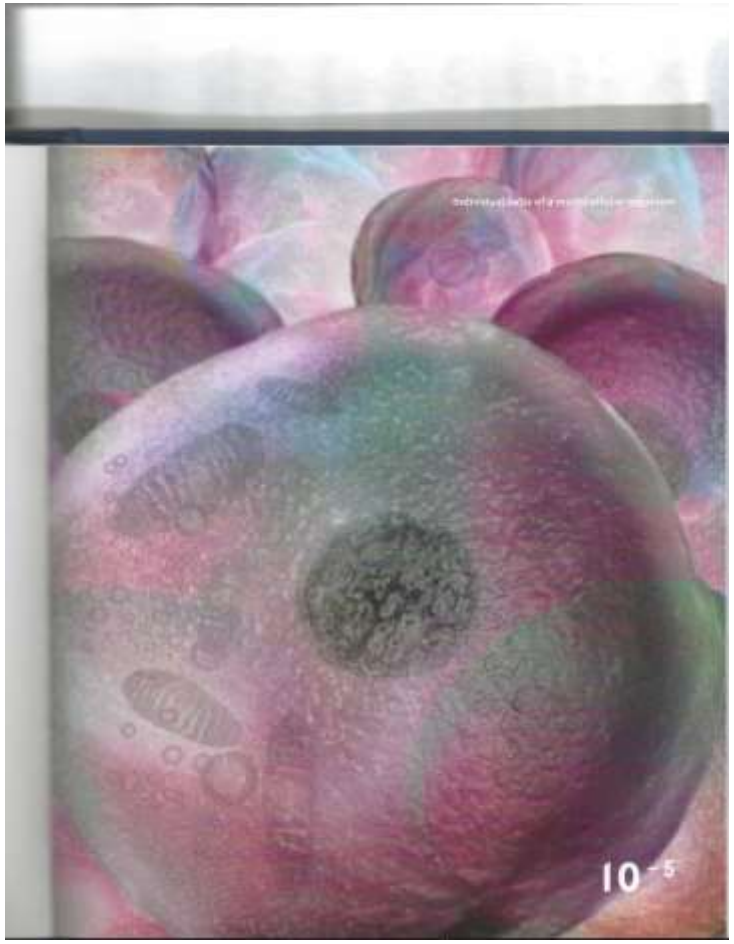


Now Let’s Go the Other Way

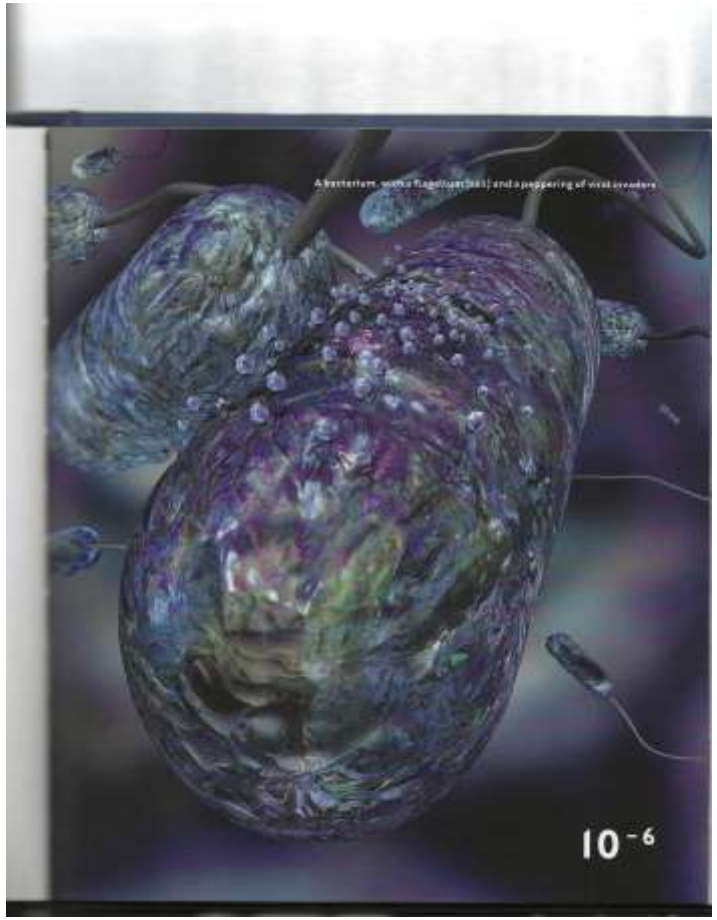
- Video
  - Powers of Ten
  - Powers of Ten - Bing video

Pollen 10^-4

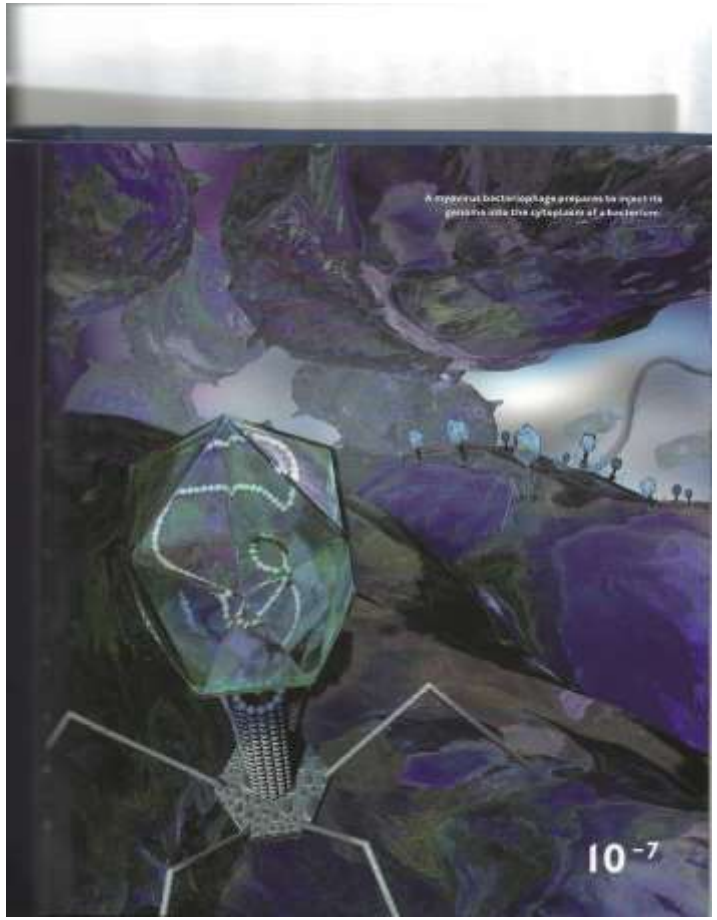
Cells 10^-5



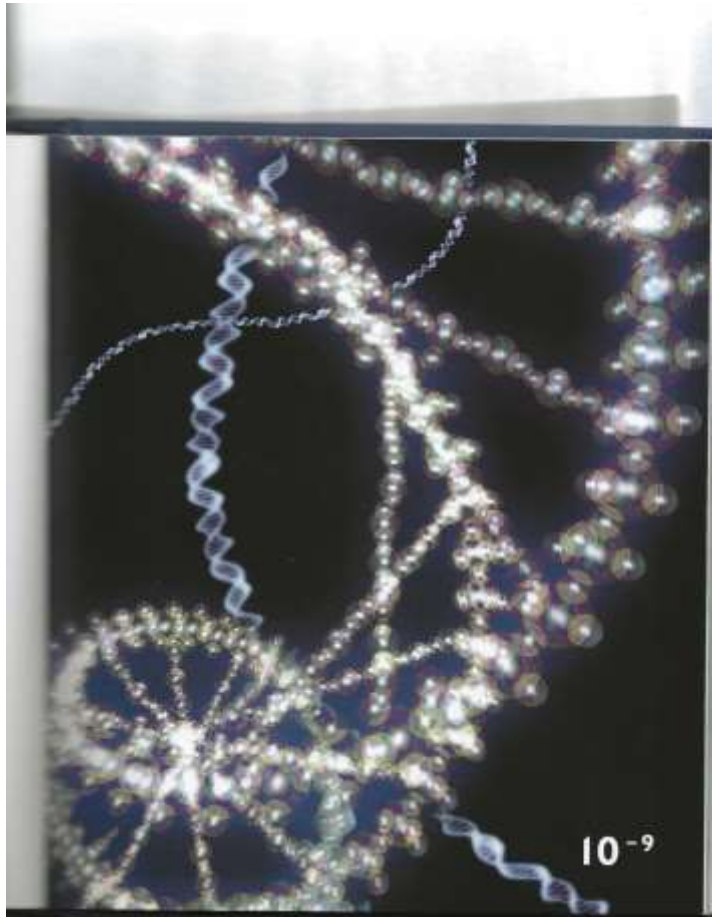
Bacteria 10^-6 (1 million times smaller)



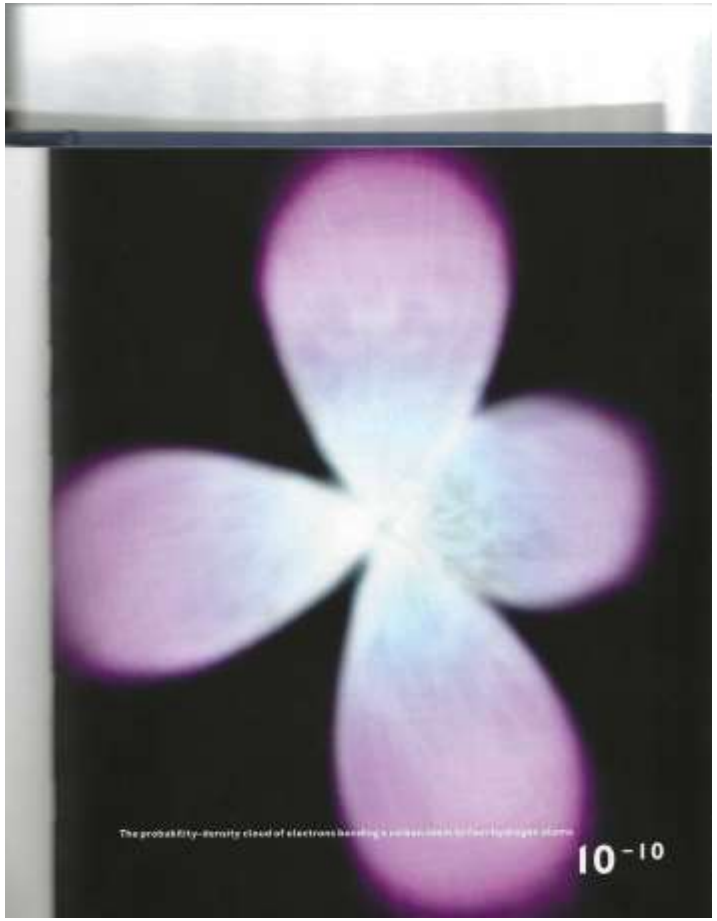
Virus 10^-7



Large Molecules (DNA) 10-9



Atoms 10^-10 (angstrom)



We are leaving the realm of the “understandable” and entering the quantum world.

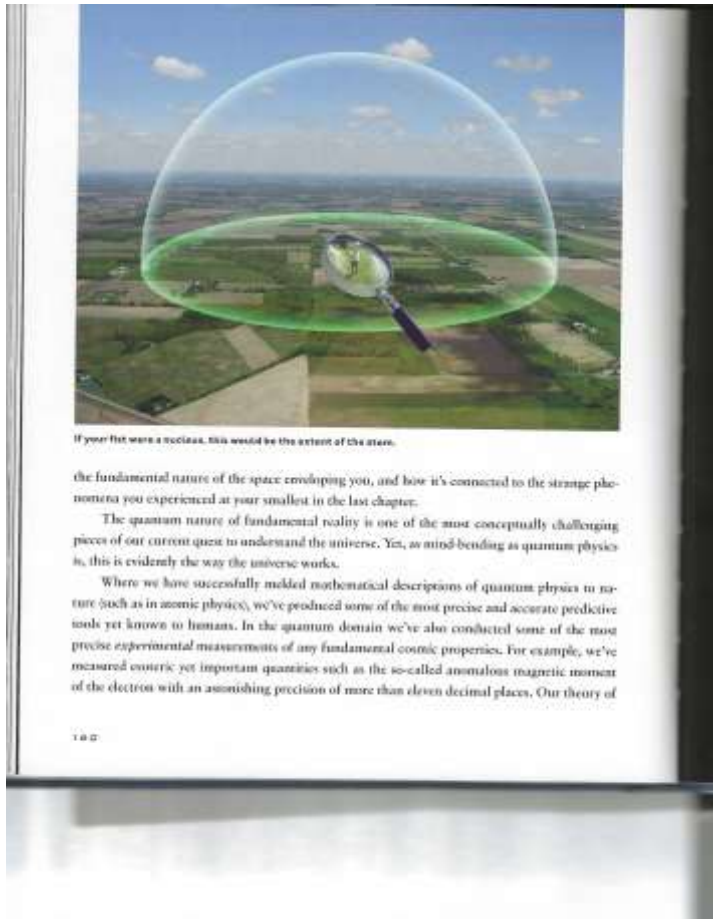
This is a carbon atom with 4 outer electrons in a probability “cloud”. The electron is everywhere and nowhere at the same time.

The closest analogy is a vibration table – electrons are disturbances in an energy field.

https://youtu.be/3kQTQ_1w6rc

Standing Waves

Atom to Nucleus



If your fist were a nucleus, this would be the extent of the atom.

the fundamental nature of the space enveloping you, and how it's connected to the strange phenomena you experienced at your smallest in the last chapter.

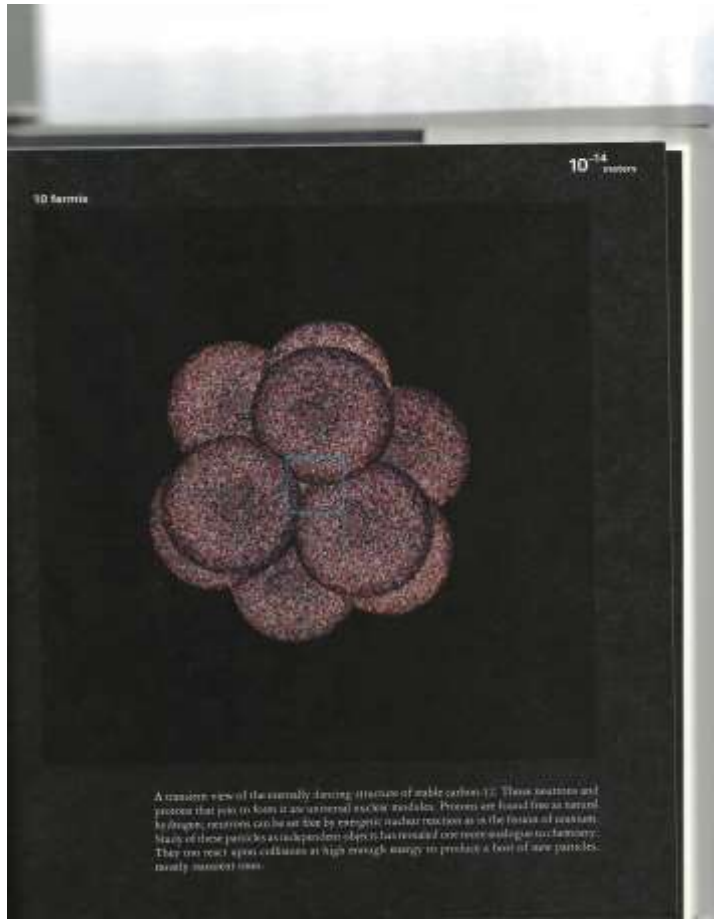
The quantum nature of fundamental reality is one of the most conceptually challenging pieces of our current quest to understand the universe. Yet, as mind-bending as quantum physics is, this is evidently the way the universe works.

Where we have successfully melded mathematical descriptions of quantum physics to nature (such as in atomic physics), we've produced some of the most precise and accurate predictive tools yet known to humans. In the quantum domain we've also conducted some of the most precise *experimental* measurements of any fundamental cosmic properties. For example, we've measured esoteric yet important quantities such as the so-called anomalous magnetic moment of the electron with an astonishing precision of more than eleven decimal places. Our theory of

Lots of empty space

Gold Experiment

Nucleus 10^-15 (femtometer)

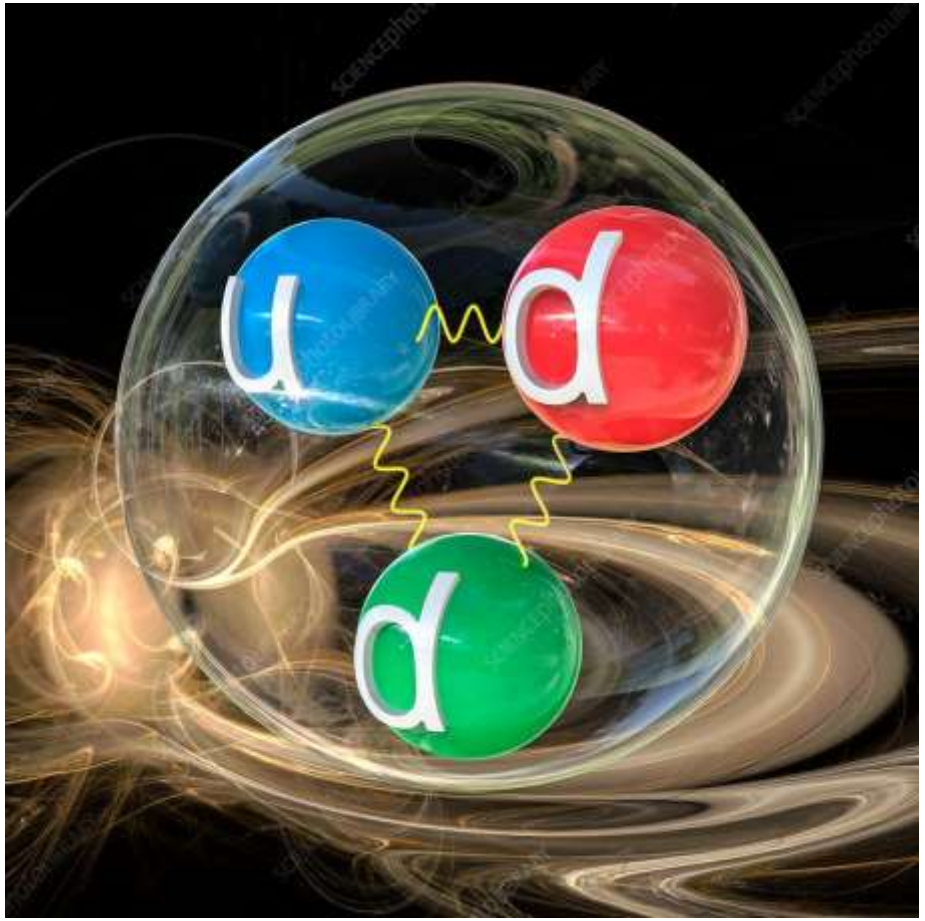


The “Strong force” holds the nucleus together.

•Now, it gets really weird!

- Inside the proton/neutron
  - Quarks and virtual particles and the strong force

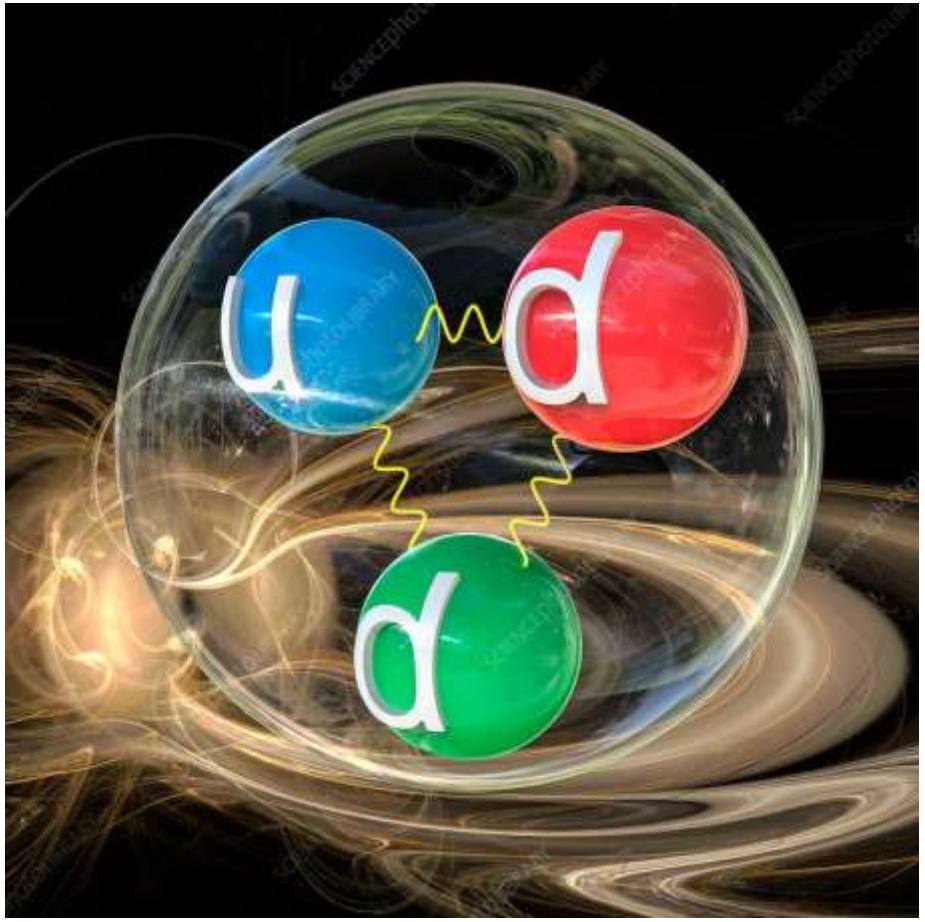
Inside the proton/neutron 10^-17 meter



Up and down quarks plus billions of virtual particles

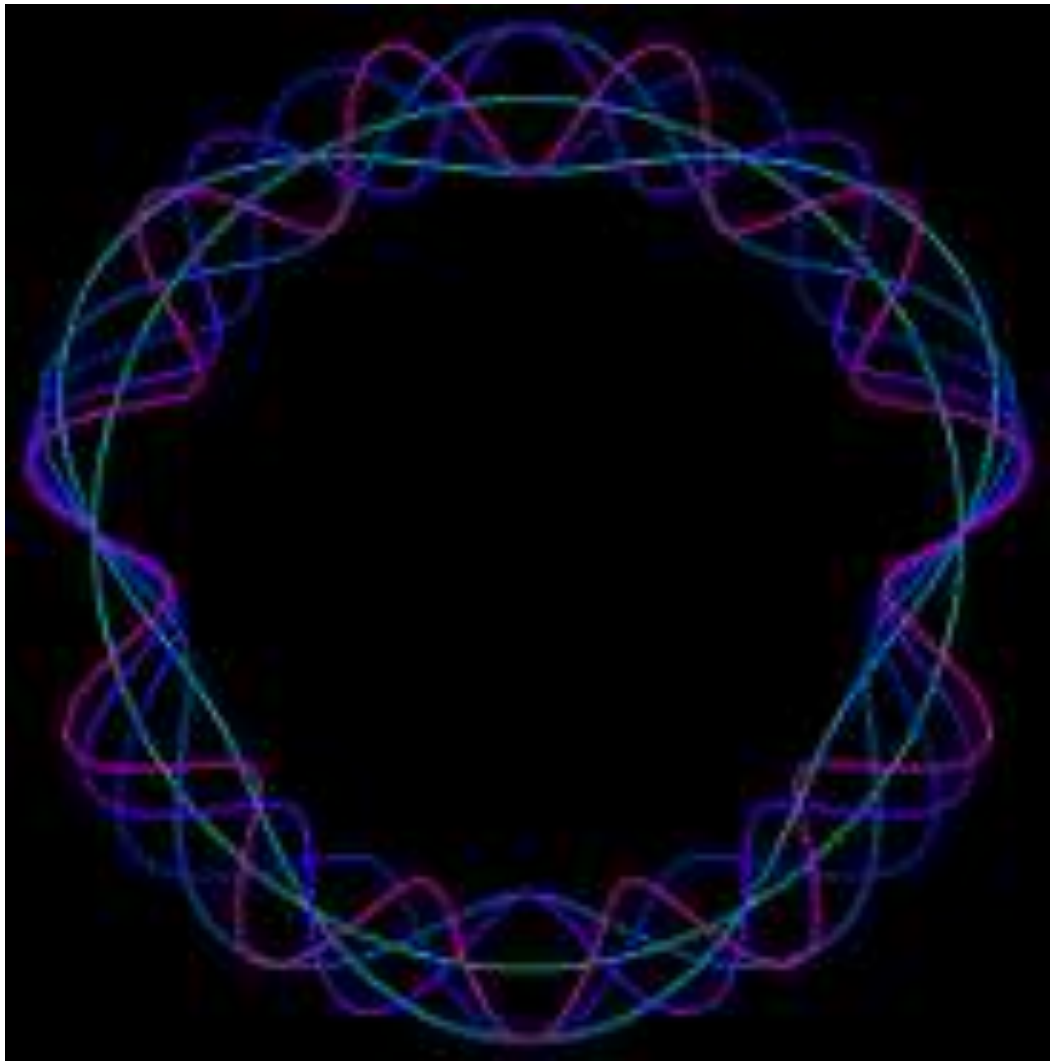
- They pop into existence from the “cosmic foam” and then recombine and disappear.
- Most of our mass (weight) is due to the strong forces between quarks (energy and mass are equivalent).
- All matter is made of “up”quarks, “down” quarks and electrons.

Inside the proton/neutron 10^-17 meter



Quarks appear to have no size and to be fundamental. But, the fractional charges and various “colors” seem to indicate more basic building blocks.

Strings (?) 10^-31 meter



Two dimensional strings (unimaginably small) vibrating in multiple dimensions. The theory can generate all the particles of the standard model.

A simple (mindless) way to explain complexity.

Consider a snowflake.

Complexity

Great complexity at low energies.

No complexity at high energies.

Steam versus a snowflake.

The Plank Length 1.61 10^-35 meter

Gravity becomes important again.

Gravity is 10^39 times weaker than electromagnetism.

A small magnet can hold a paper clip against the mass of the entire earth.

Gravity can be ignored at molecular scales (it doesn't do anything).

mass so low and gravity so weak that gravity plays no part.

BUT, at the Plank scale, distances are so close that gravity becomes dominant again.

How does this play out, no one knows. What happens at the center of a black hole? Can matter be crushed beyond the Plank length ? Does gravity operate in other dimensions. Maybe one of our grandkids will figure this out.

In Conclusion

This will blow your mind.

If the Plank length were increased to the size of .1 millimeter
A meter would be the size of the Observable Universe.

We have gone from
10^26 meter to
10^-35 meter
61 orders of magnitude