Looking for the INVISIBLES

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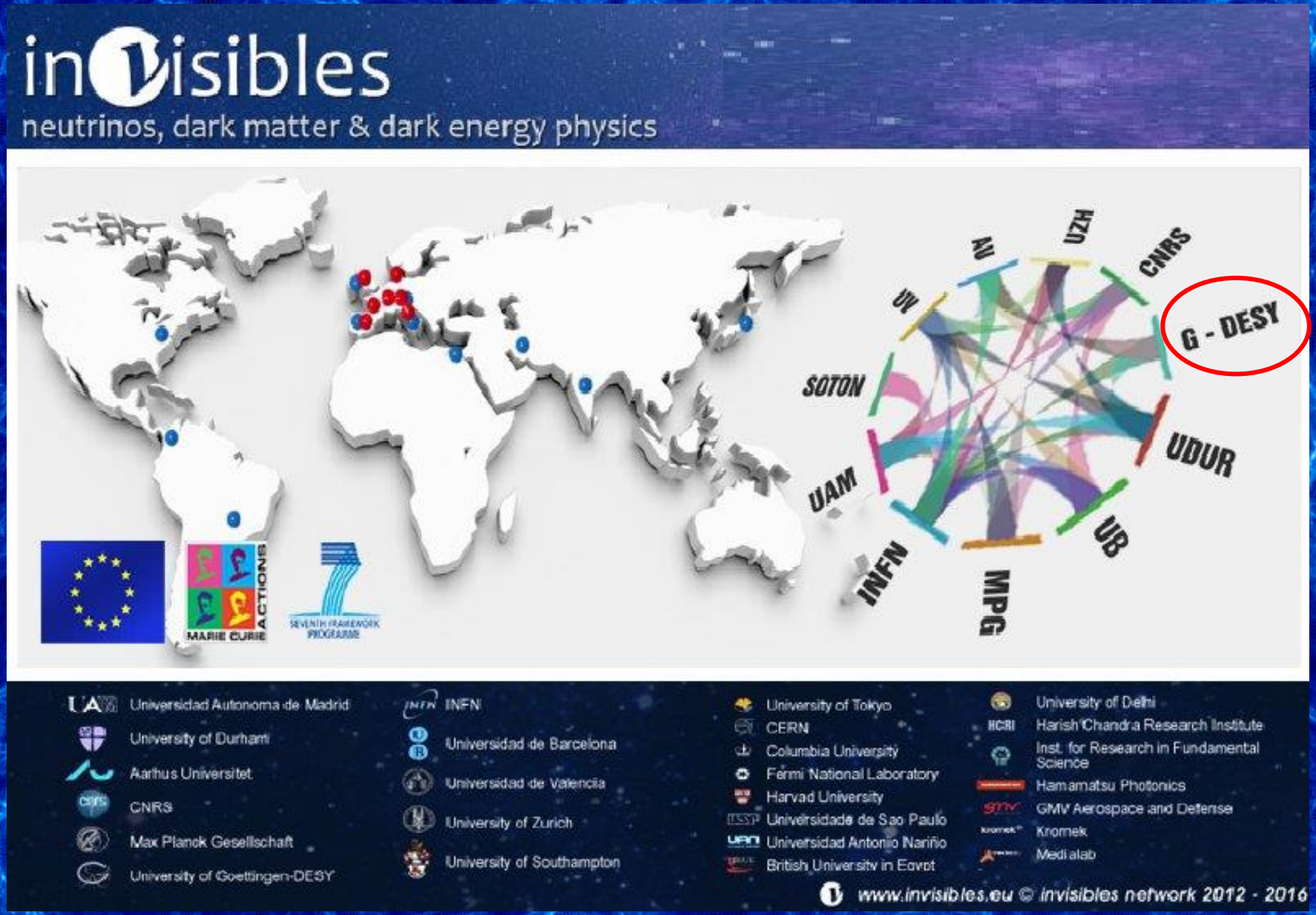
invisibles
neutrinos, dark matter & dark energy physics



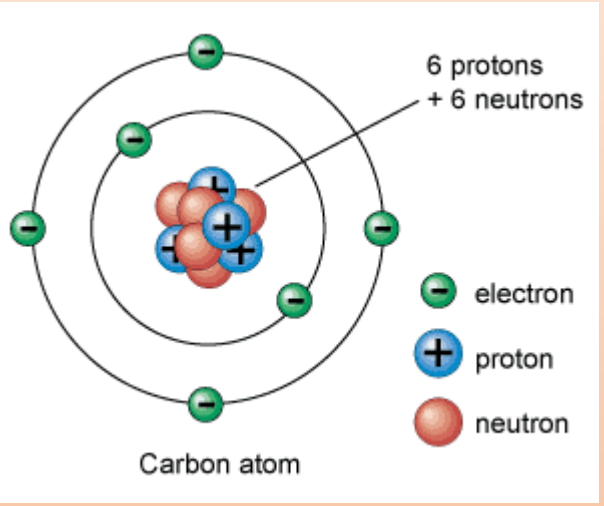
www.invisibles.eu

What are the Invisibles?

What we know.

At the macroscopic level…

Matter



....

Four fundamental forces:

-Gravity

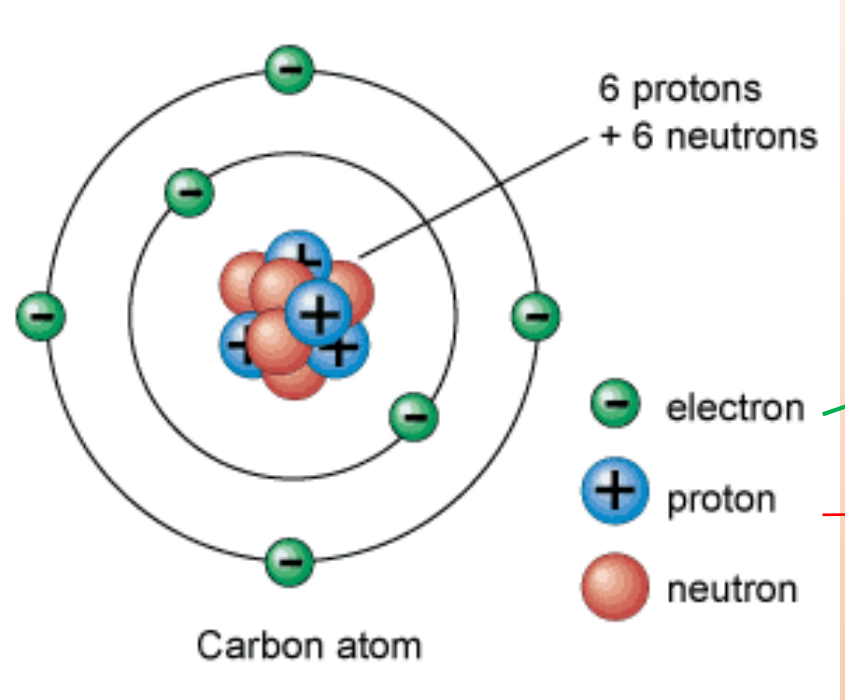
-Electromagnetic

-Strong Interaction

-Weak Interaction

Nuclear forces

At the fundamental level

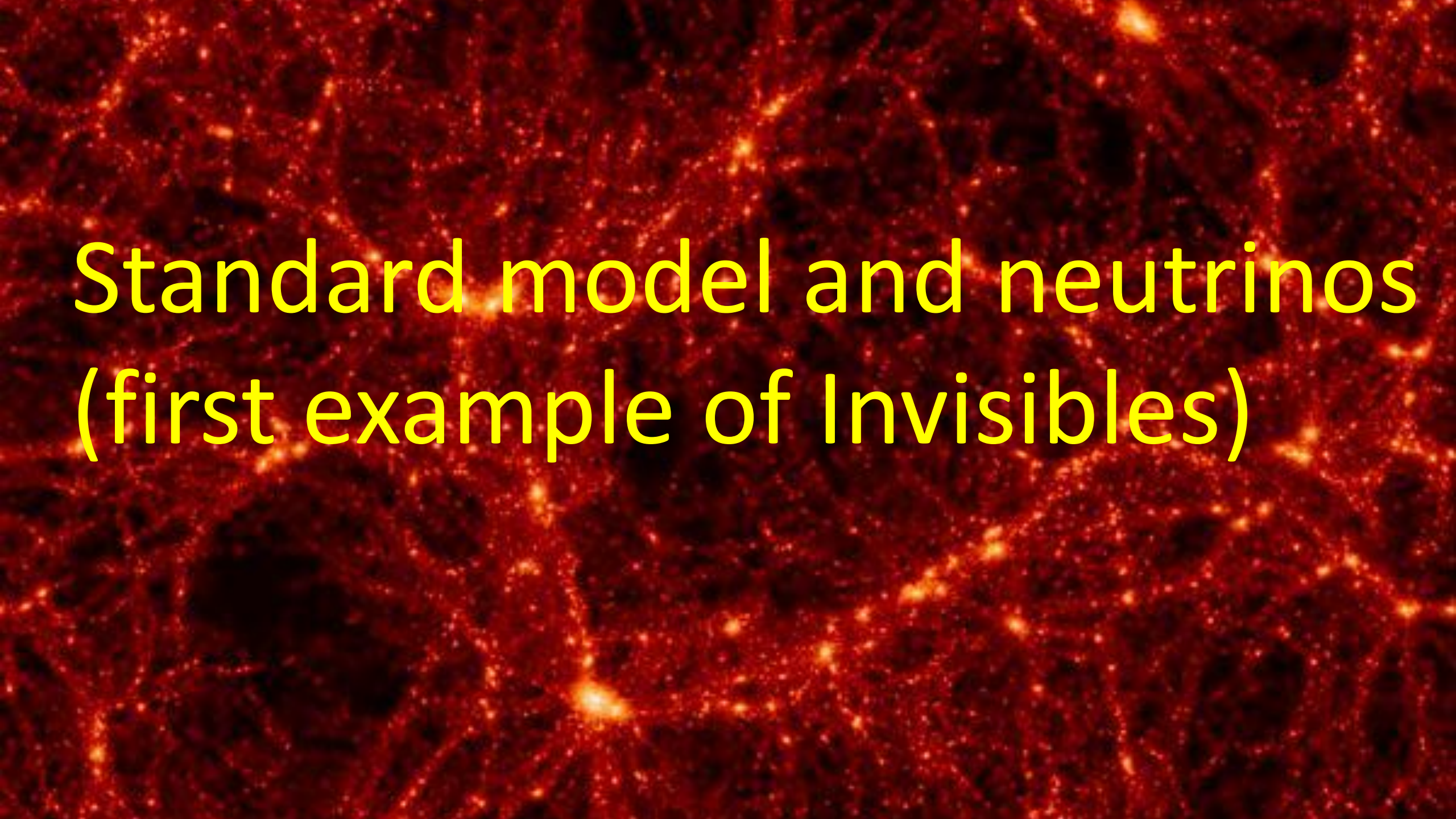


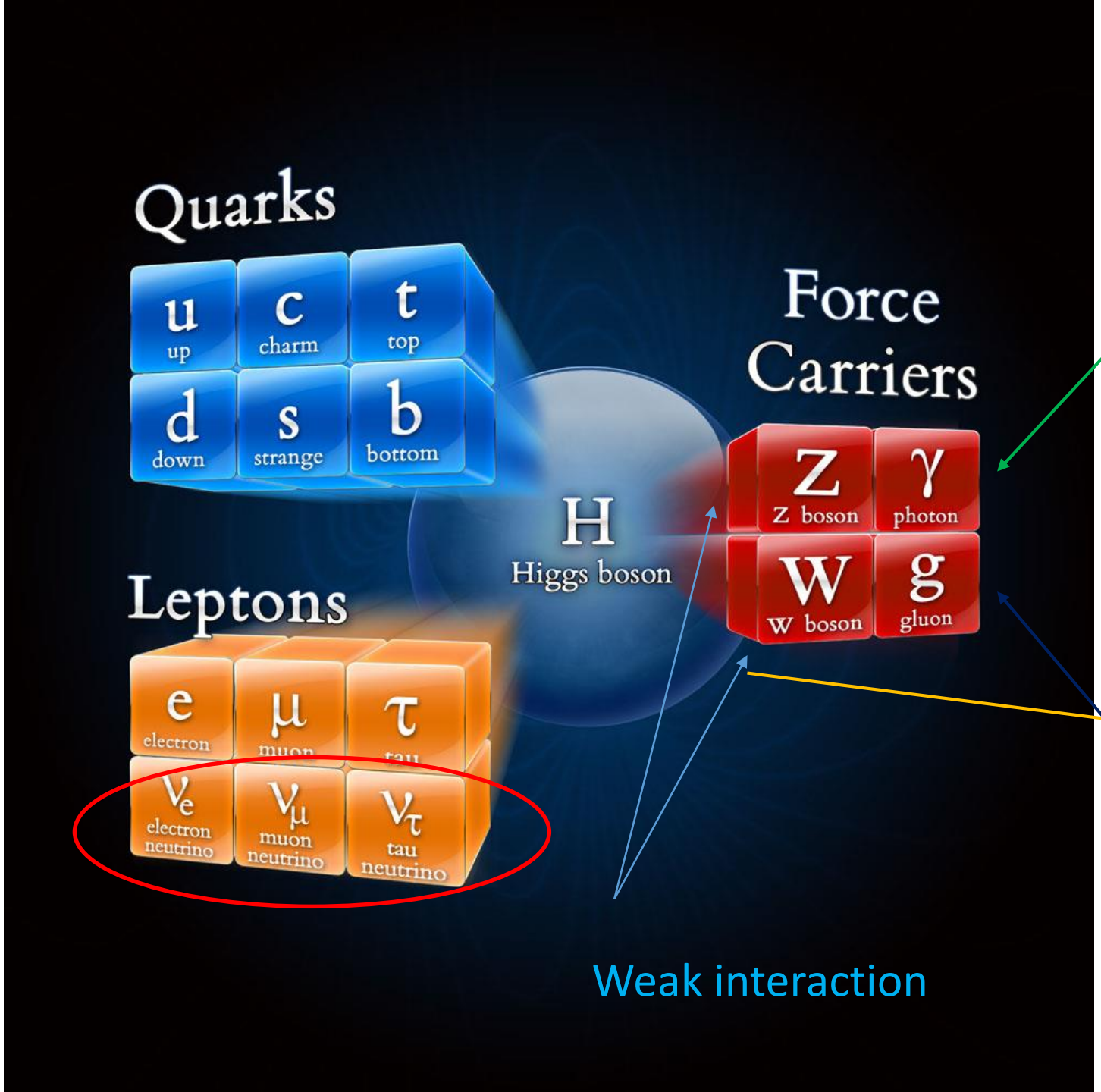
Elementary particle

Not elementary particles.
Constituted by elementary particles: quarks

Electromagnetic, strong and weak interactions are described at the fundamental level by the Standard Model of Particle Phyisics (SM).

Gravity evades a unified picture. Only macroscopic description provided by Einstein‘s relativity.


Standard model and neutrinos
(first example of Invisibles)



Electromagnetic interaction

Strong interaction

Weak interaction

Neutrinos are almost massless particles with a very tiny probability of interaction with the other particles.

Whatever material is substantially transparent to neutrinos. They are apparently undetectable.

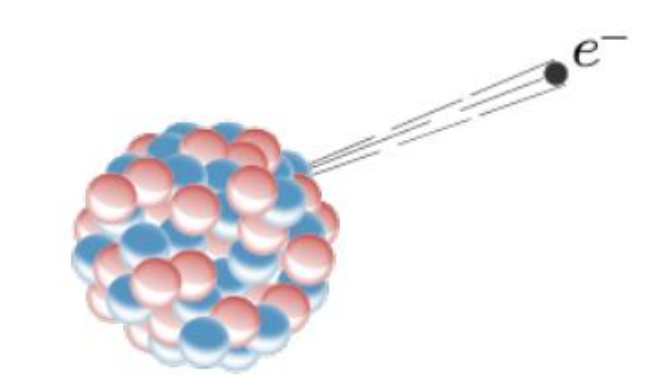
They are (almost) invisibles.

How one can detect an (almost) invisible particle?

Option 1:

Even undetectable particles can indirectly affect observable phenomena.

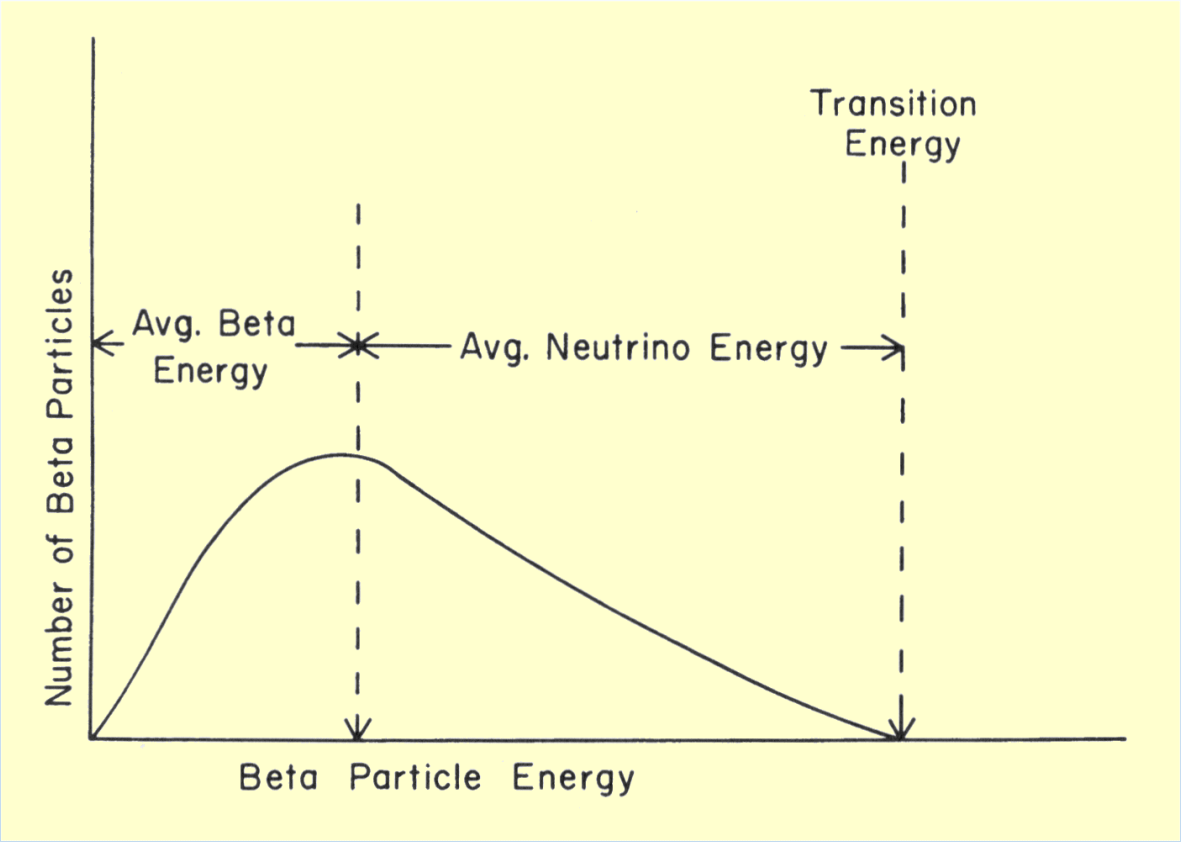
Example:Beta-decay



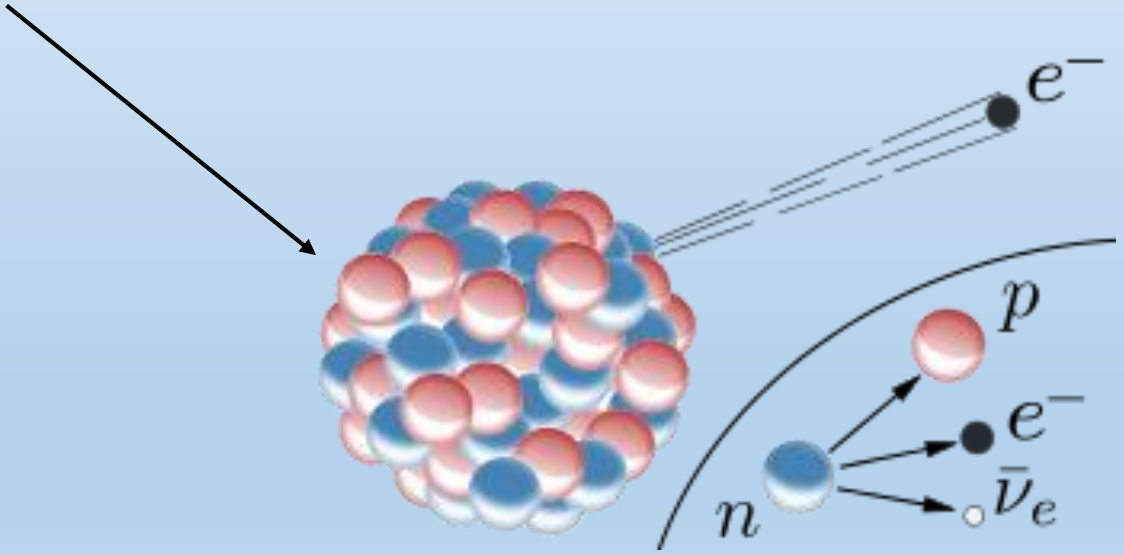
Beta-decay: decay of a nucleous with the emission of electrons.

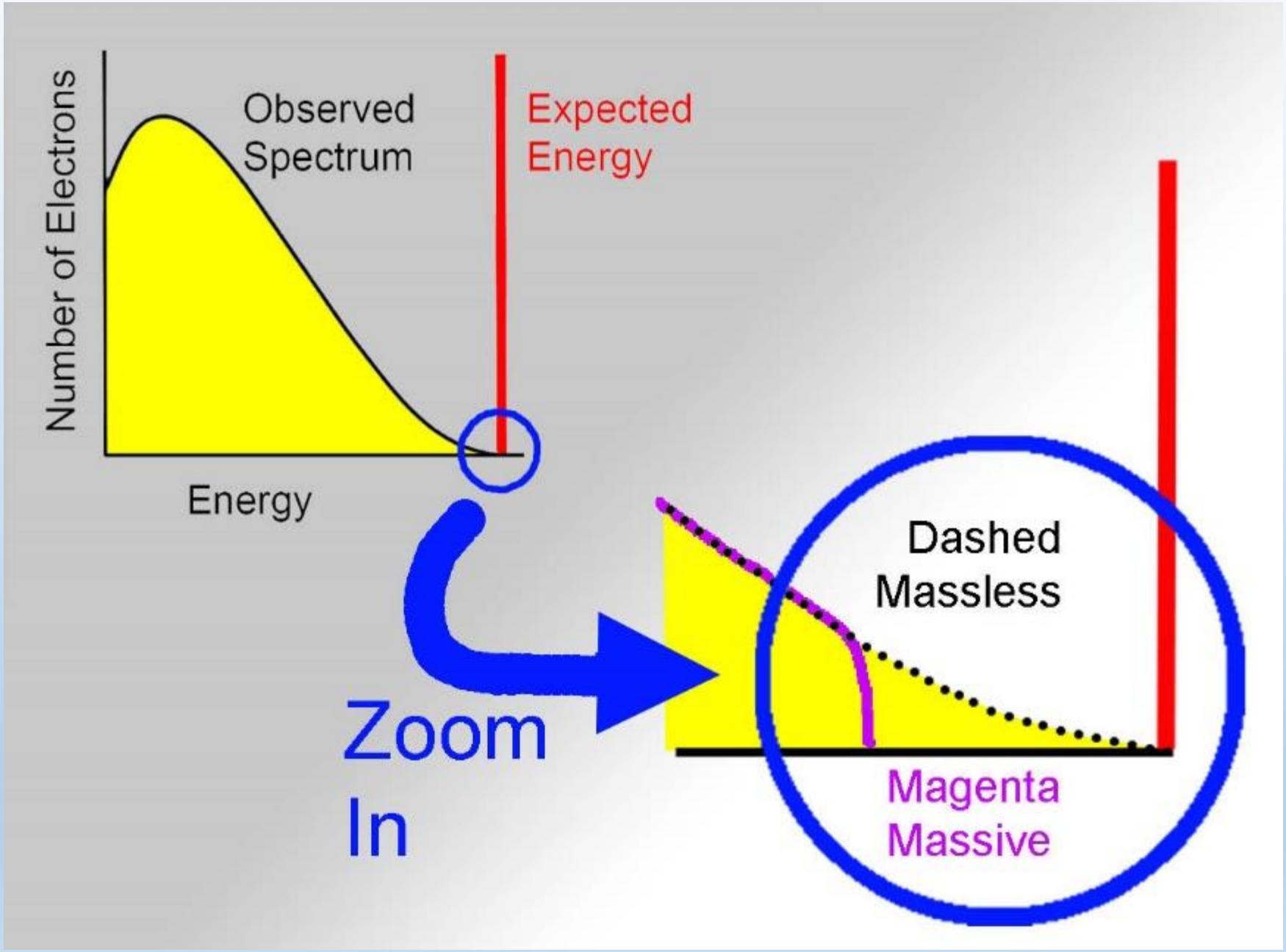
In a world without neutrinos energy conservation would imply fixed energy for the emitted electrons, approximately given by the mass difference between the original and the daughter nucleous.

However...



The energy of the electrons is not fixed. This is possible
only if there is another (invisible) decay product.




Number of Electrons
Observed Spectrum
Expected Energy
Energy
Zoom In
Dashed Massless
Magenta Massive

Option 2:

Low probability of detection can be compensated by a very efficient source

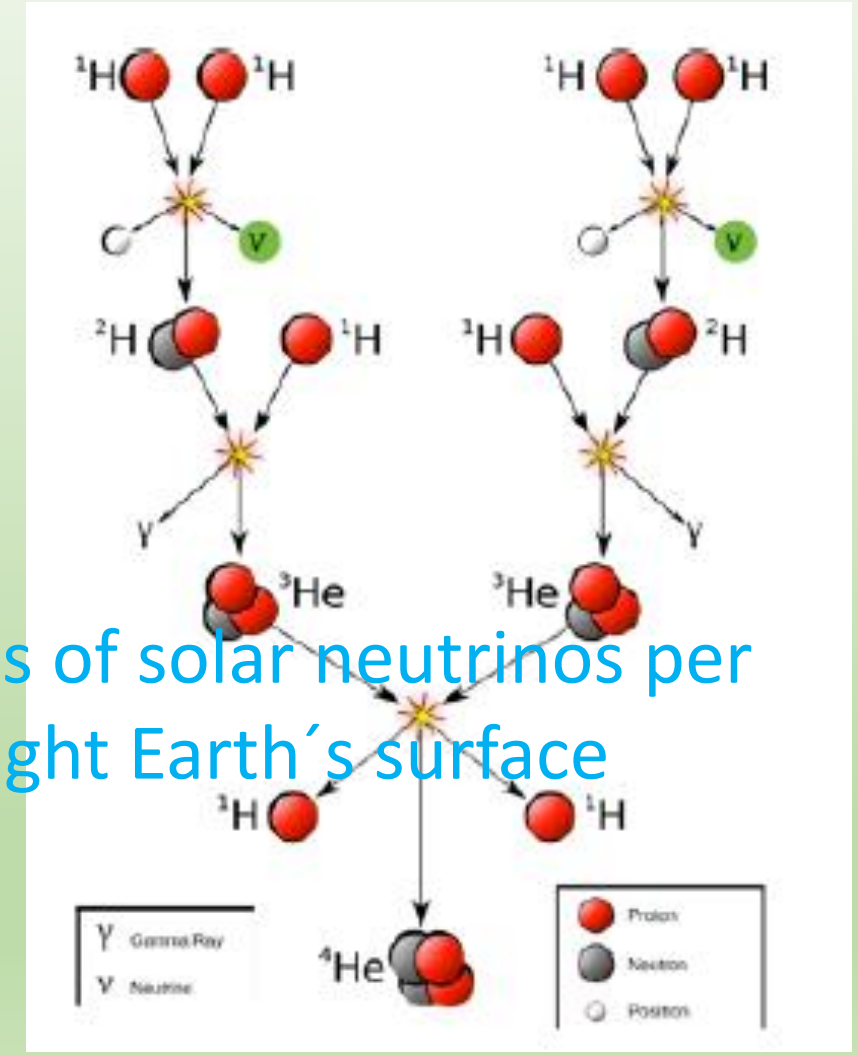
(*Phys.Rev.Lett.* 9, 36, 1962)

OBSERVATION OF HIGH-ENERGY NEUTRINO REACTIONS AND THE EXISTENCE OF TWO KINDS OF NEUTRINOS*

Very efficient source of neutrinos

The sun is an extremely powerful source of neutrinos

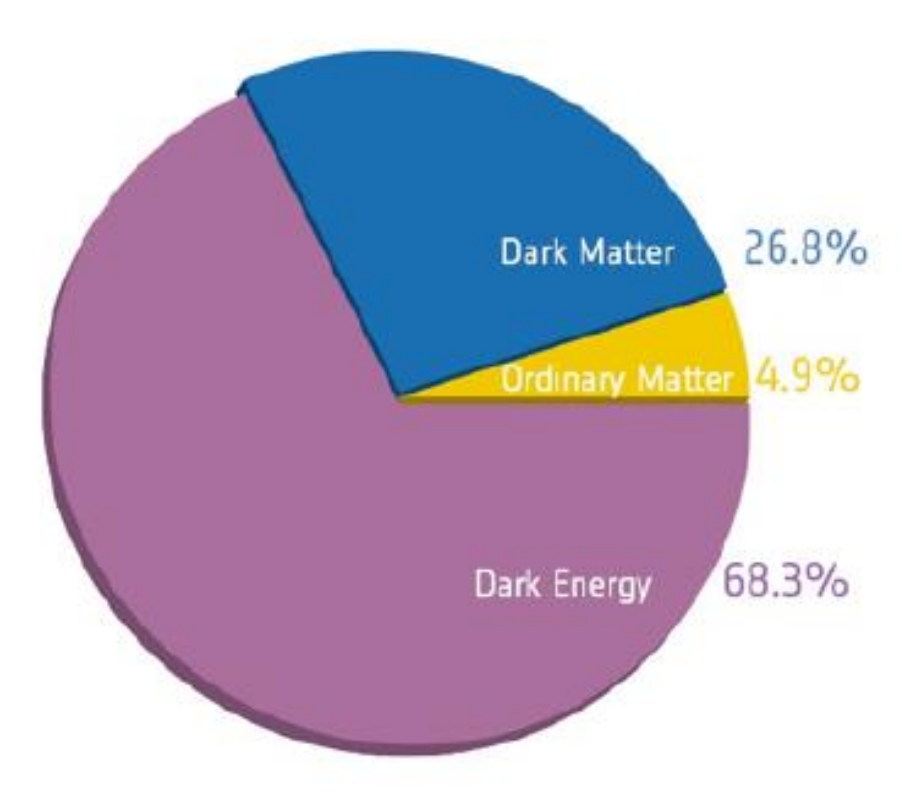
Hundred of billions of solar neutrinos per second pass throught Earth´s surface




Beyond the Standard Model:
Dark Matter

The Standard Model provides a succesful description of observed phenomena.

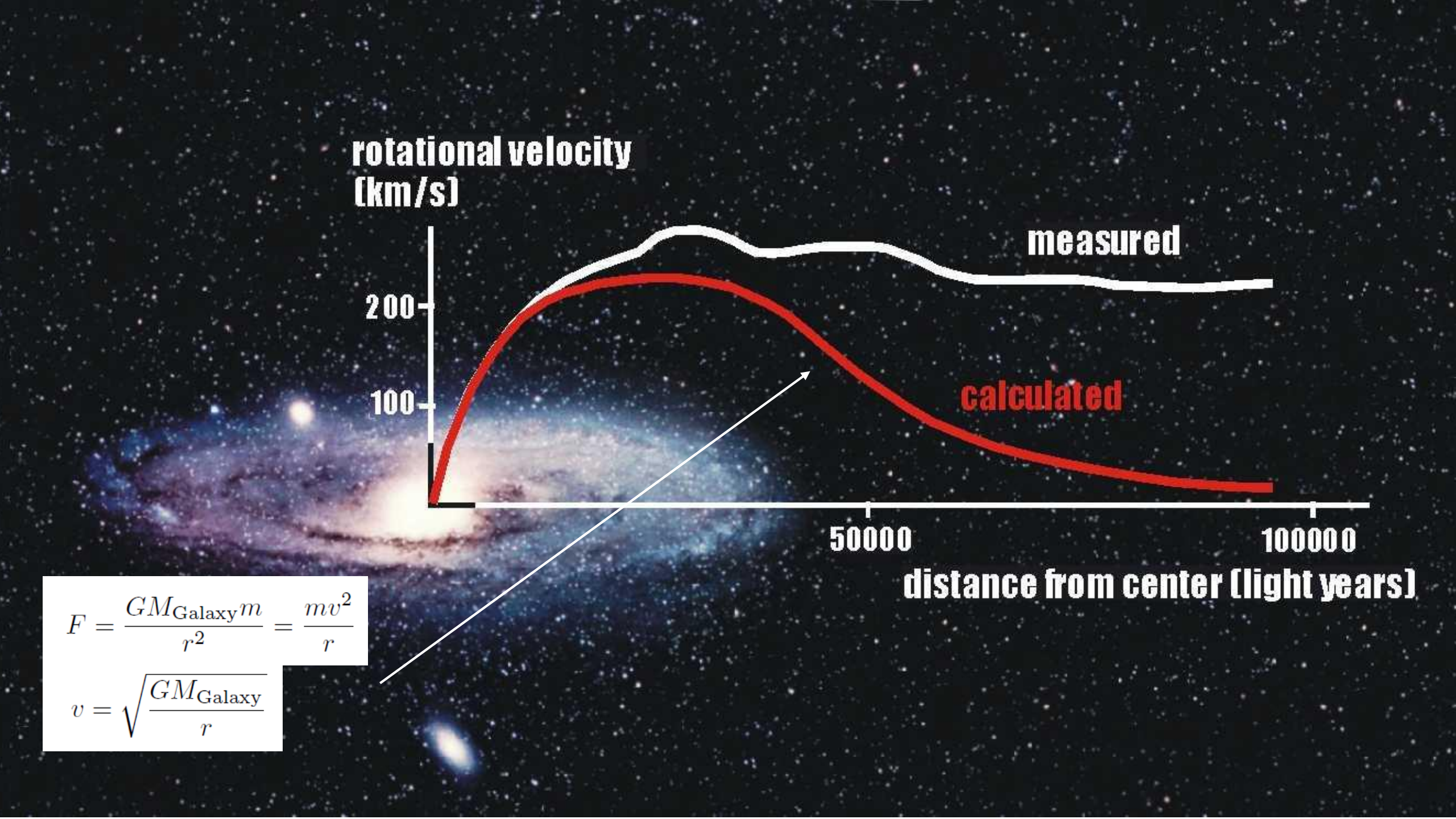
However the majority of the Universe is “Invisible“



SM describes only ordinary matter, only about 5% of our Universe

How we know that most of the Universe is Invisible?

Again, Invisibles can influence observable matter

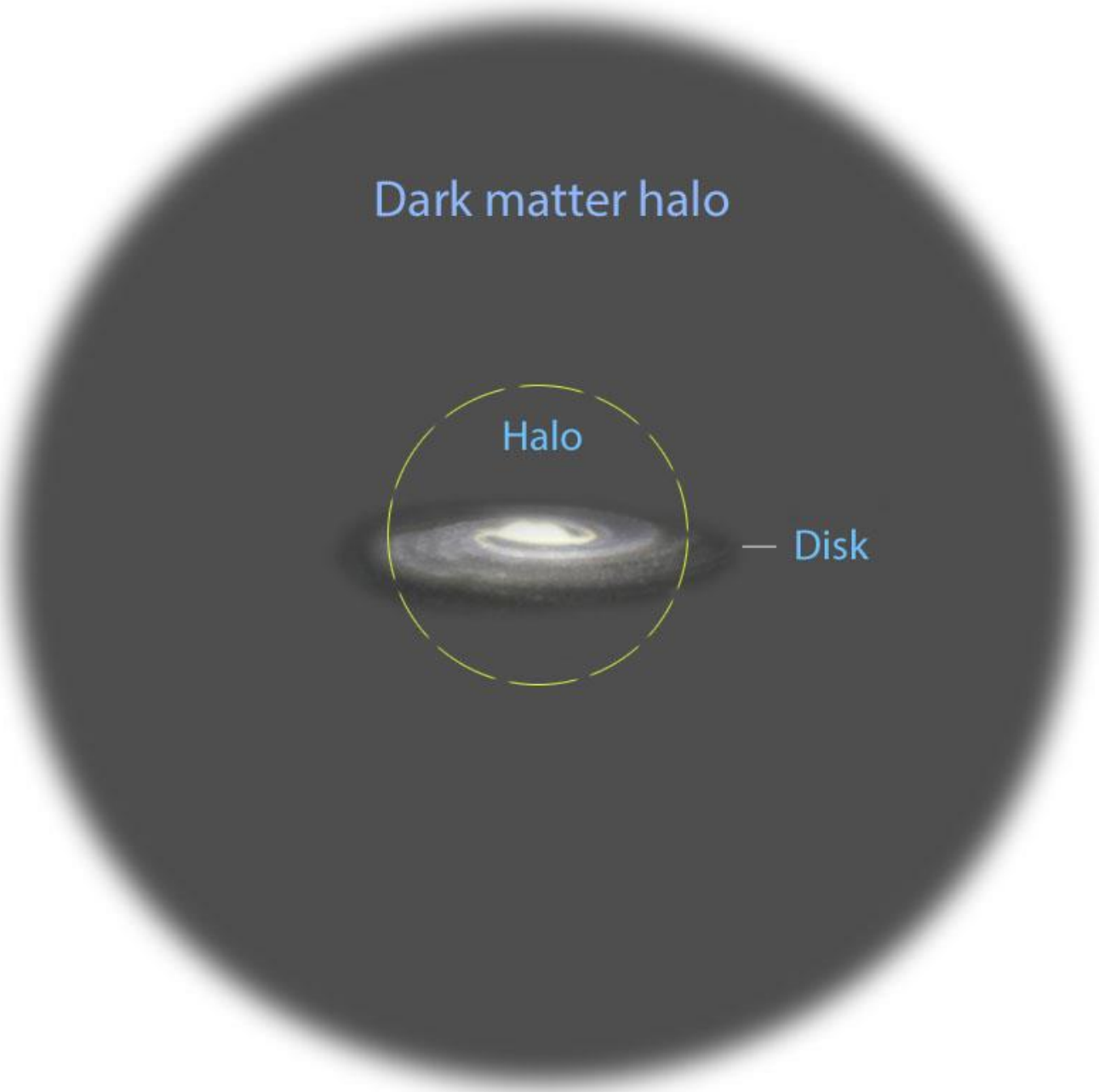


$$F = \frac{GM_{\text{Galaxy}}m}{r^2} = \frac{mv^2}{r}$$

$$v = \sqrt{\frac{GM_{\text{Galaxy}}}{r}}$$

Fritz Zwicky

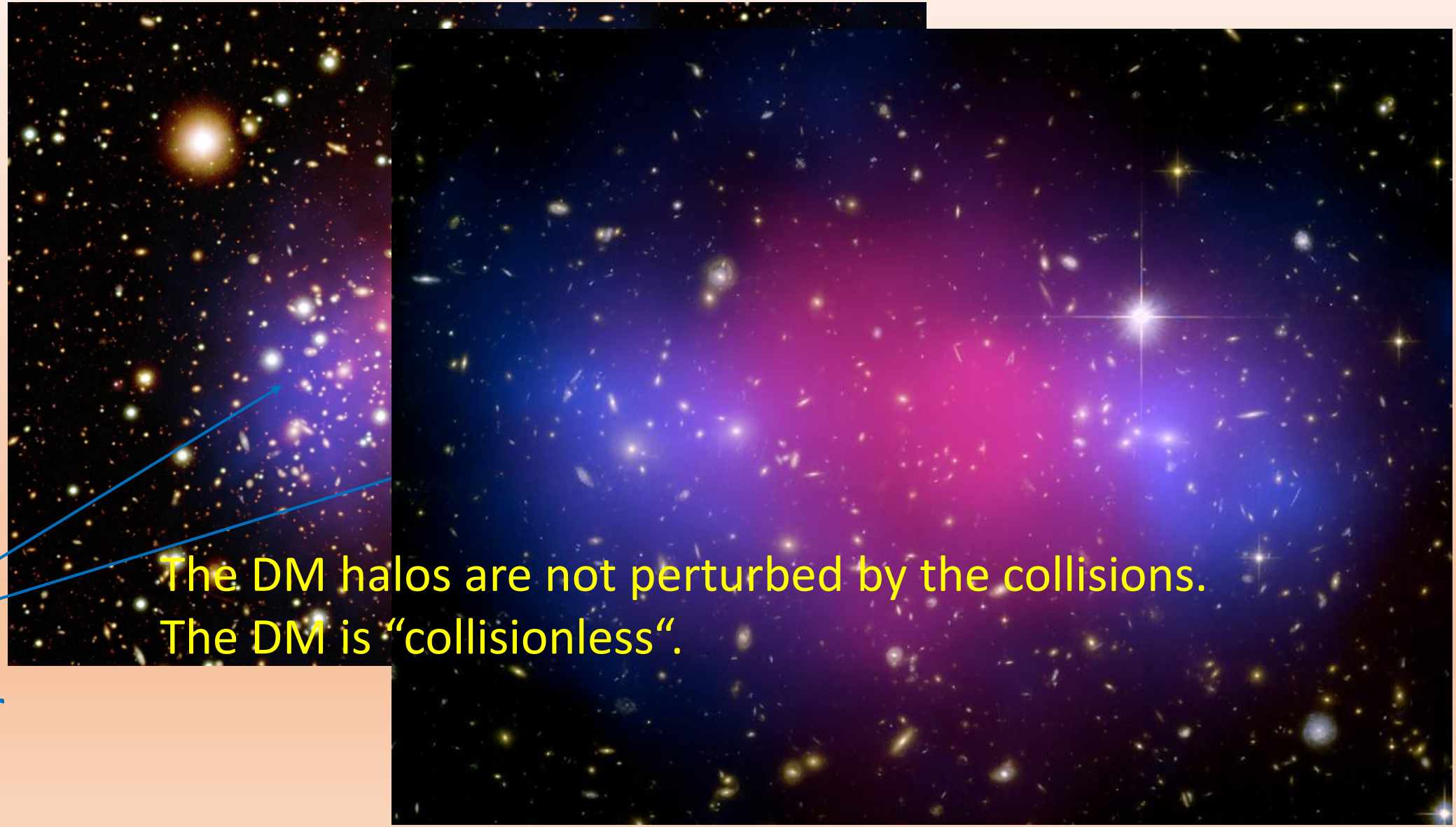
Galaxies are surrounded by an invisible matter component:
THE DARK MATTER



Milky Way model

A gravitational field can deviate the path of the light.

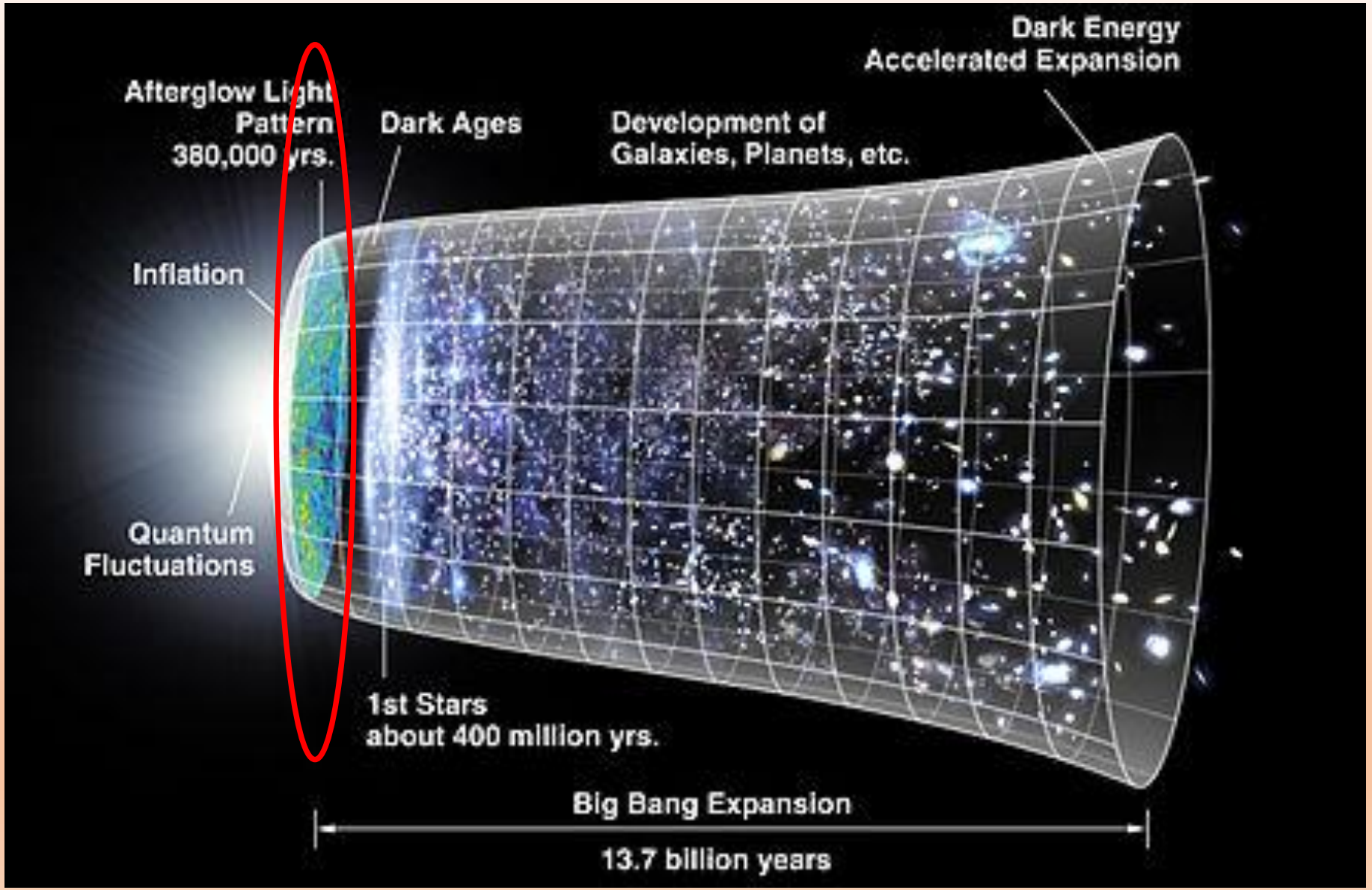
It is possible to observe invisible objects through their effect on the light of visible sources (gravitational lensing).



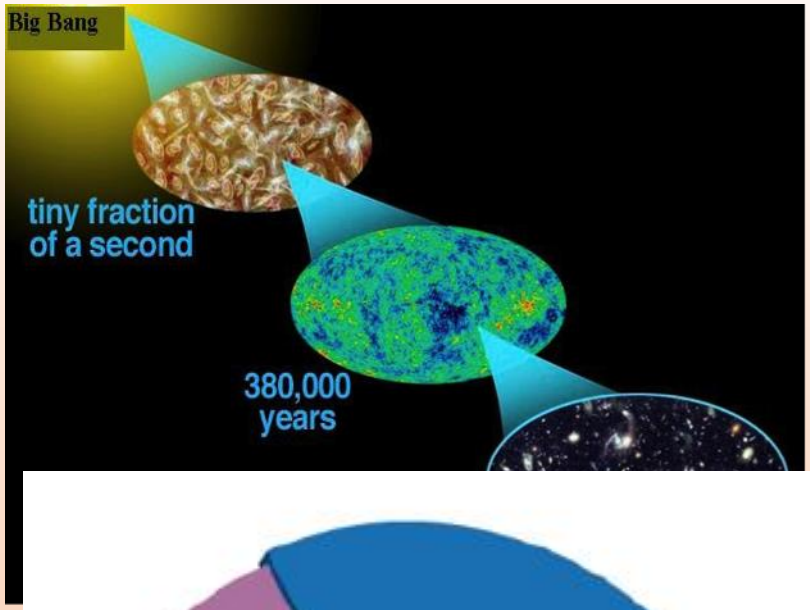
The DM halos are not perturbed by the collisions.
The DM is “collisionless“.

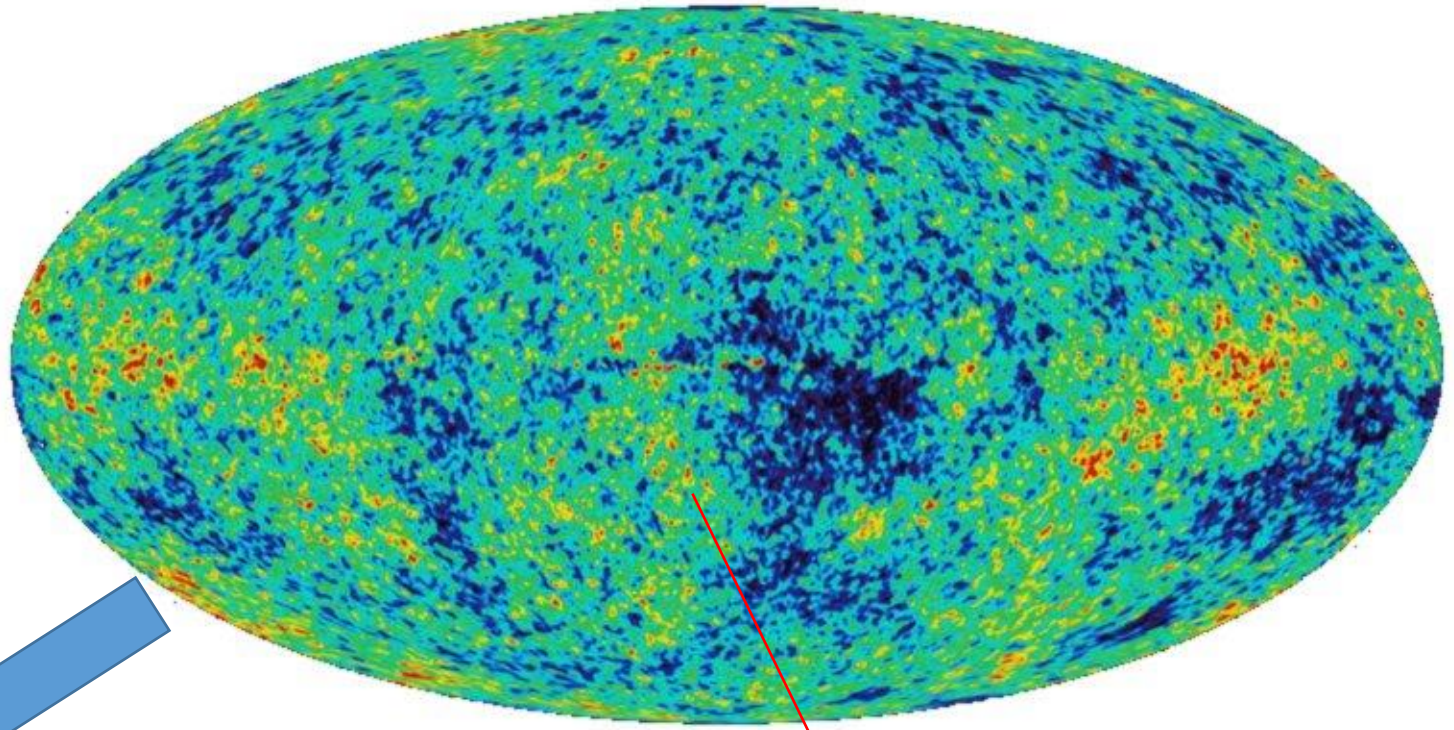
Dark Matter

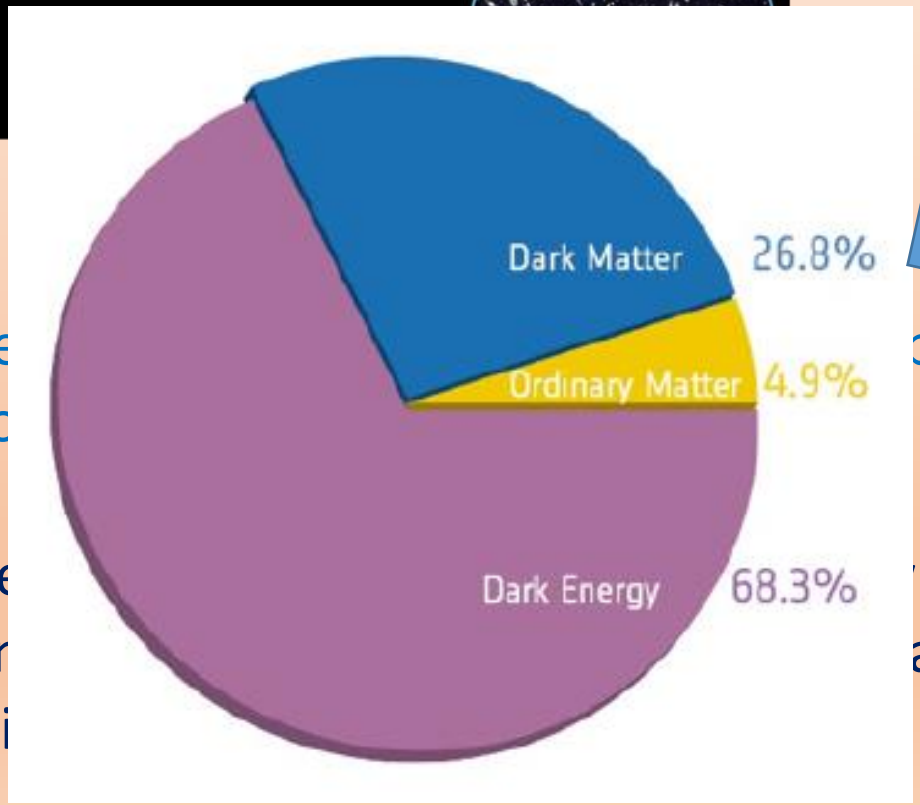
How we know the amount of DM in the Universe?



The DM influences the history of the Universe







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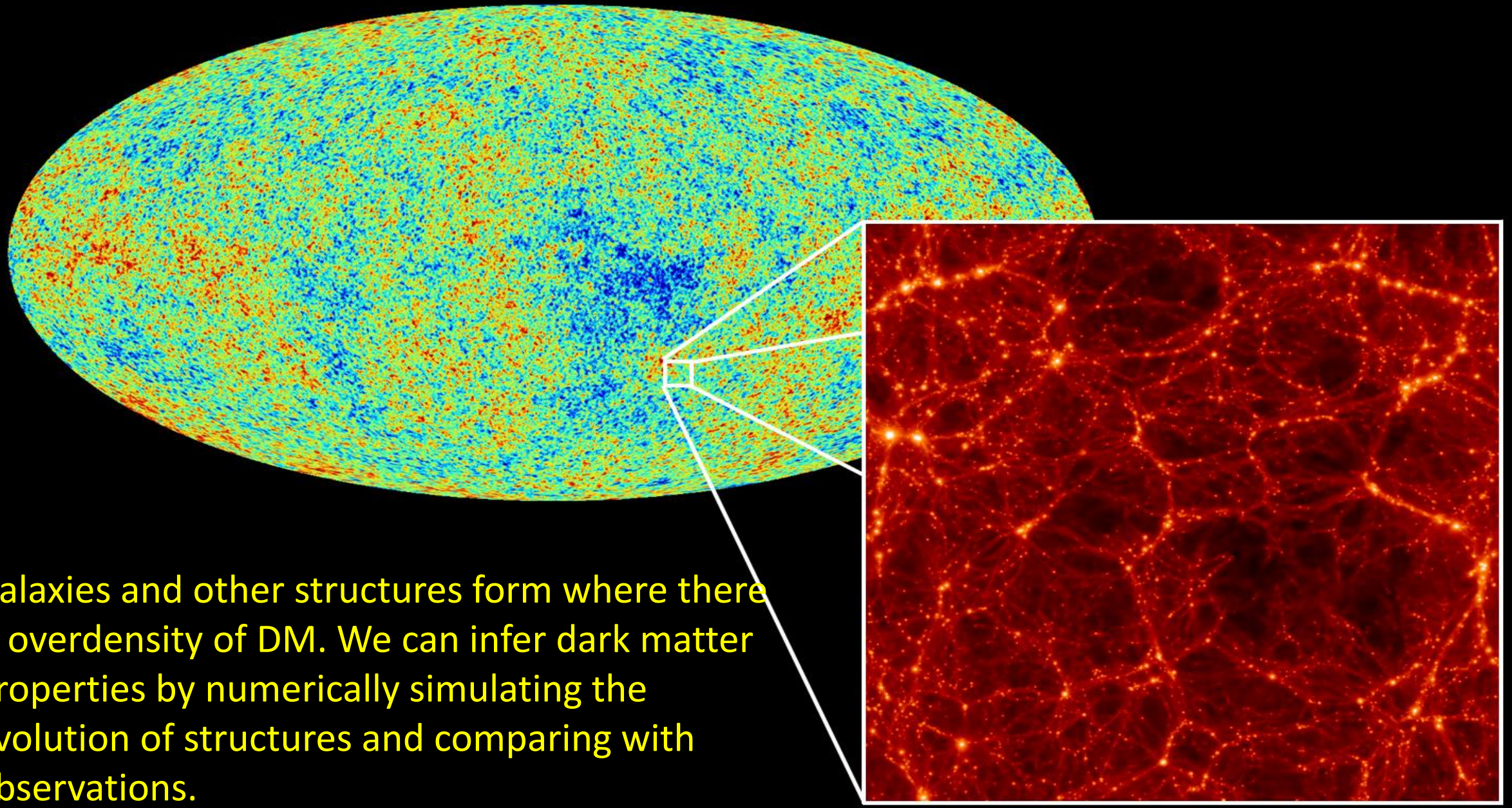
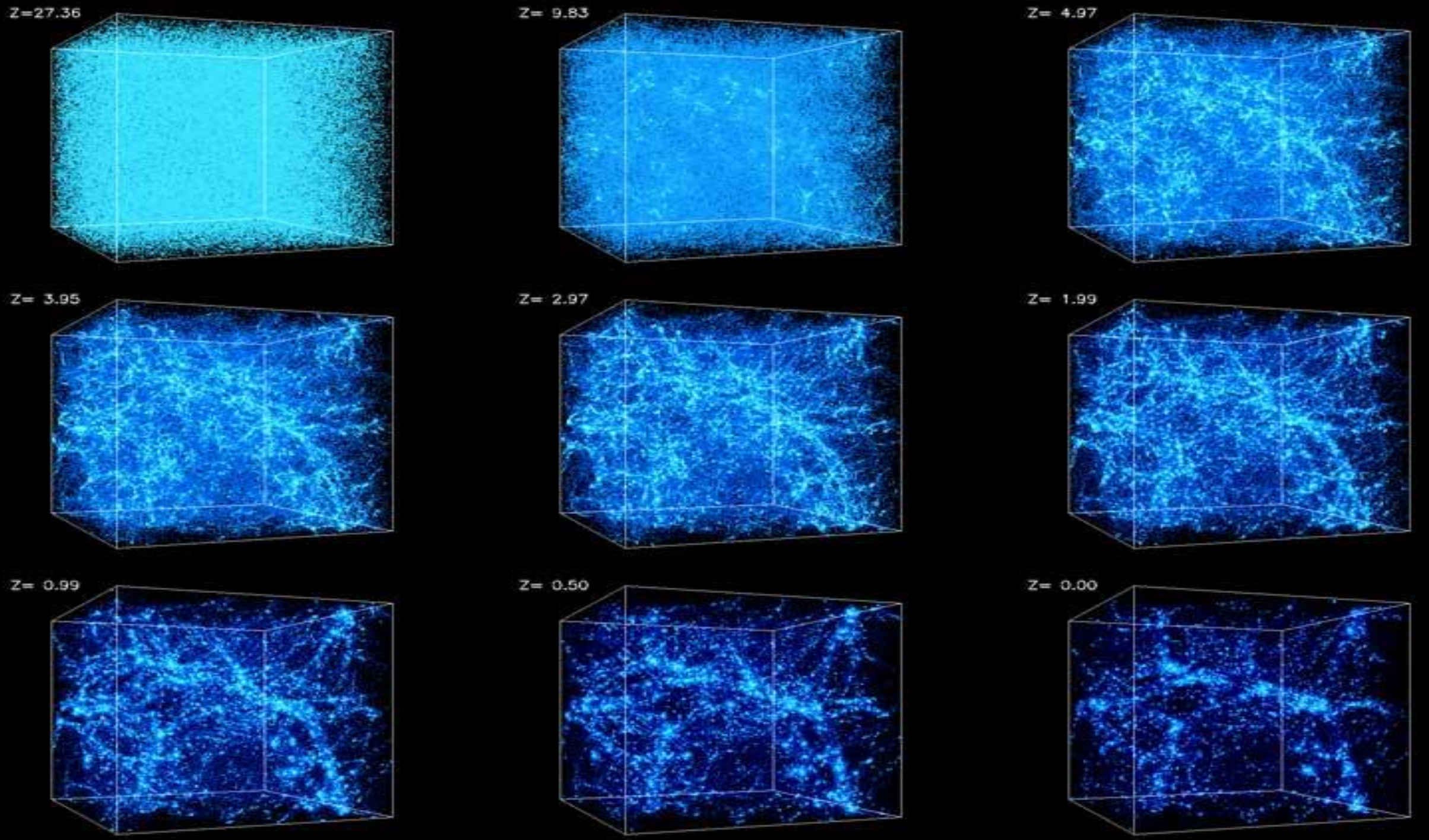
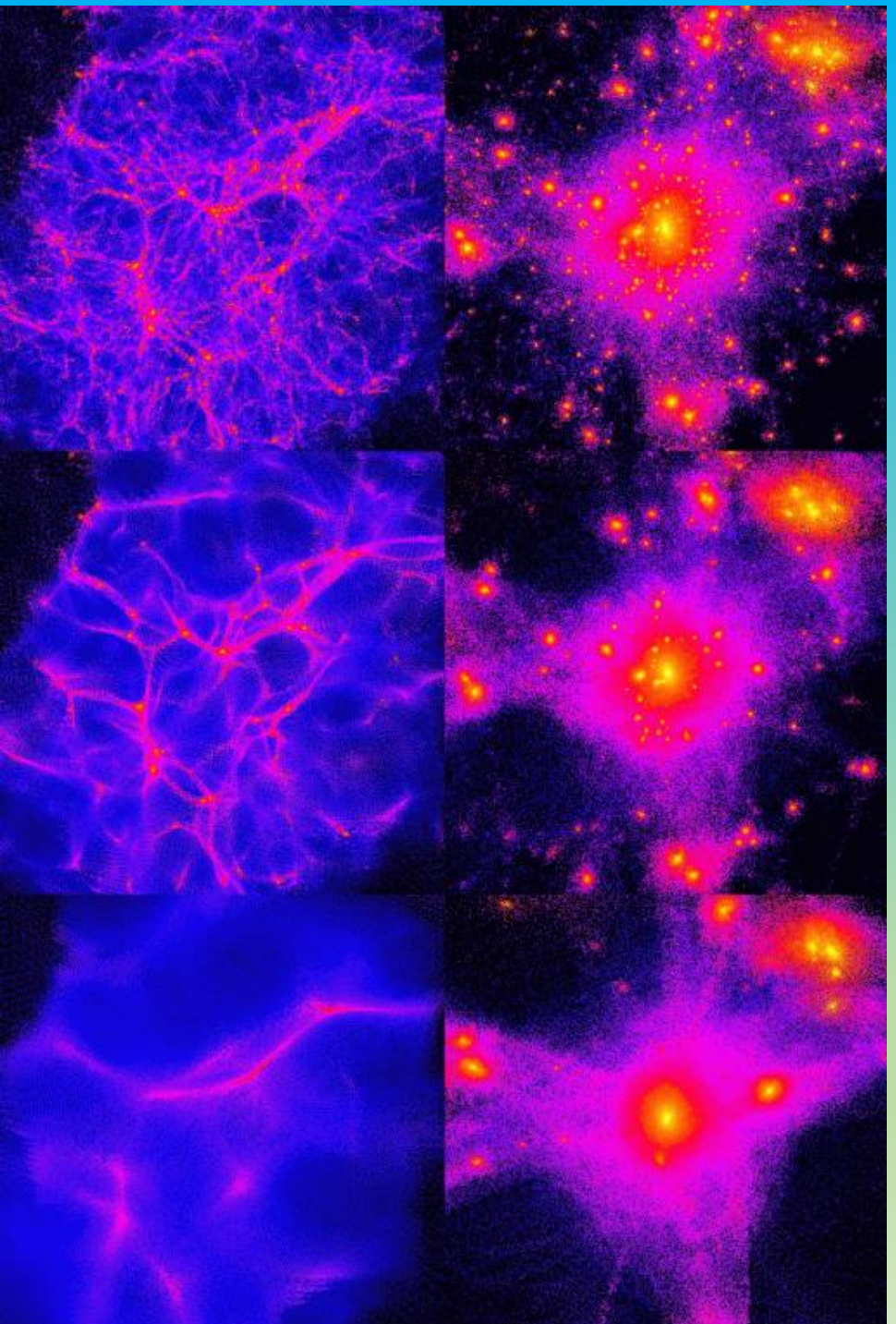
The observed CMB depends on the content of the Universe.



Galaxies and other structures form where there is overdensity of DM. We can infer dark matter properties by numerically simulating the evolution of structures and comparing with observations.


Z=27.36
Z= 9.83
Z= 4.97
Z= 3.95
Z= 2.97
Z= 1.99
Z= 0.99
Z= 0.50
Z= 0.00



Cold Da

smaller

At late

Warm

Hot D

bigge

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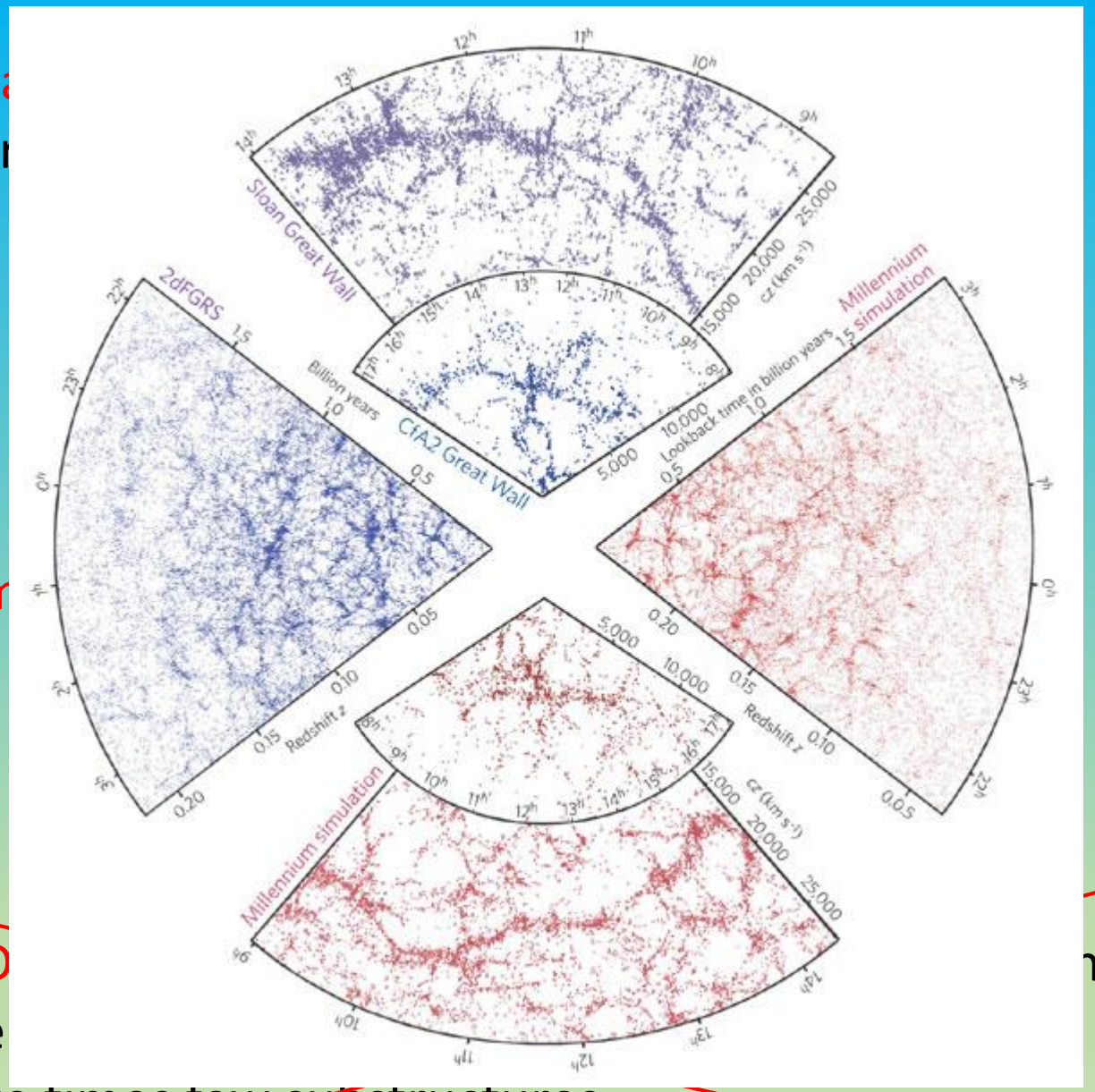
At late times few substructures.



What we know about from dark matter from current observations?

It is not made by ordinary matter (baryon, protons, neutrons ….)

It is not dissipative, i.e. not condense in the center of galaxies (it rather form halos)

It is collisionless (buller cluster)

Does not significally emit, absorb or reflects light (no direct observation so far)

It consist of approximately 26% of the Universe

We have to look for a new particle, electrically neutral, massive and stable on cosmological scales.

In order to determine the particle nature and properties of the DM we need a direct observation.

We need to find an efficient way
to compensate the tiny probability of interaction.

Strategies for DM detection:

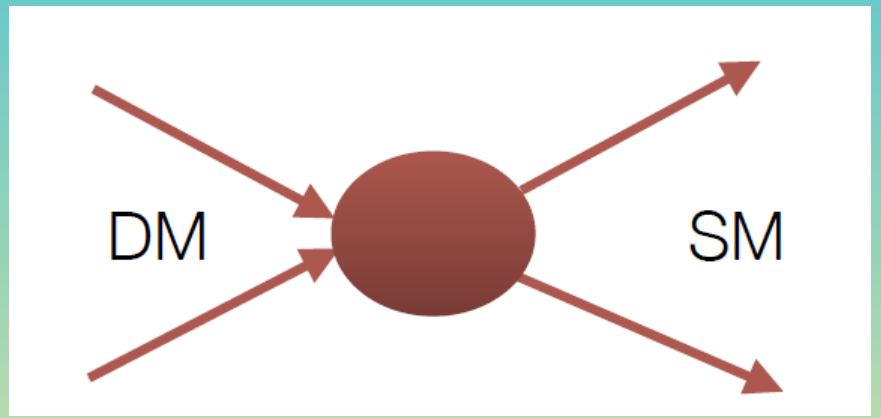
Detection of the DM in the space

- Direct
- Indirect

Production of the DM at collider

Dark Matter Indirect Detection

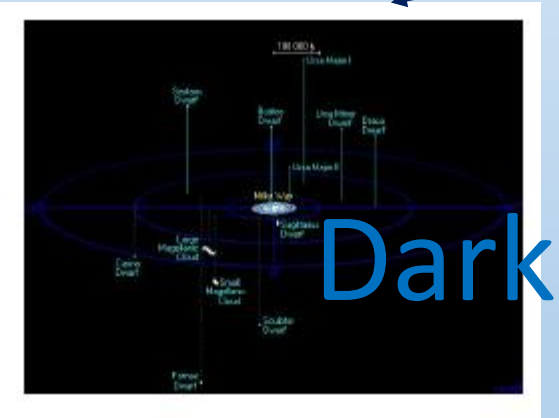
In most of model the DM is capable of processes, dubbed annihilations, in which two DM particles are converted into two SM particles.



Indirect detection looks at the final products of this annihilation processes.

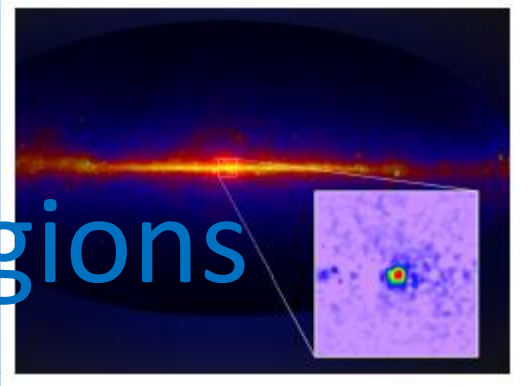
Where we look for annihilation processes?

Cosmic rays



Dwarf Galaxies

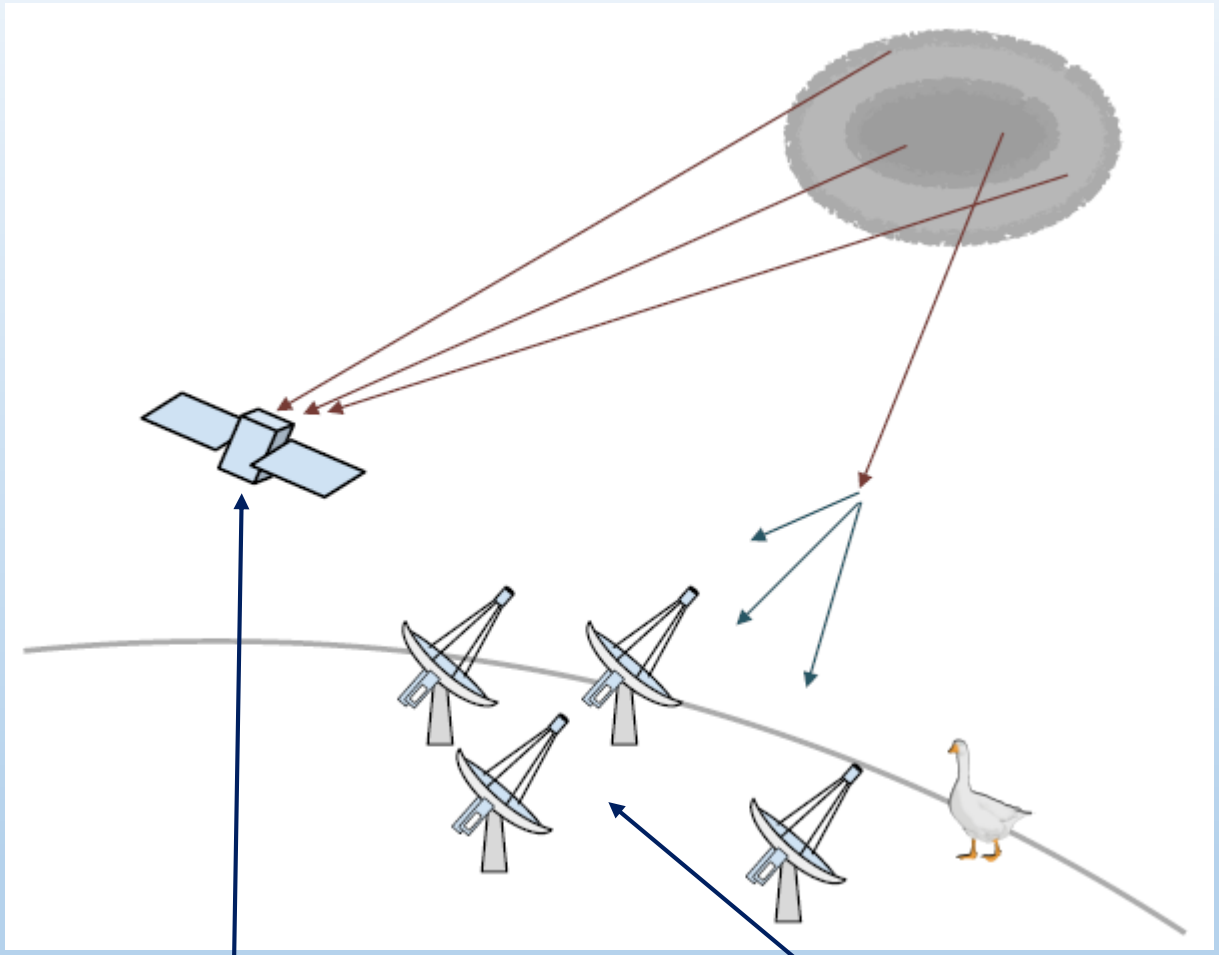
Galaxy Clusters



Galactic Center

Dark Matter Dense Regions

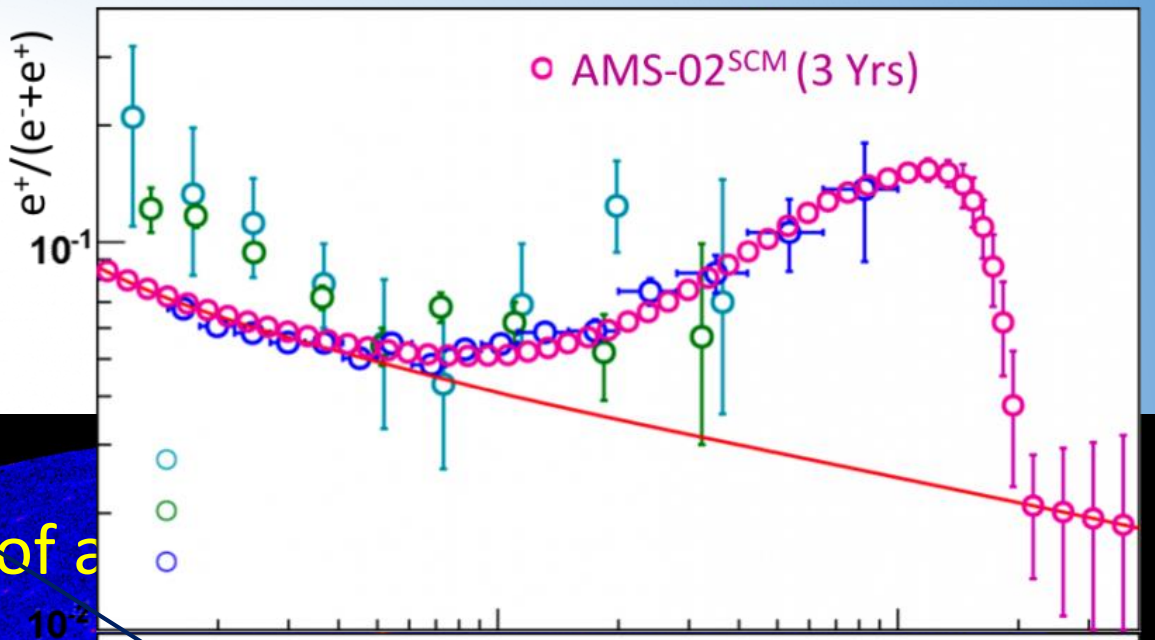
How we detect Dark Matter Annihilations?



Satellites

Ground Telescopes

Dark Matter Candidate $m\chi^0$ = 200 GeV



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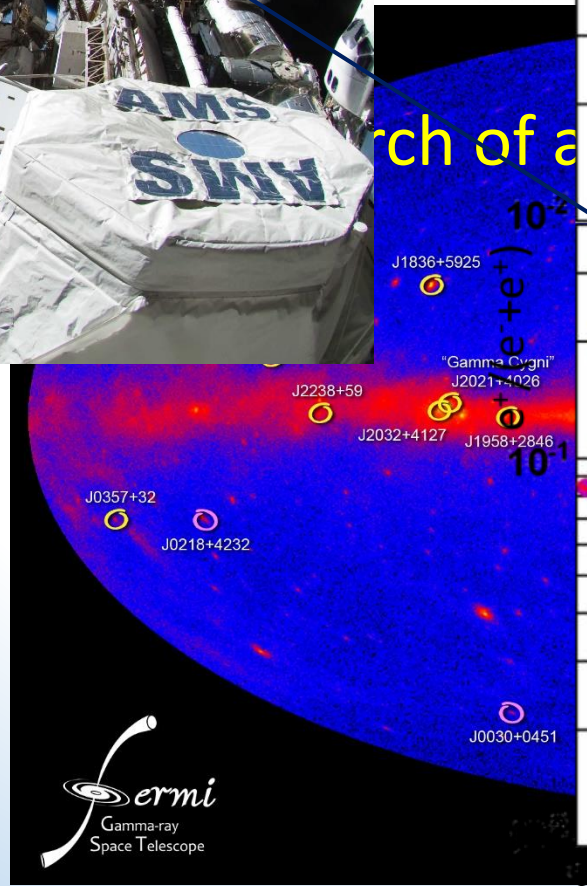
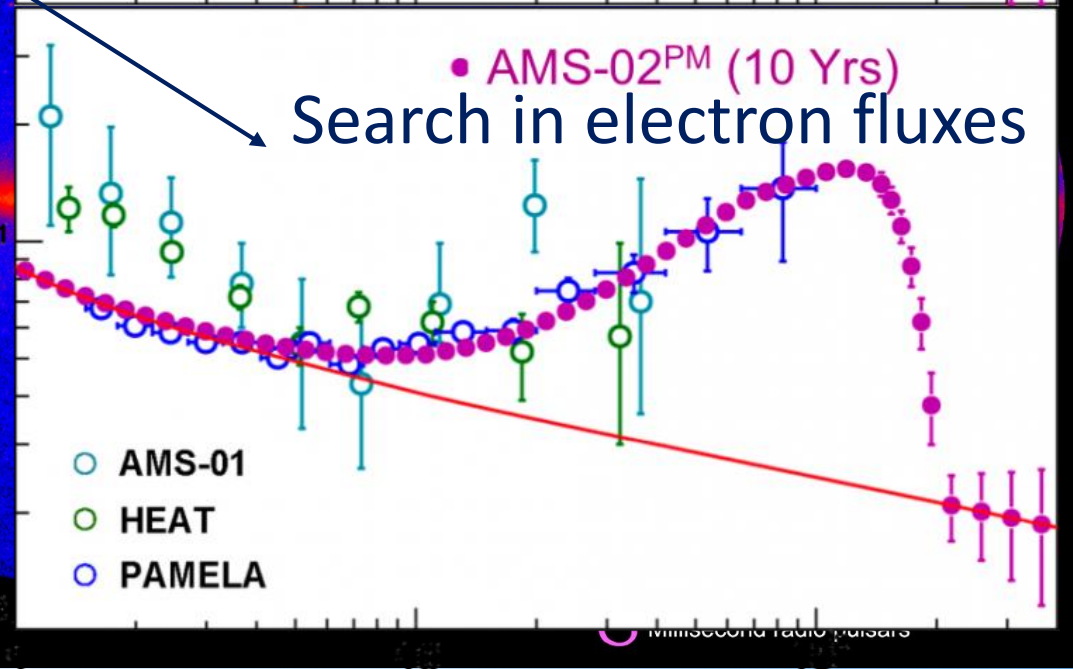
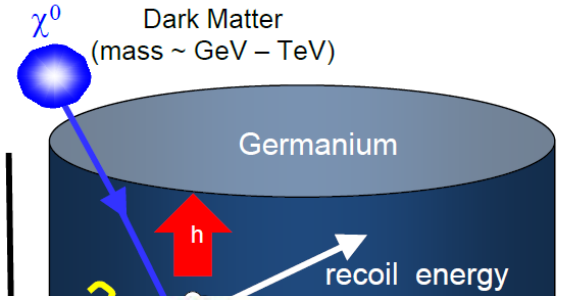
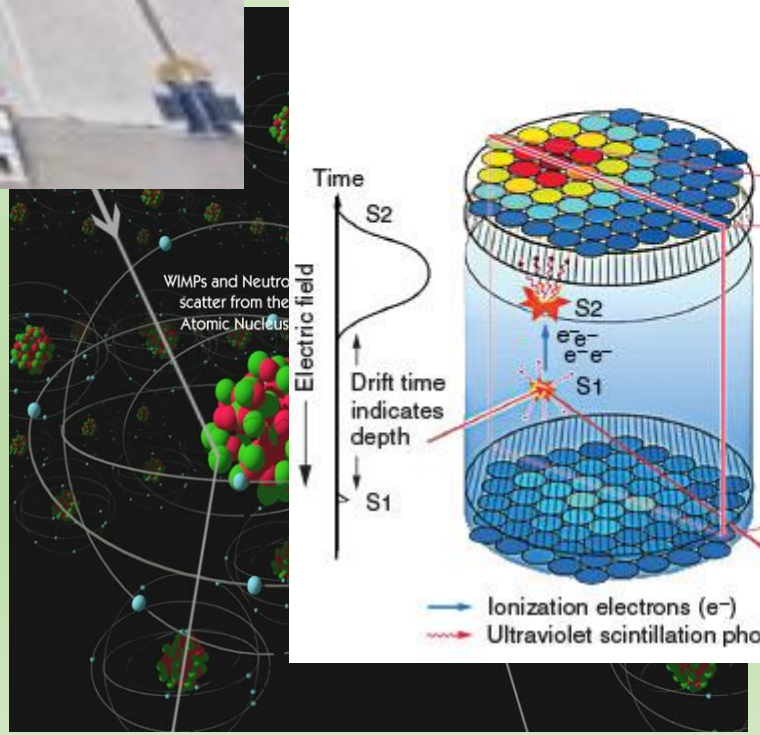




Search in electron fluxes

Dark Matter Direct Detection

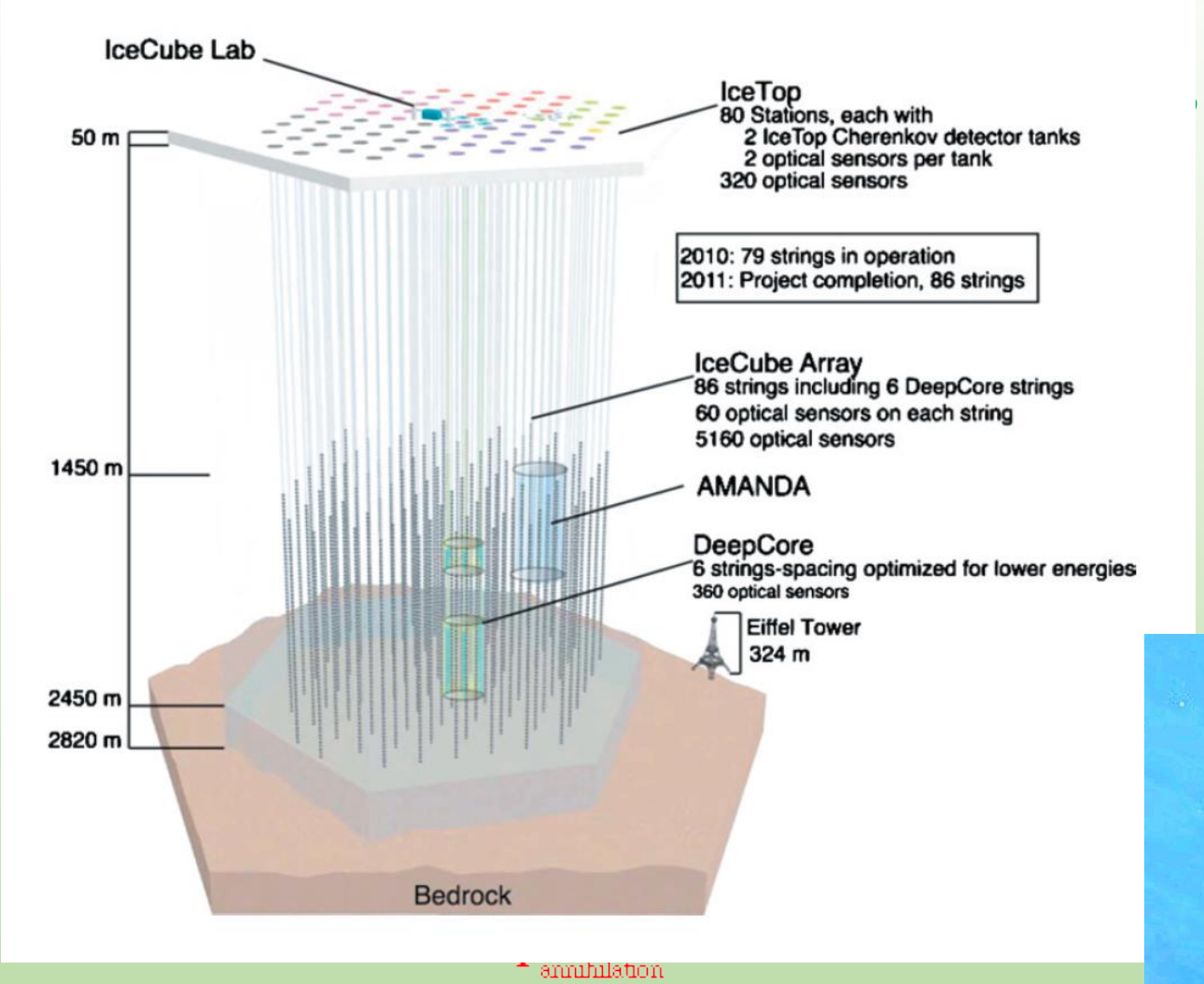


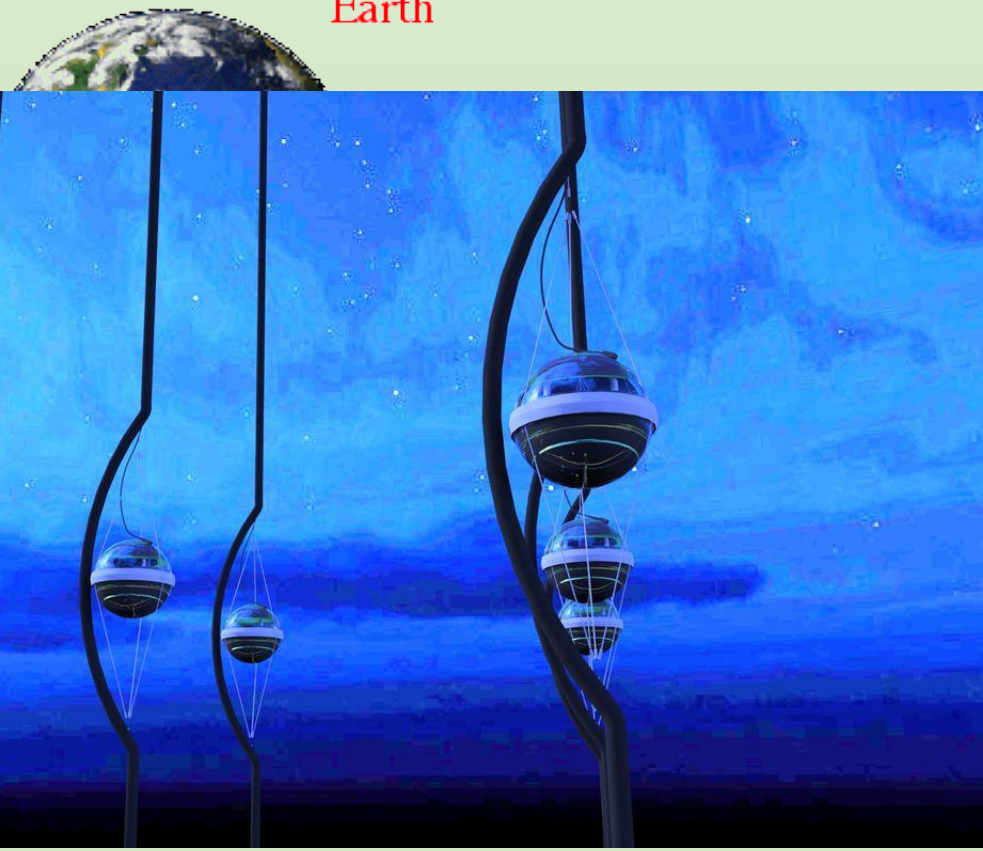


Direct detection experiments aim to detect the DM of our galactic halo which hit the nuclei of a detector. Big volumes and long exposure times are needed.

Many detectors all over the world…

just outside





The sun can capture with ist gravitational field
in its overdense inner shells.
We can detect neutrinos produced by possible

Our Universe is deeply influenced by “Invisible“ components.

Revealing their nature and properties is one of the most intriguing challenges of Science today

Research is very active and progresses are expected rather soon


Danke!