

# Dónde y cómo buscar a la materia oscura?

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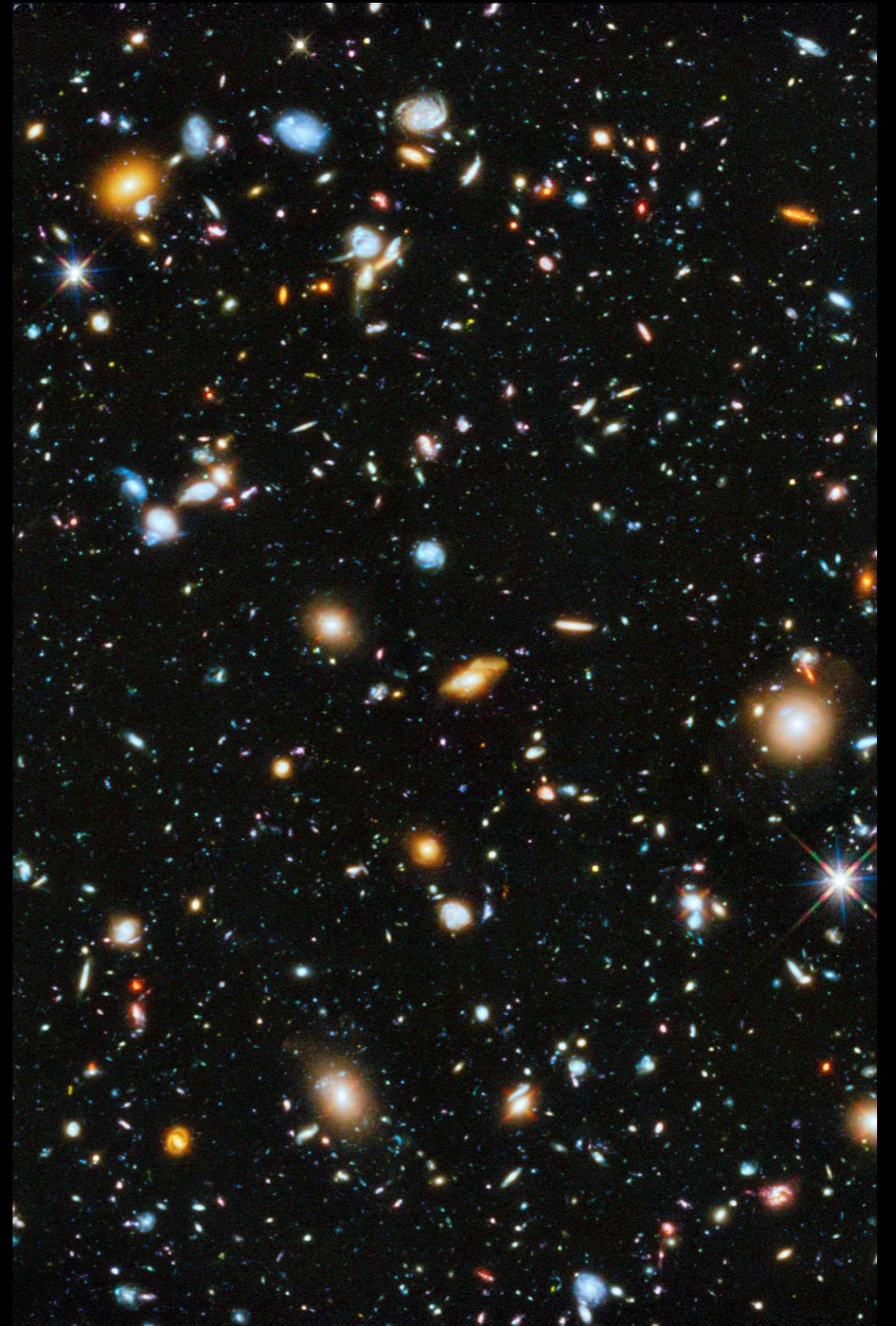
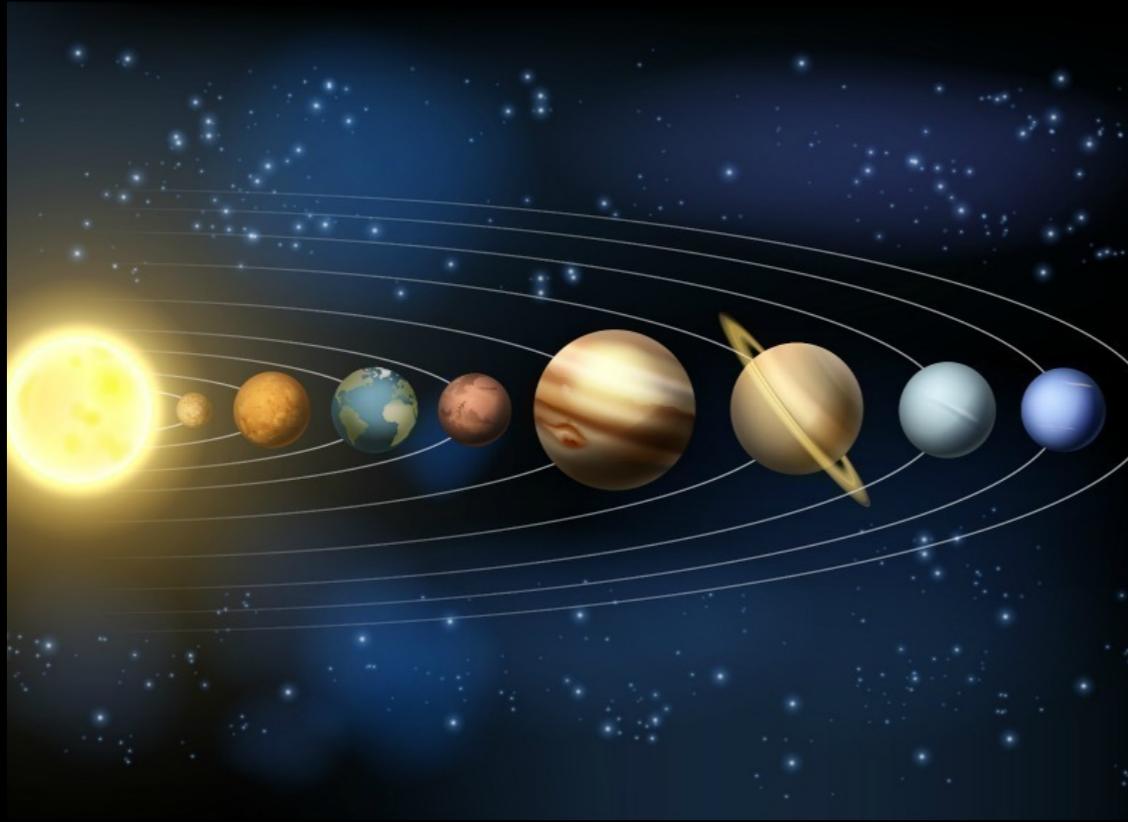
*Ciclo: El horizonte de la Física fundamental*

Residencia de estudiantes CSIC, Madrid, 14 de noviembre de 2019

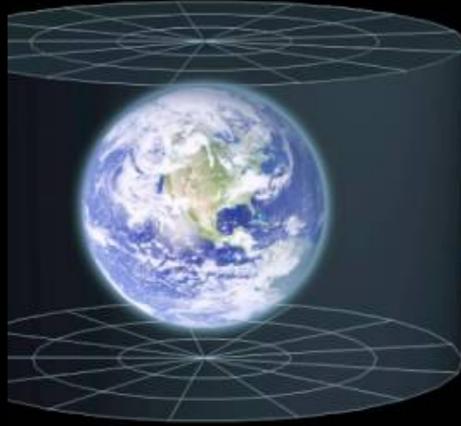


A theater stage with red curtains and a blue background, with the text "Lambda-CDM model" centered on the stage. The stage is lit with a warm yellow light, and there are four black objects on the floor. The foreground shows rows of empty seats.

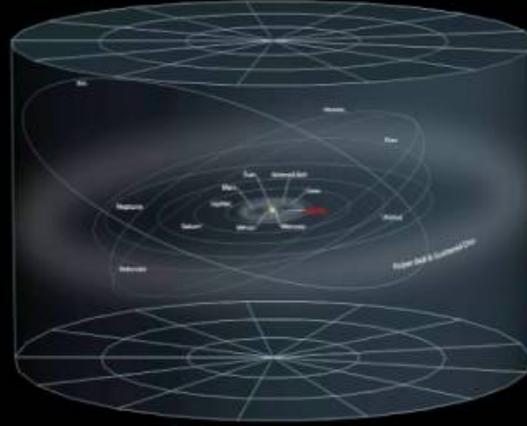
Lambda-CDM model



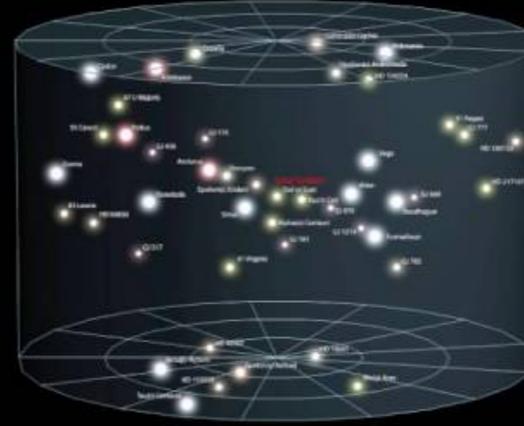
Earth



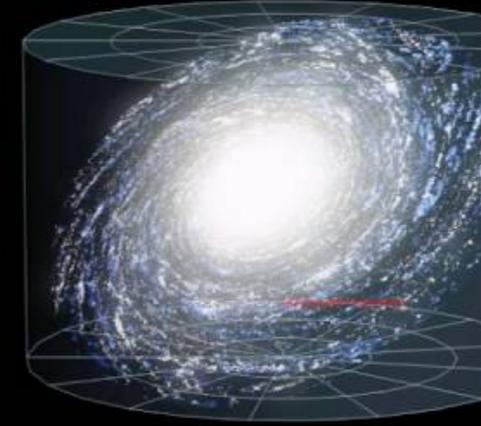
Solar System



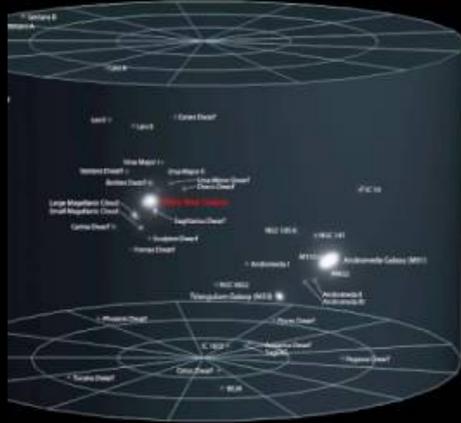
Solar Interstellar Neighborhood



Milky Way Galaxy



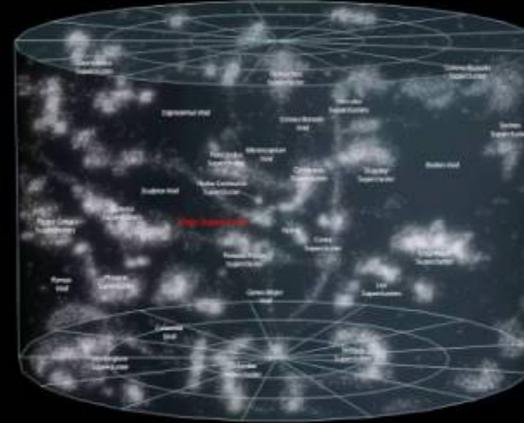
Local Galactic Group



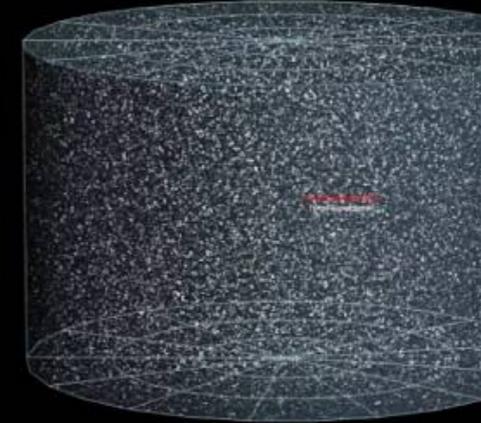
Virgo Supercluster



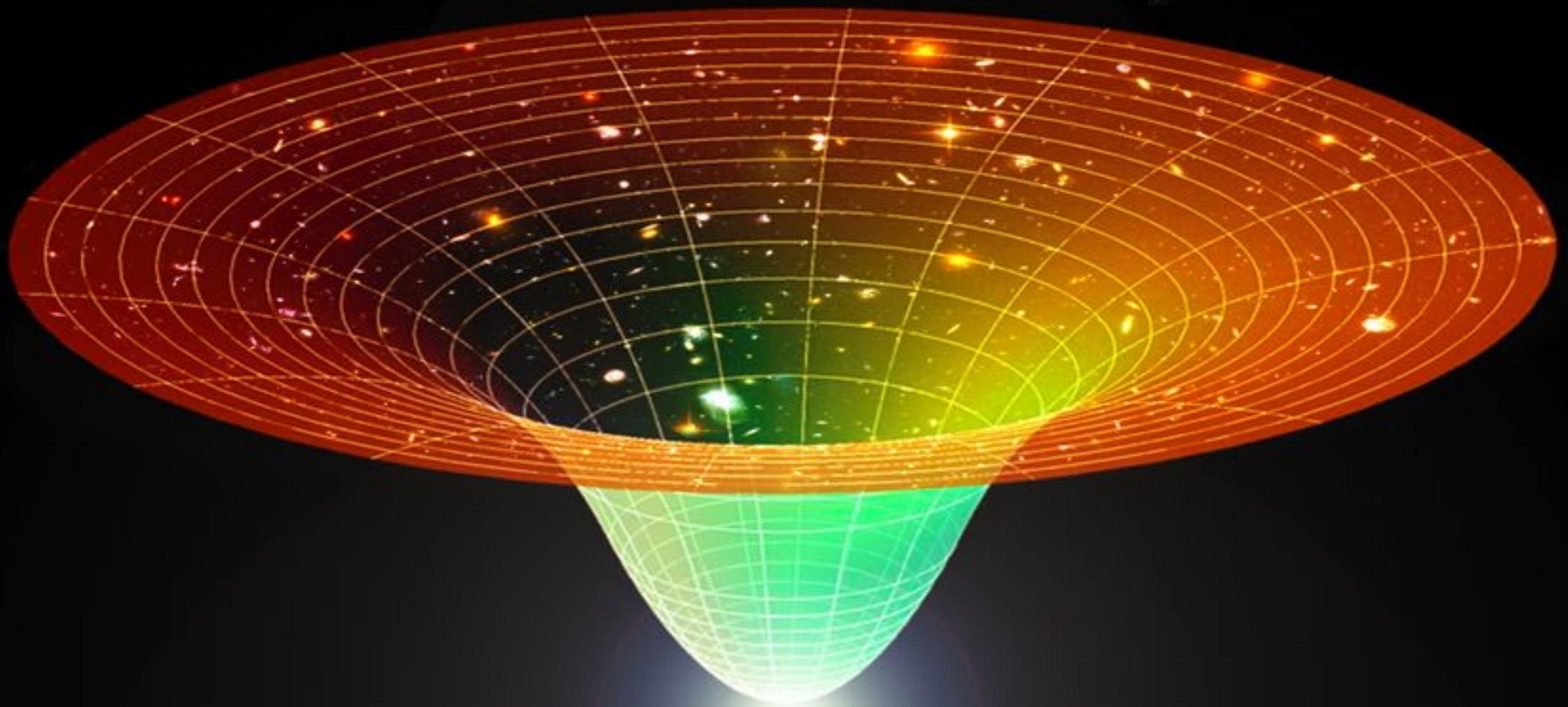
Local Superclusters



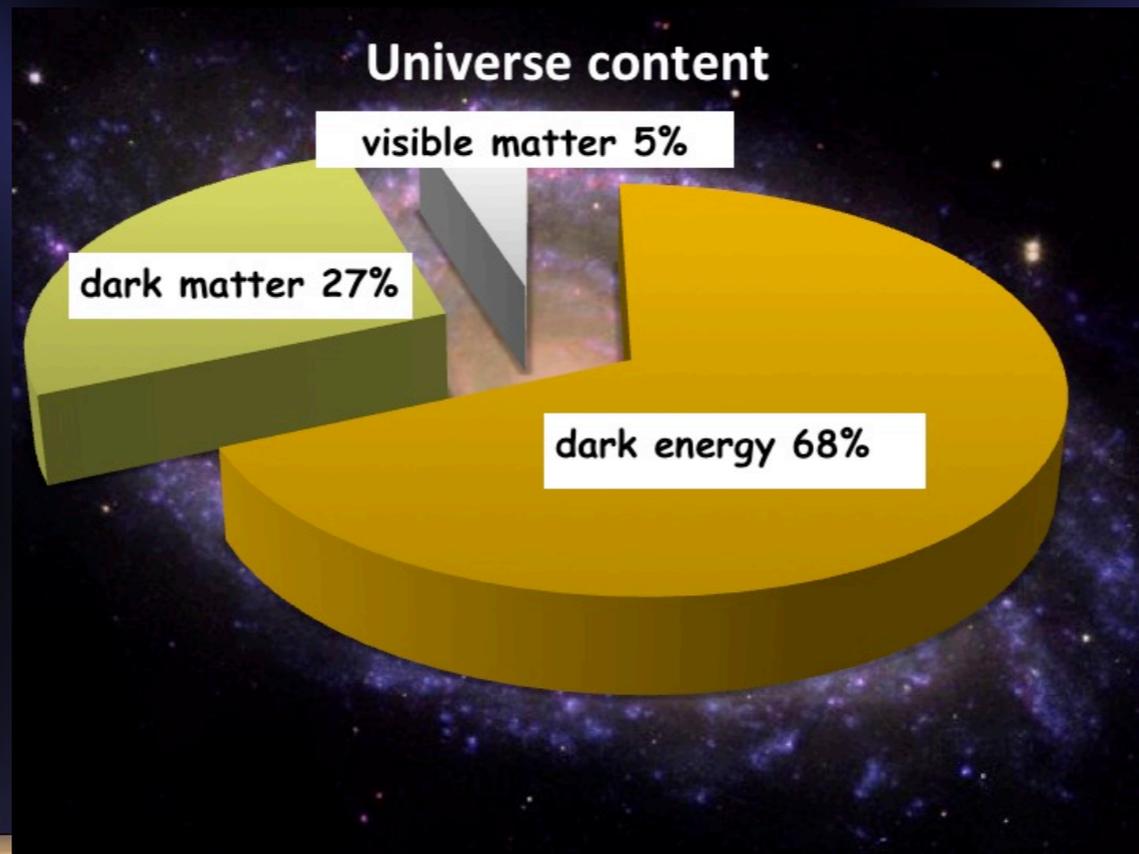
Observable Universe



Sólo un 5% de nuestro Universo !

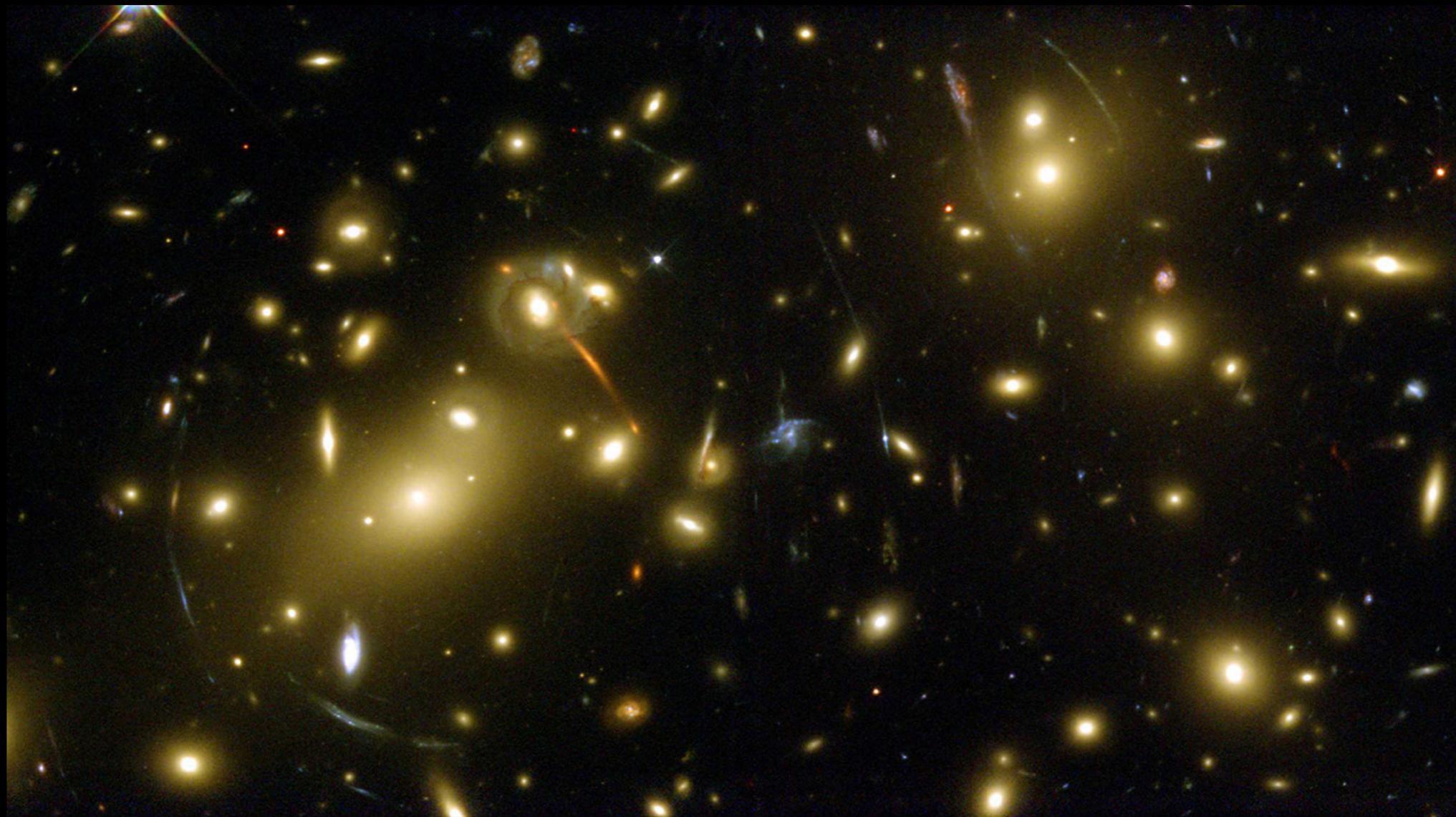


Big Bang-Inflation



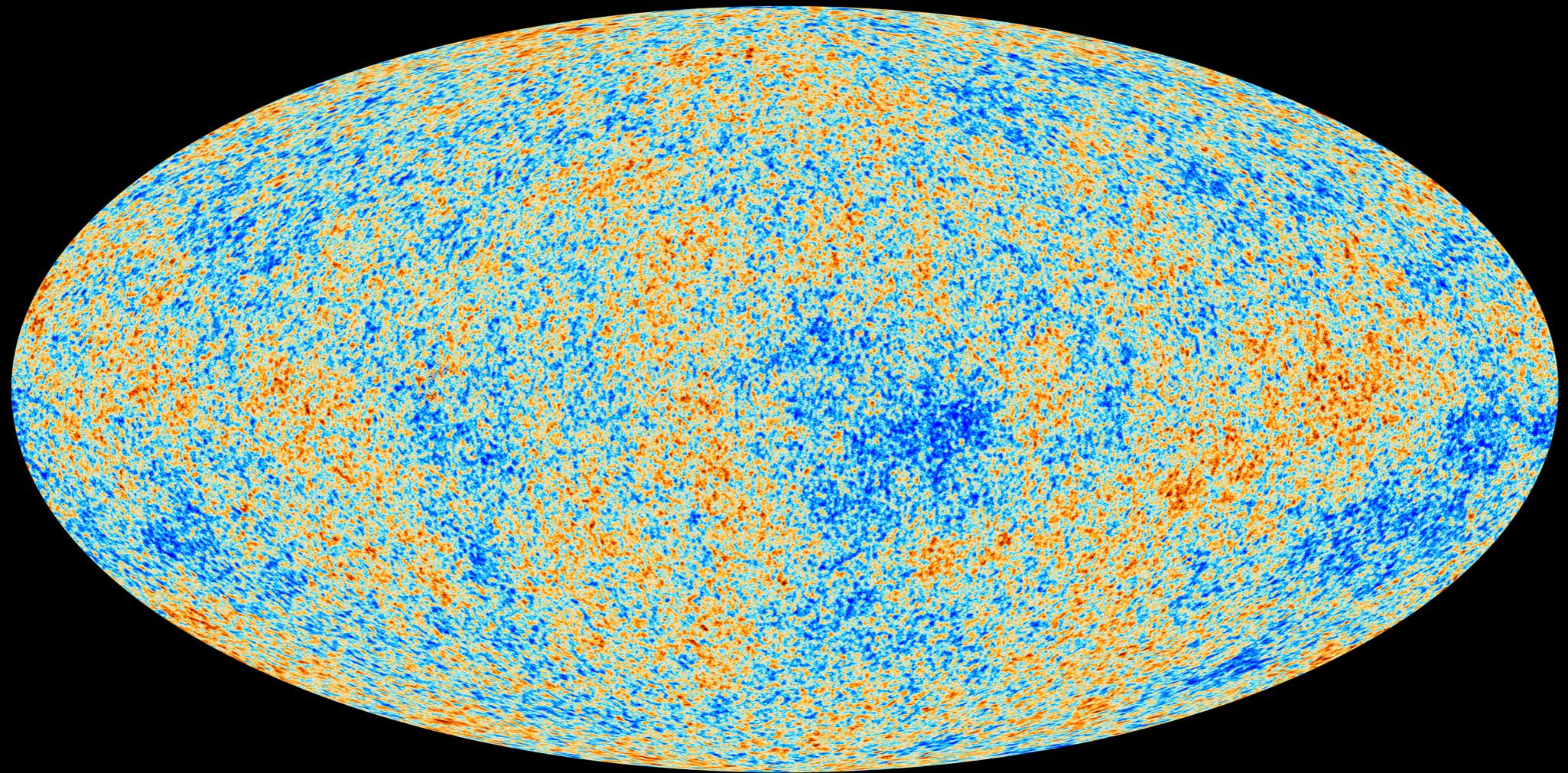
# Por qué materia oscura?





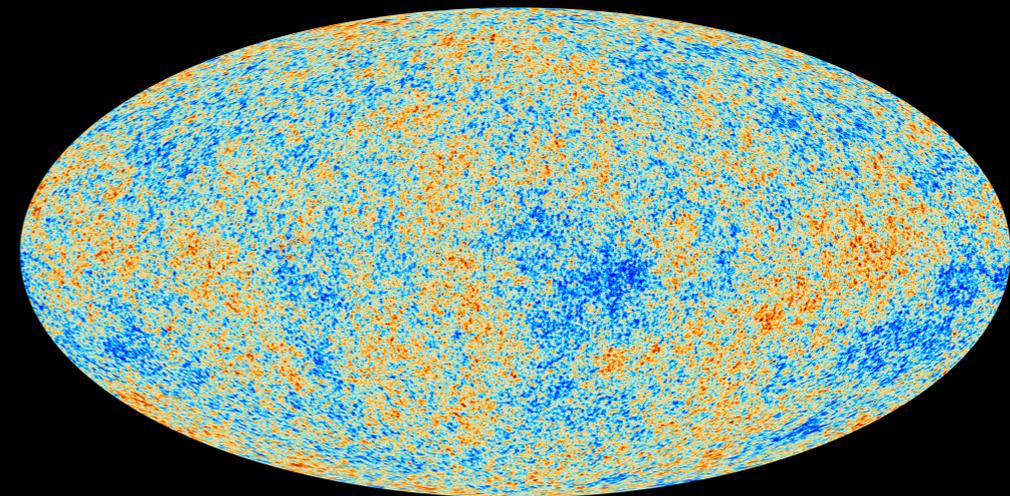
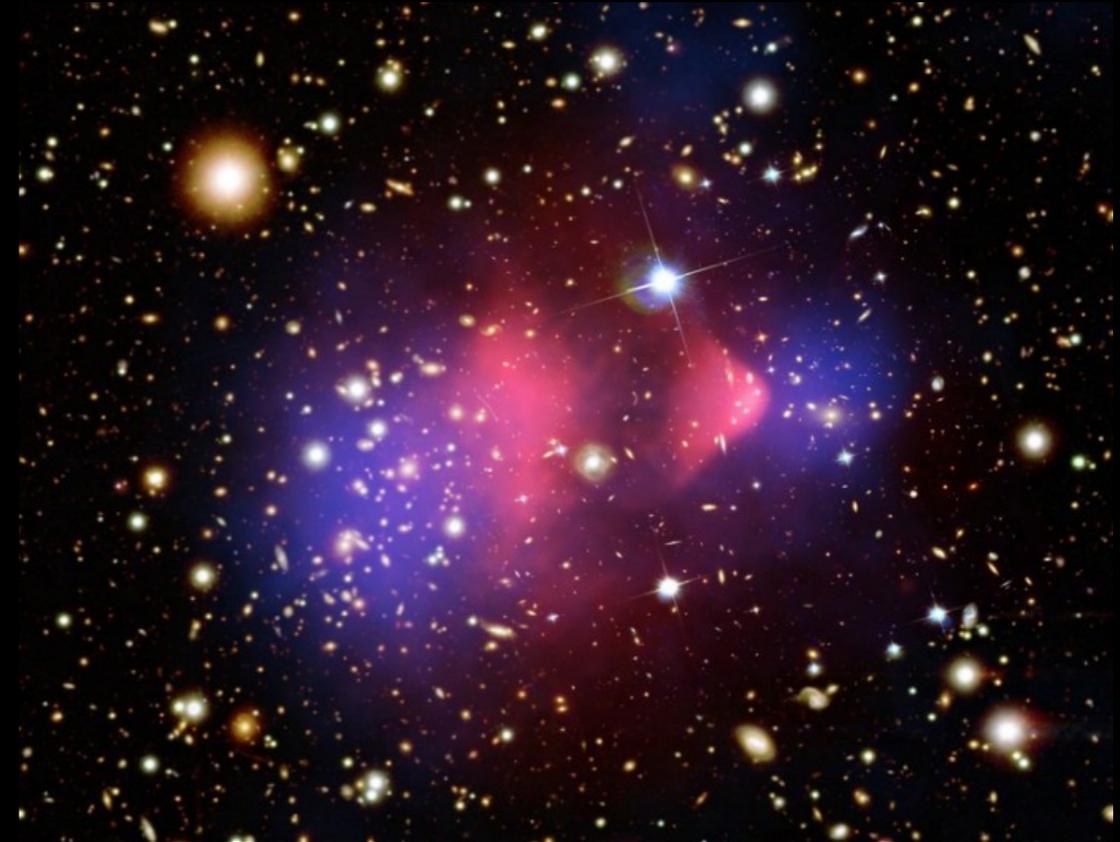
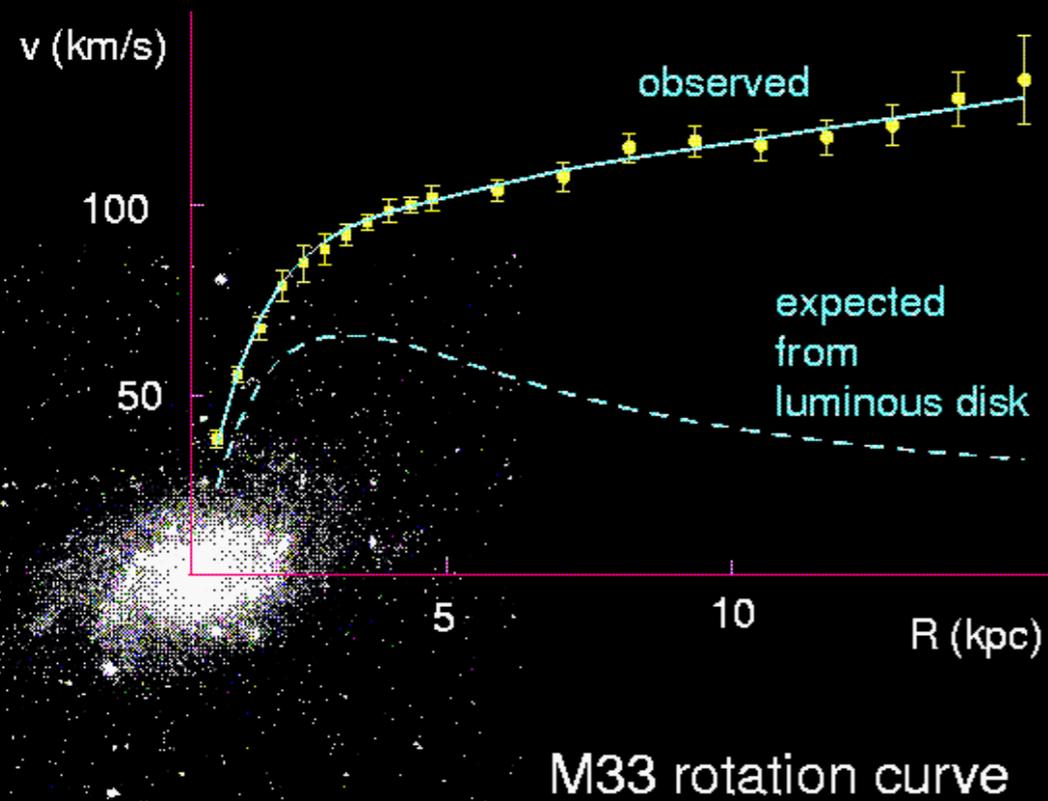


**The Bullet Cluster**



**El fondo cósmico de microondas (CMB)**

# Por qué materia oscura?



# De qué está formada?

Modelo estándar de la física de partículas

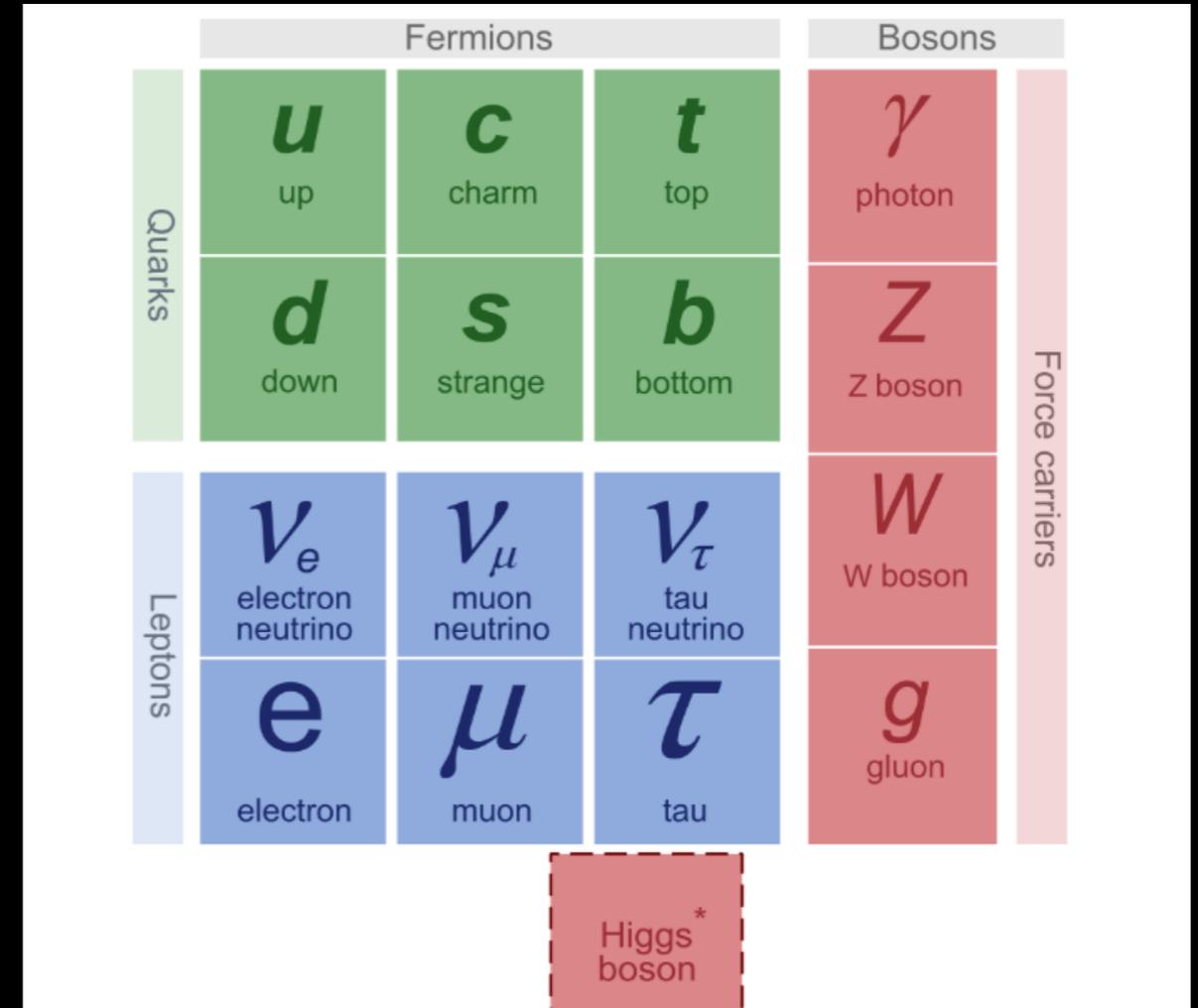
	Fermions			Bosons		
Quarks	$u$ up	$c$ charm	$t$ top	$\gamma$ photon	Force carriers	
	$d$ down	$s$ strange	$b$ bottom	$Z$ Z boson		
Leptons	$\nu_e$ electron neutrino	$\nu_\mu$ muon neutrino	$\nu_\tau$ tau neutrino	$W$ W boson		
	$e$ electron	$\mu$ muon	$\tau$ tau	$g$ gluon		
						Higgs <sup>*</sup> boson



# Propiedades de la materia oscura



- No emite luz (o muy debilmente)
- Estable a escalas cosmológicas ( $t_U \sim 13.8$  Gyr)
- Fría (Cold DM)
- Masiva
- No es materia ordinaria



# Candidatos



MACHOs are Massive Compact Halo Objects, which can include Brown Dwarfs, White Dwarfs, and Black Holes



**Brown Dwarfs** are failed stars – stars that never gained enough mass to start burning. They are very cool and dim, making them difficult to detect.

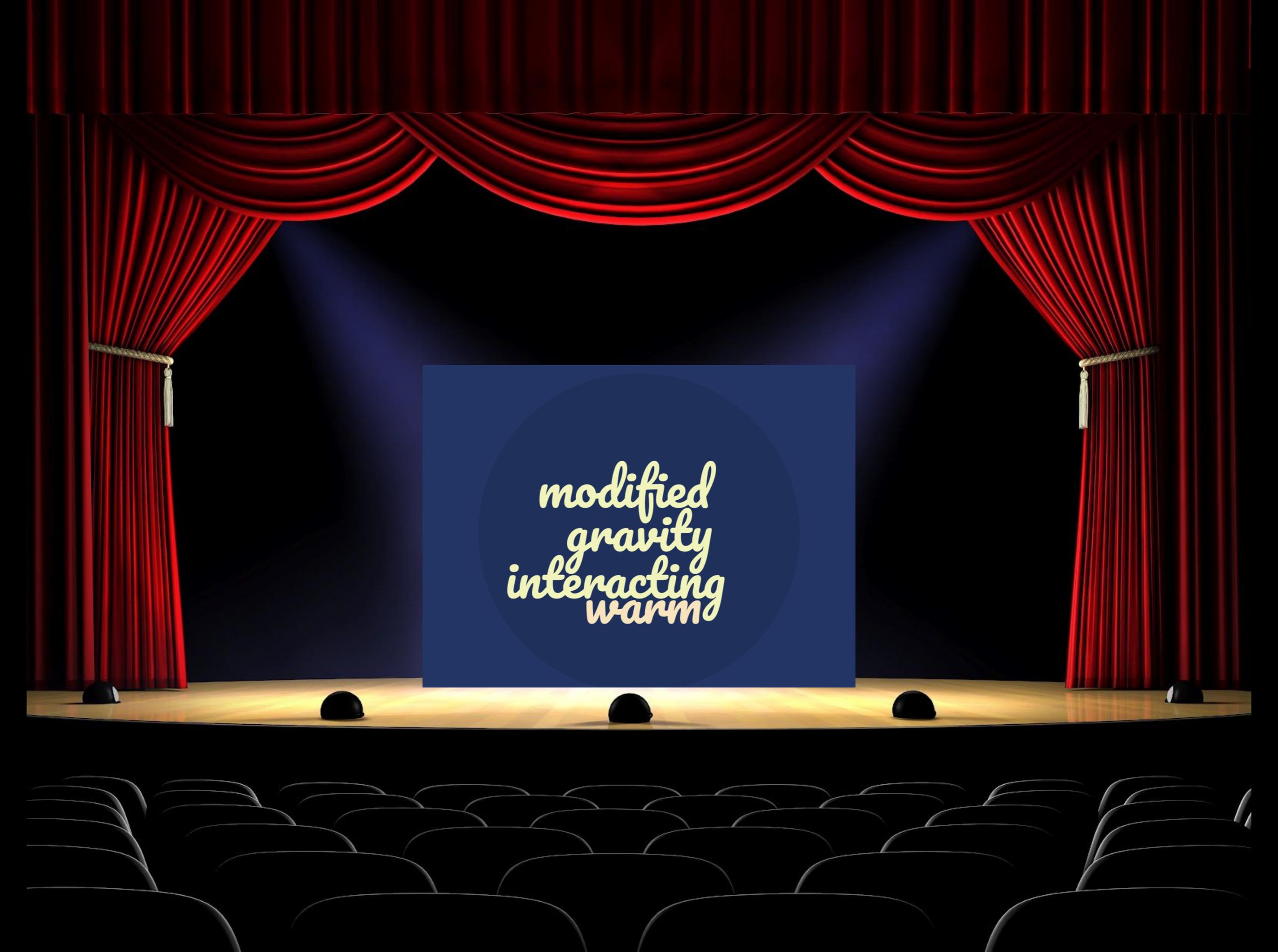


The Sun as a White Dwarf (5 billion years from now)

**White Dwarfs** are the remnants of stars like our Sun, which have collapsed after burning all their energy. They are very compact and dim.



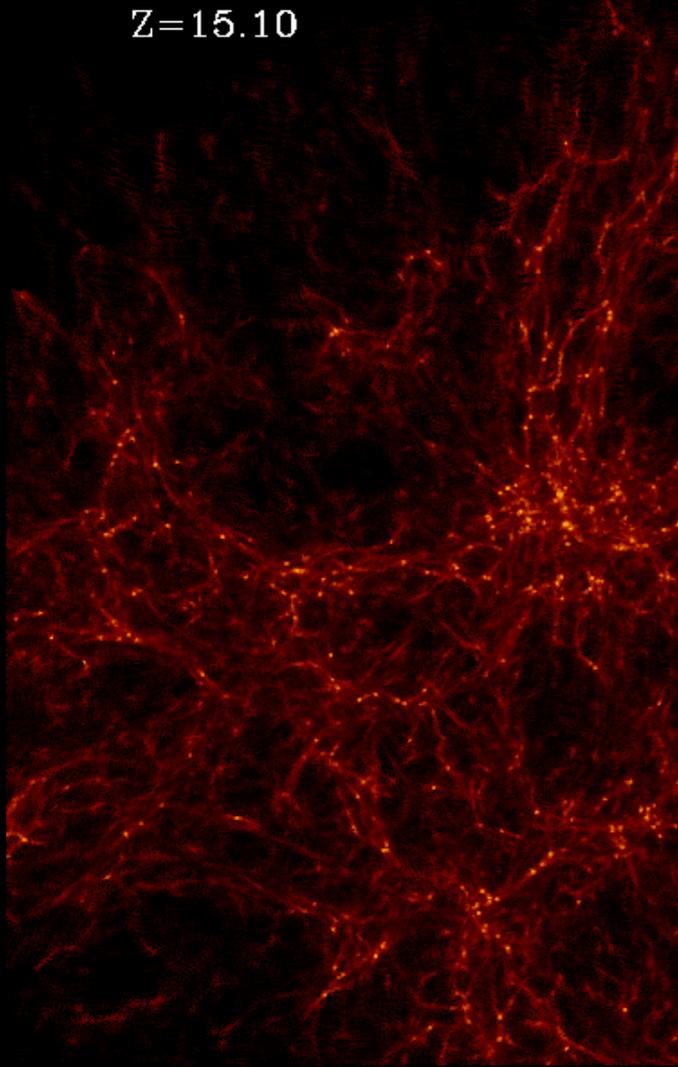
**Supermassive Black Holes**, like the one shown in this artist depiction, may contain much of the "missing mass" in the Universe.

A theater stage with red curtains and a blue screen displaying text. The stage is lit with a warm yellow light, and the audience seats are visible in the foreground.

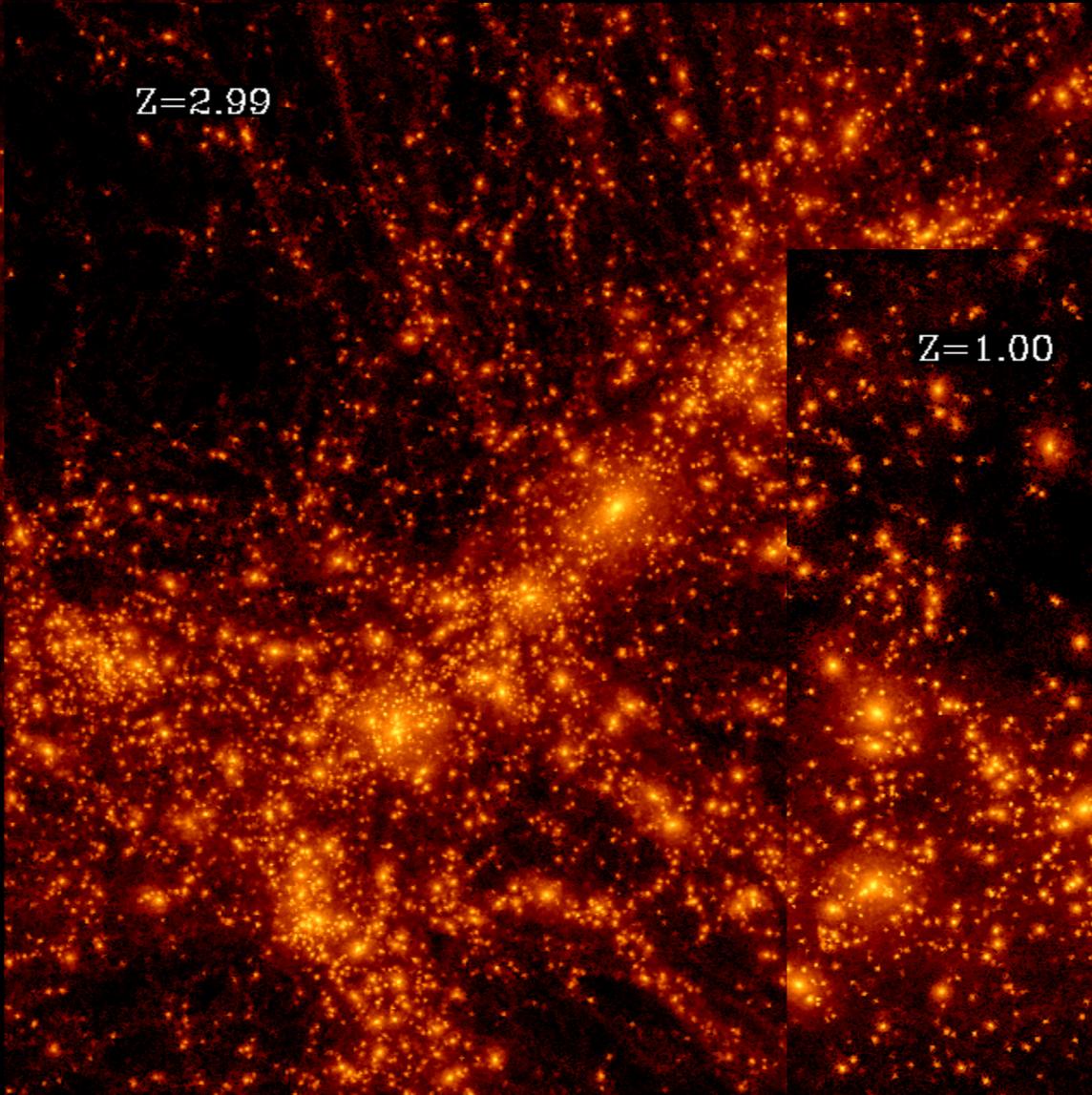
*modified  
gravity  
interacting  
warm*

# Formación de estructuras en el Universo

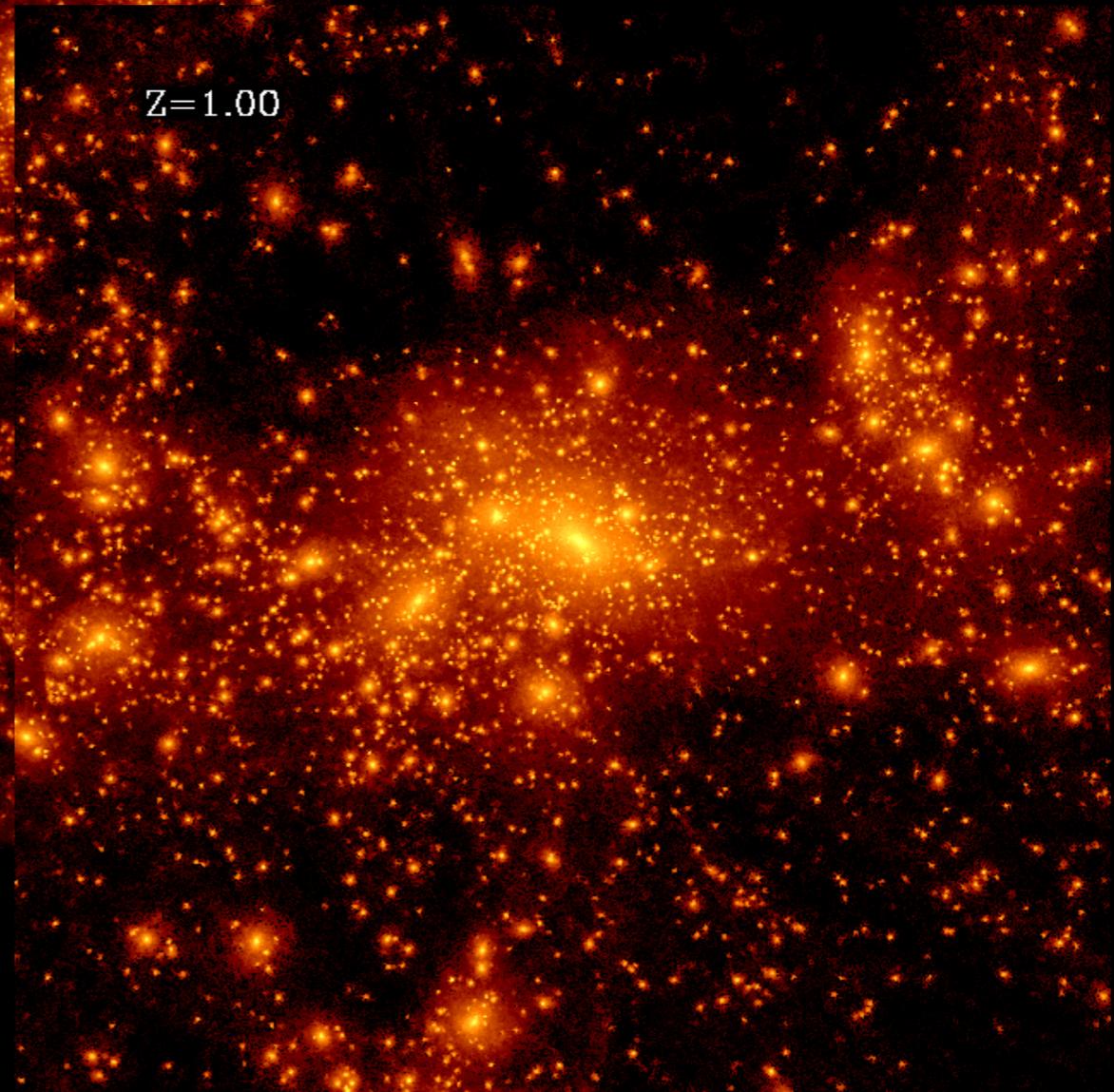
$Z=15.10$

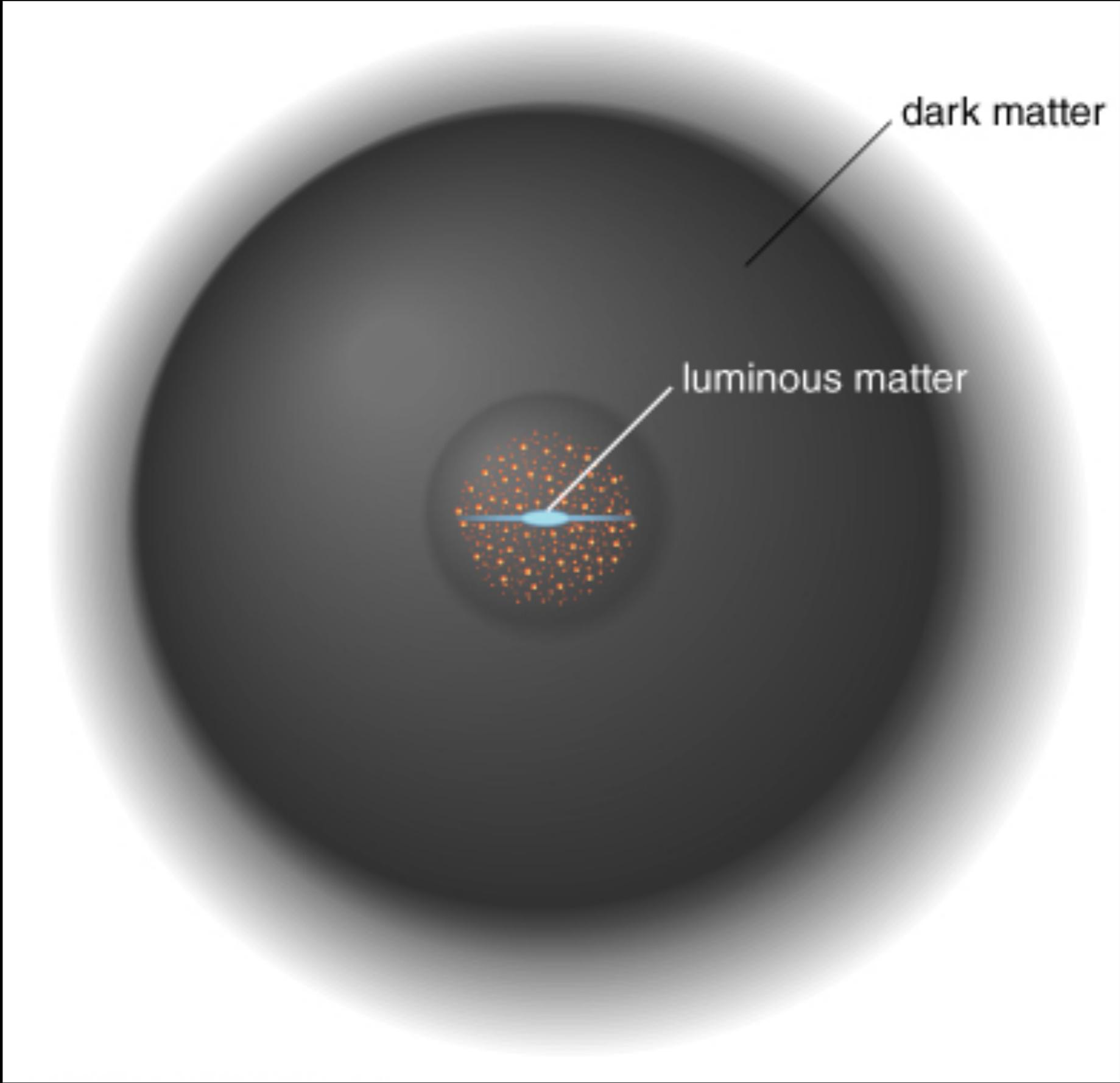


$Z=2.99$



$Z=1.00$

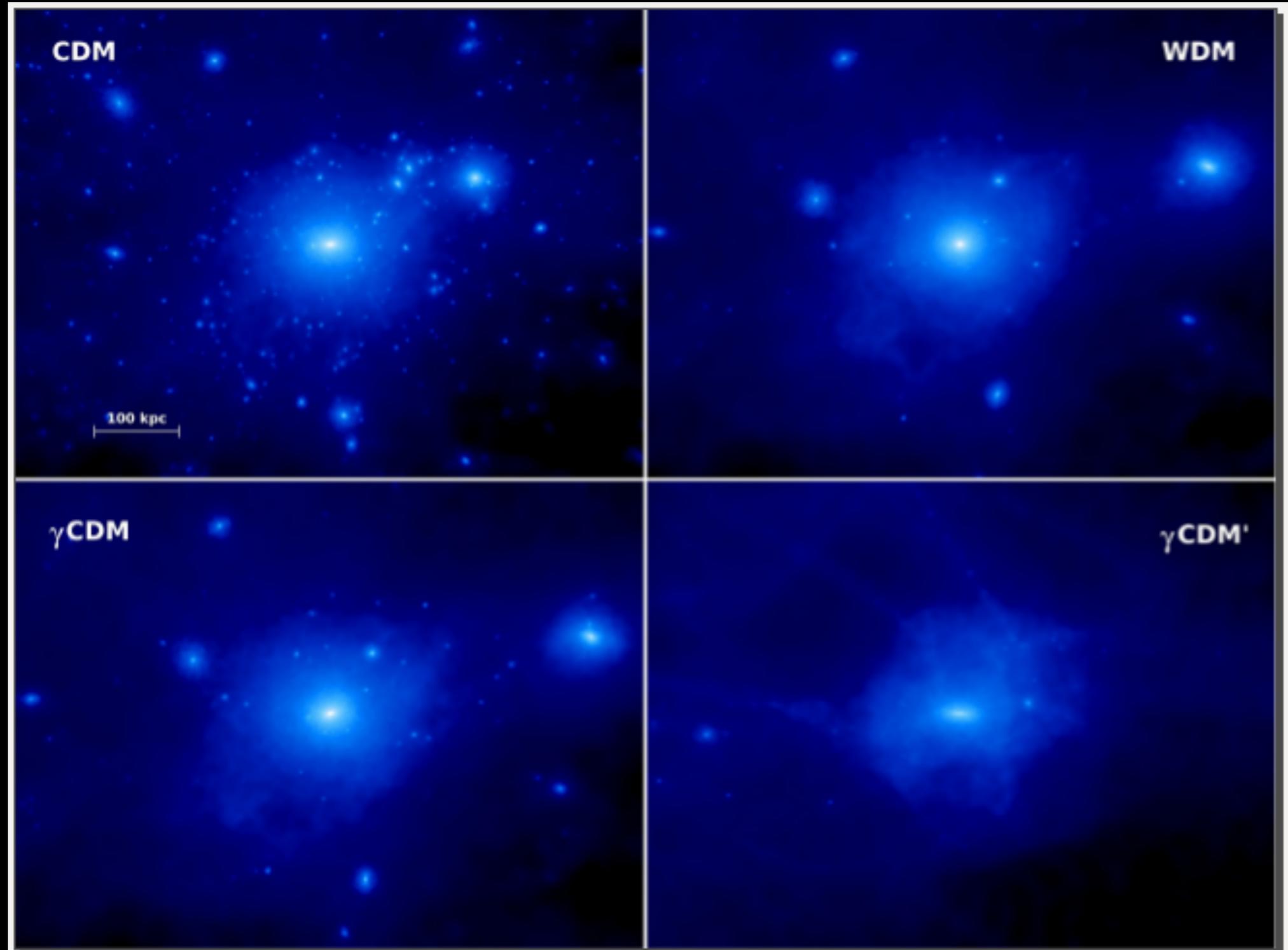




dark matter

luminous matter

# Diferencias en la formación de estructura según el escenario elegido

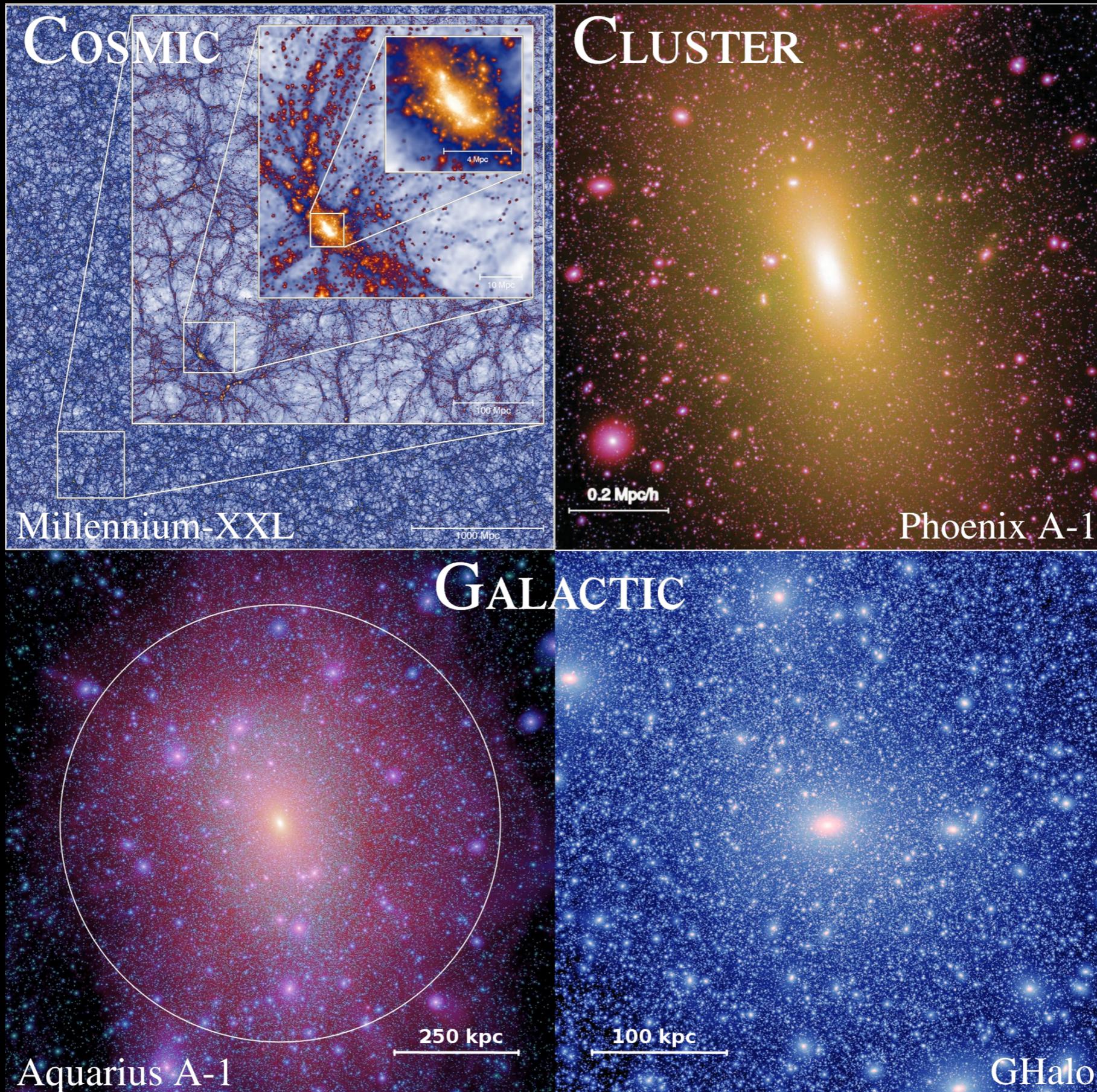


Credit: Boehm & Schewtschenko

A photograph of a server room with rows of server racks on both sides, illuminated by blue light. The racks are filled with server units, and the floor is a light-colored tile. The perspective is looking down a long aisle.

# Herramienta Fundamental: Simulaciones Cosmológicas

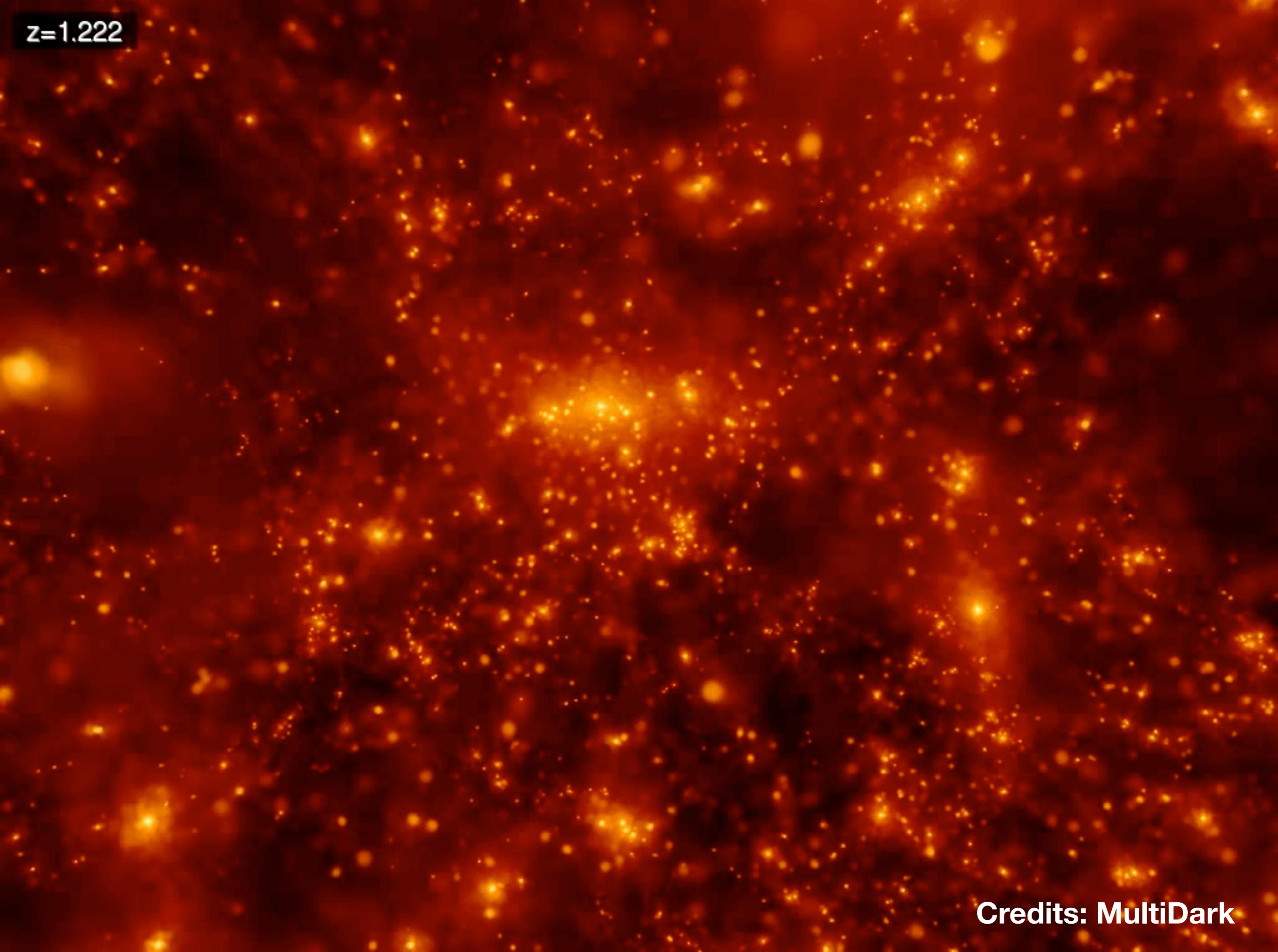
# A diferentes escalas cosmológicas





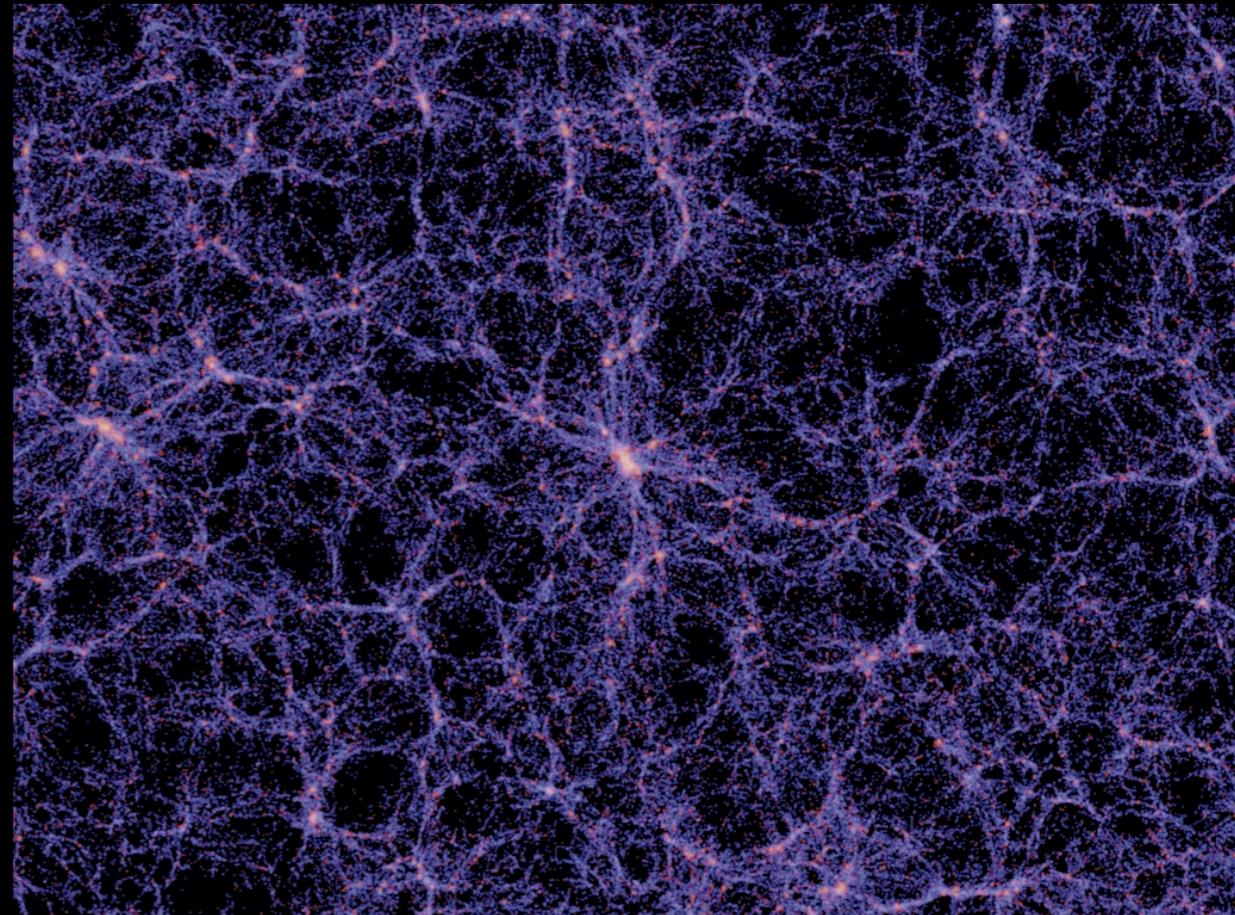
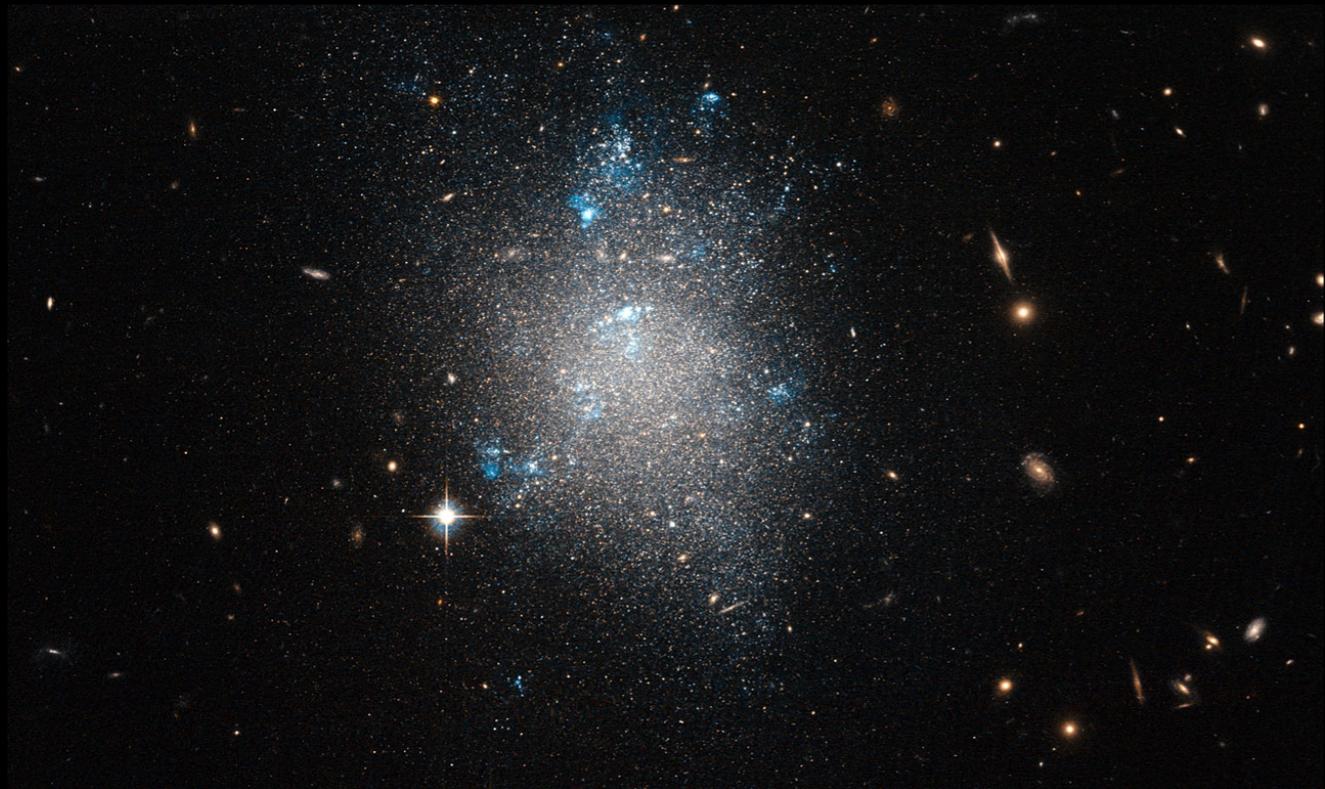
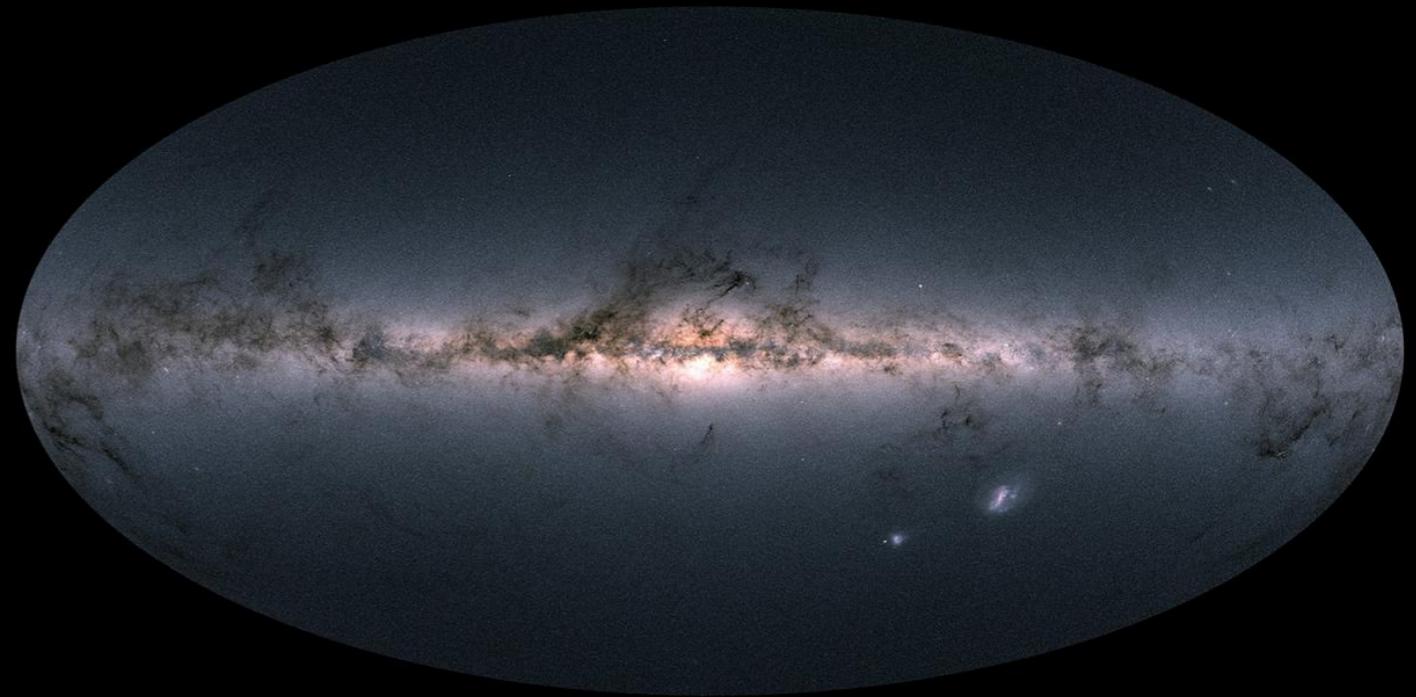
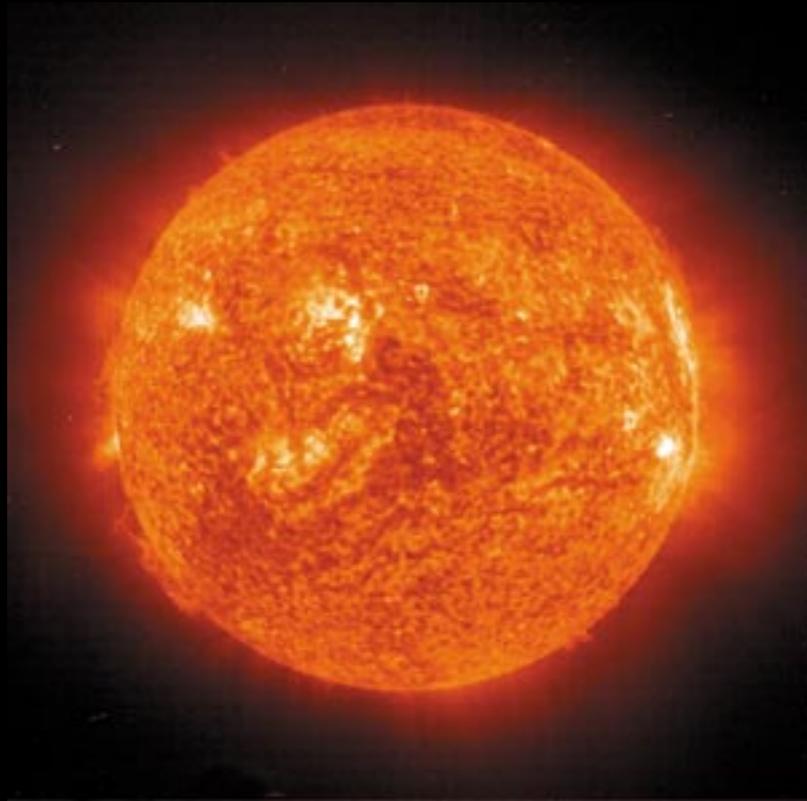
Credit: CLUES  
simulations

$z=1.222$



Credits: MultiDark

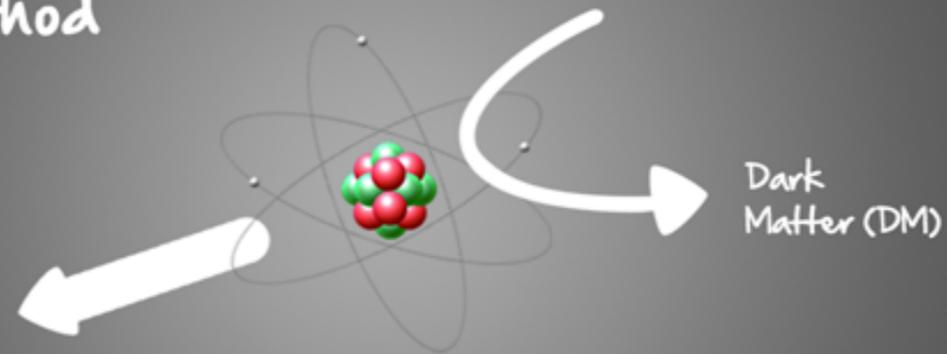
# Dónde buscar?



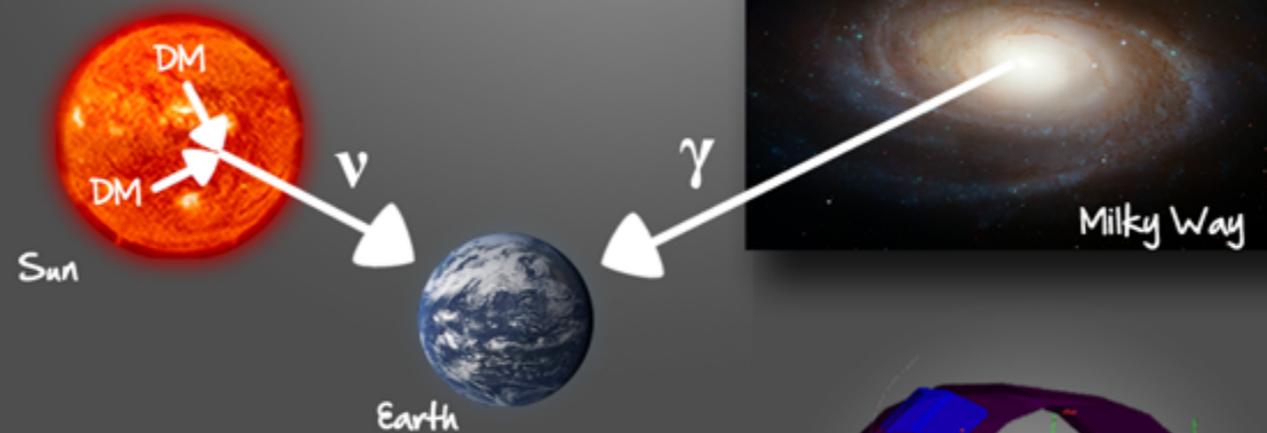
# Métodos de detección

## Dark Matter search strategies

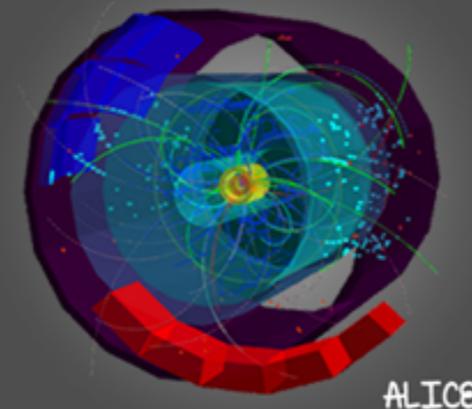
### Direct Method



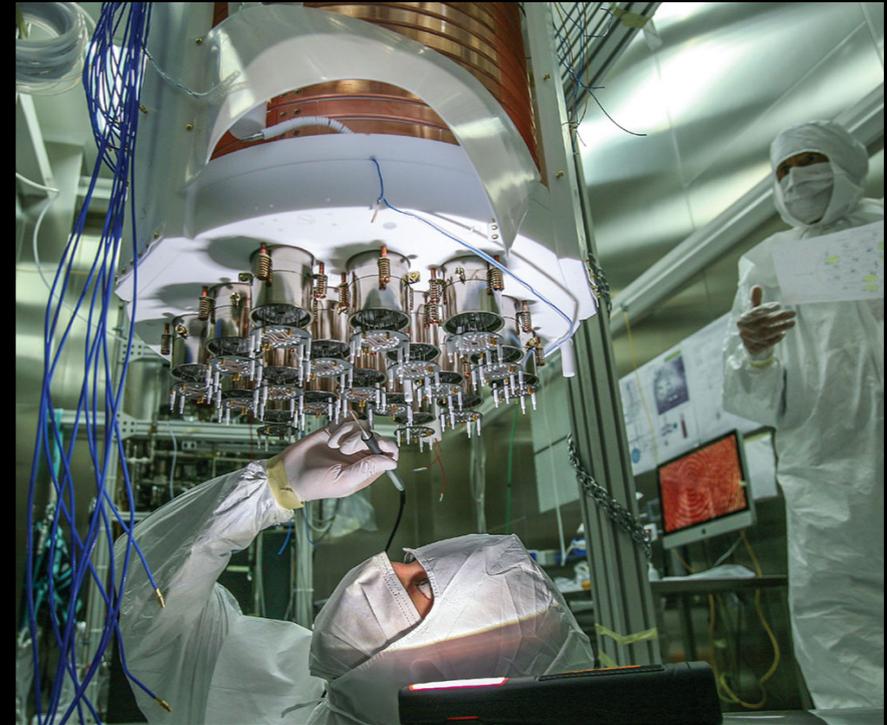
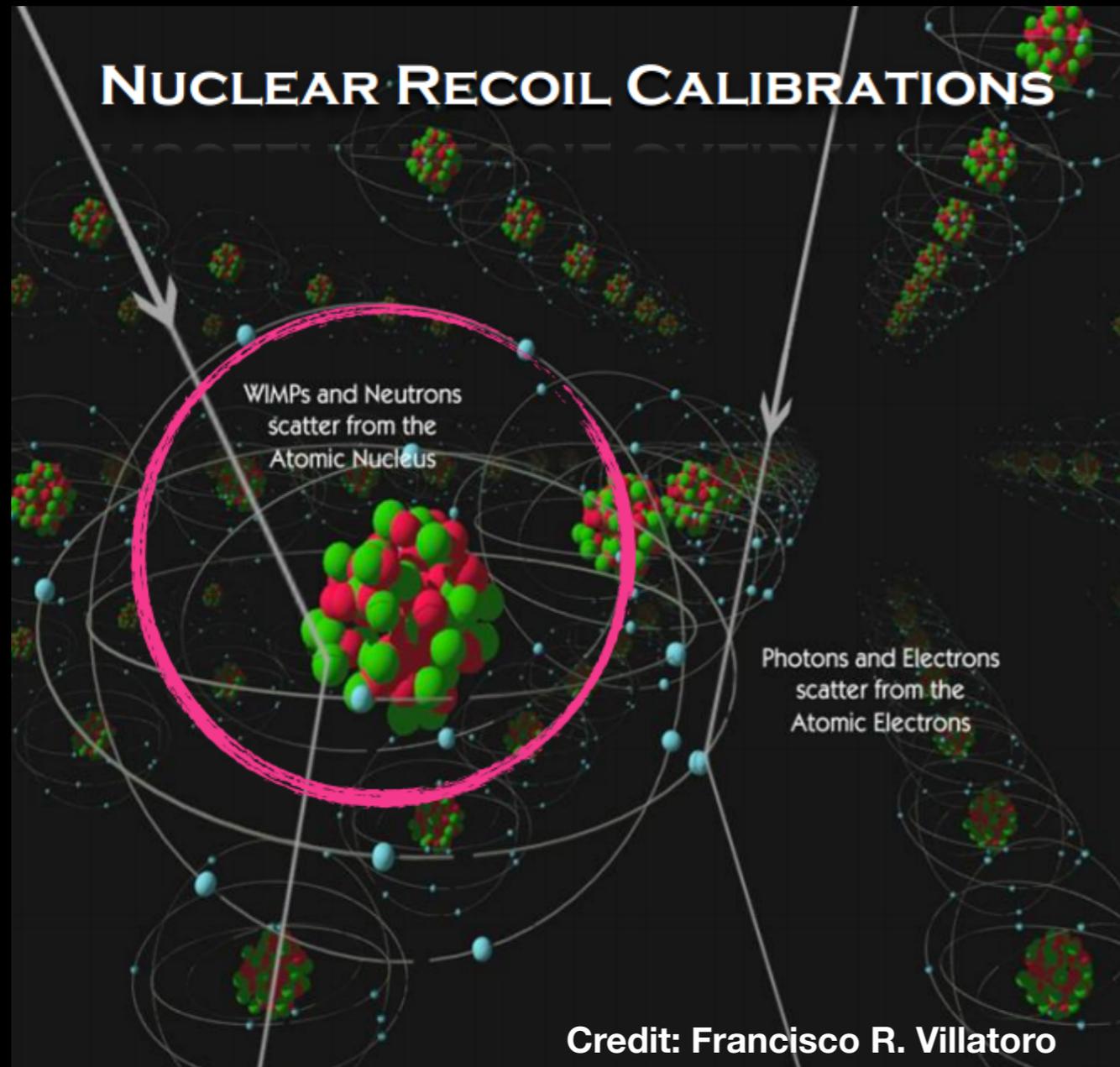
### Indirect Method



### Production at the Large Hadron Collider



# Búsquedas directas

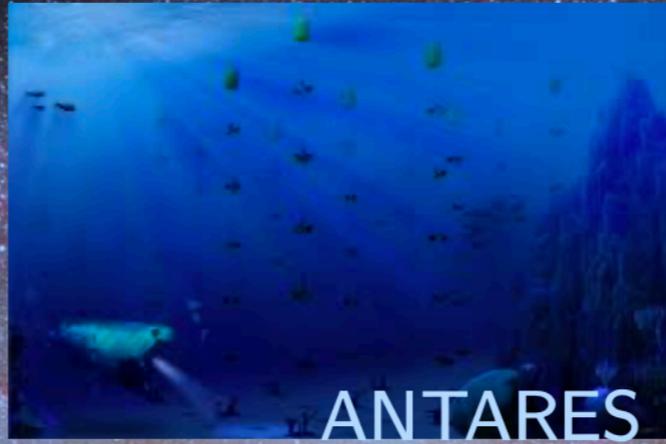


# Detección Indirecta

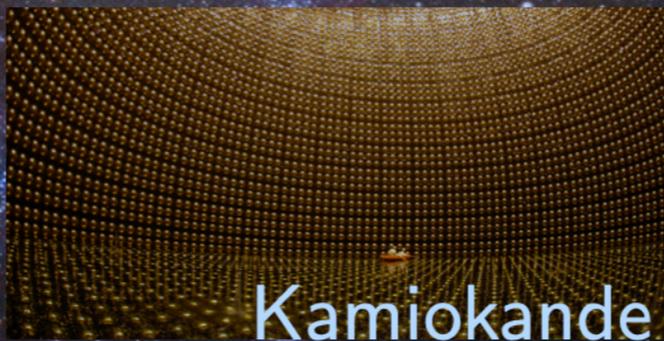
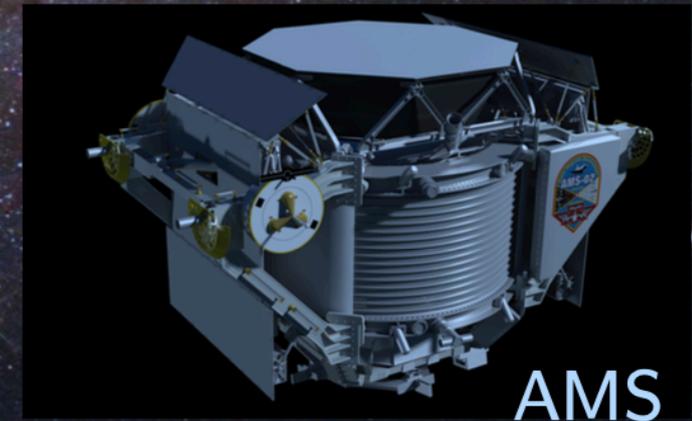
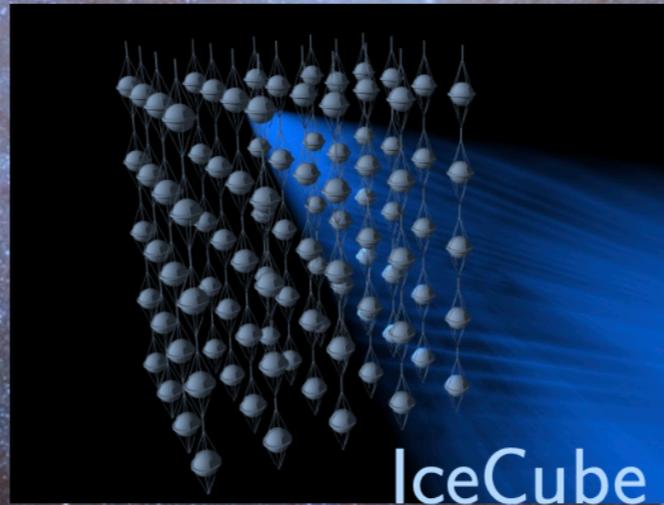
$\gamma$



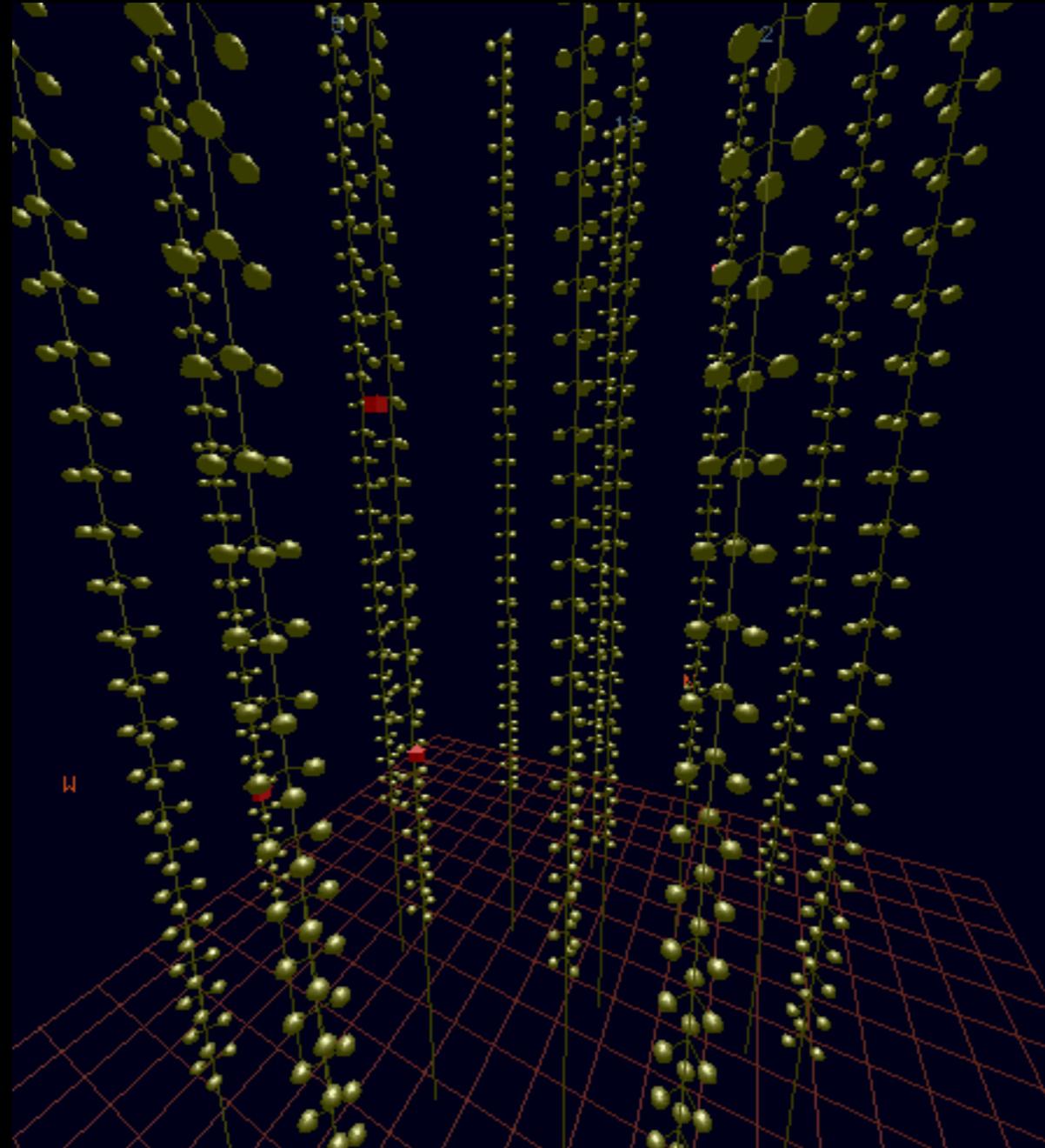
$\nu$



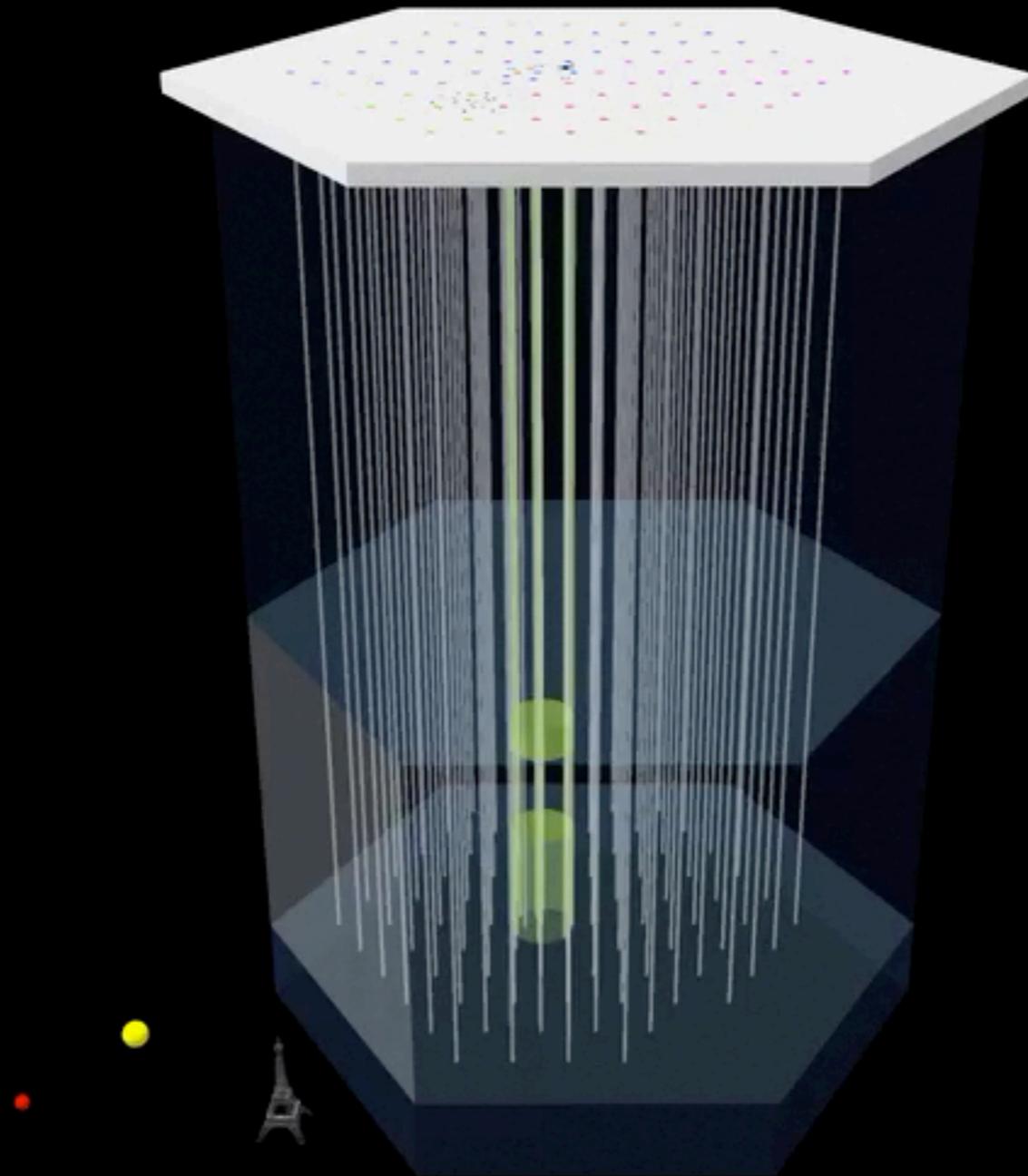
$e^+, e^-, p, \bar{p}$



# Antares

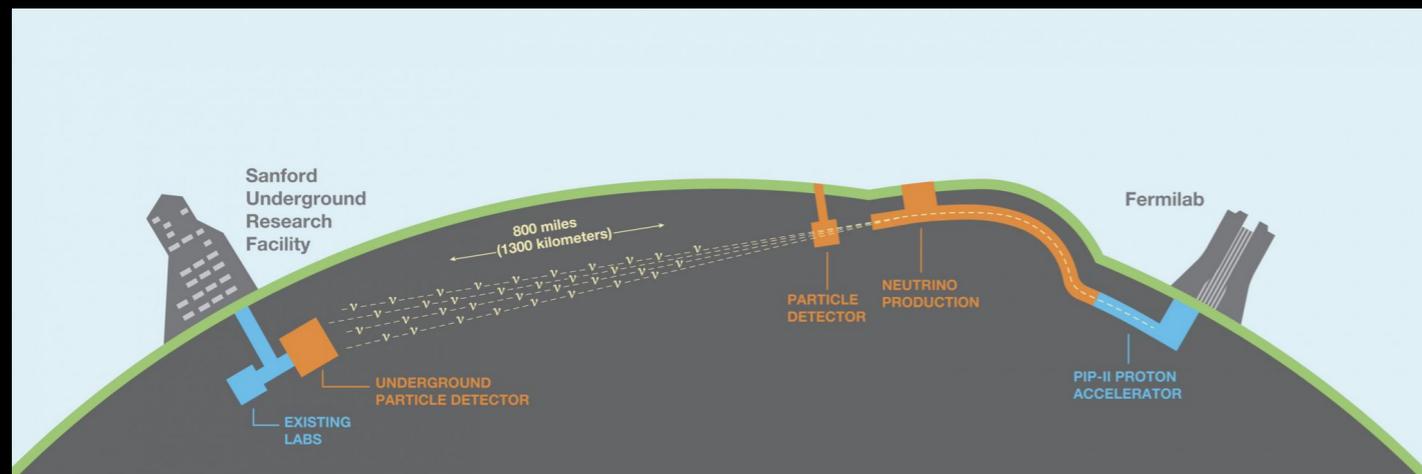
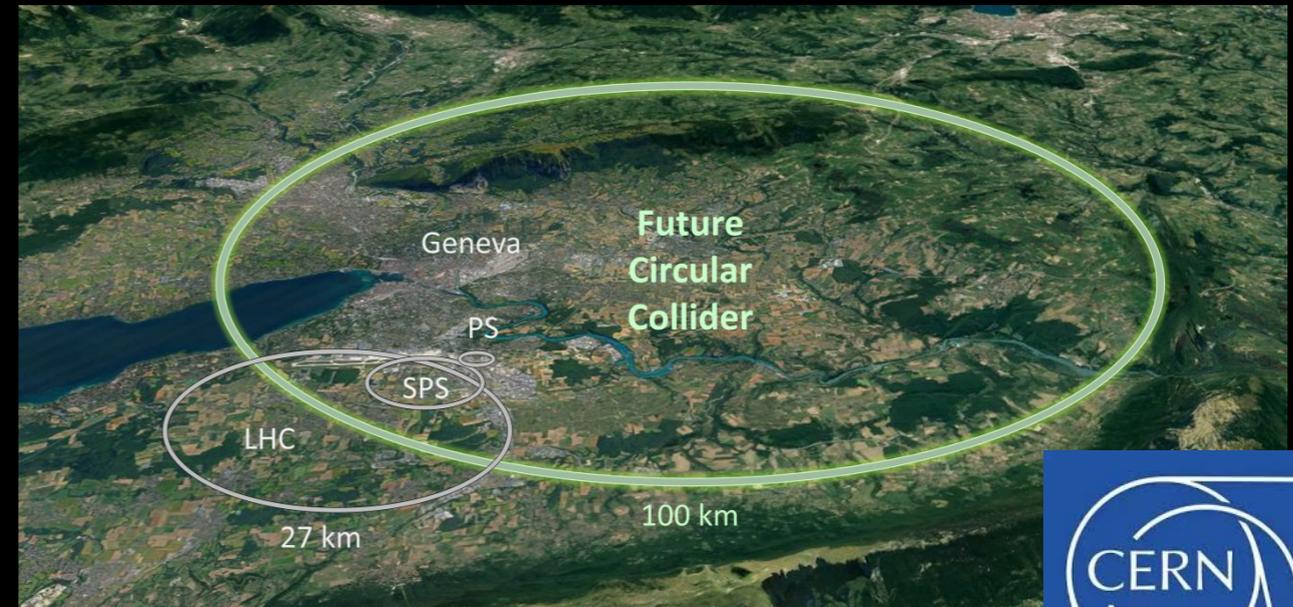
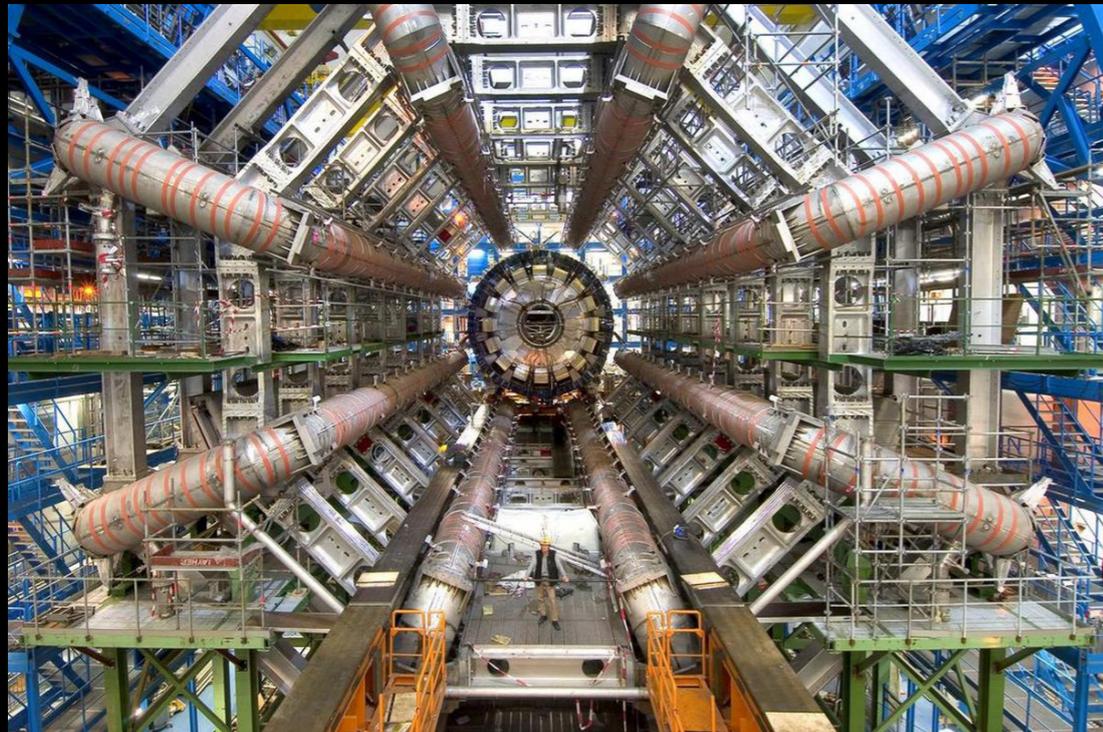


# Ice Cube Detector

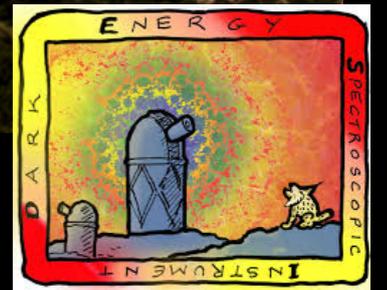
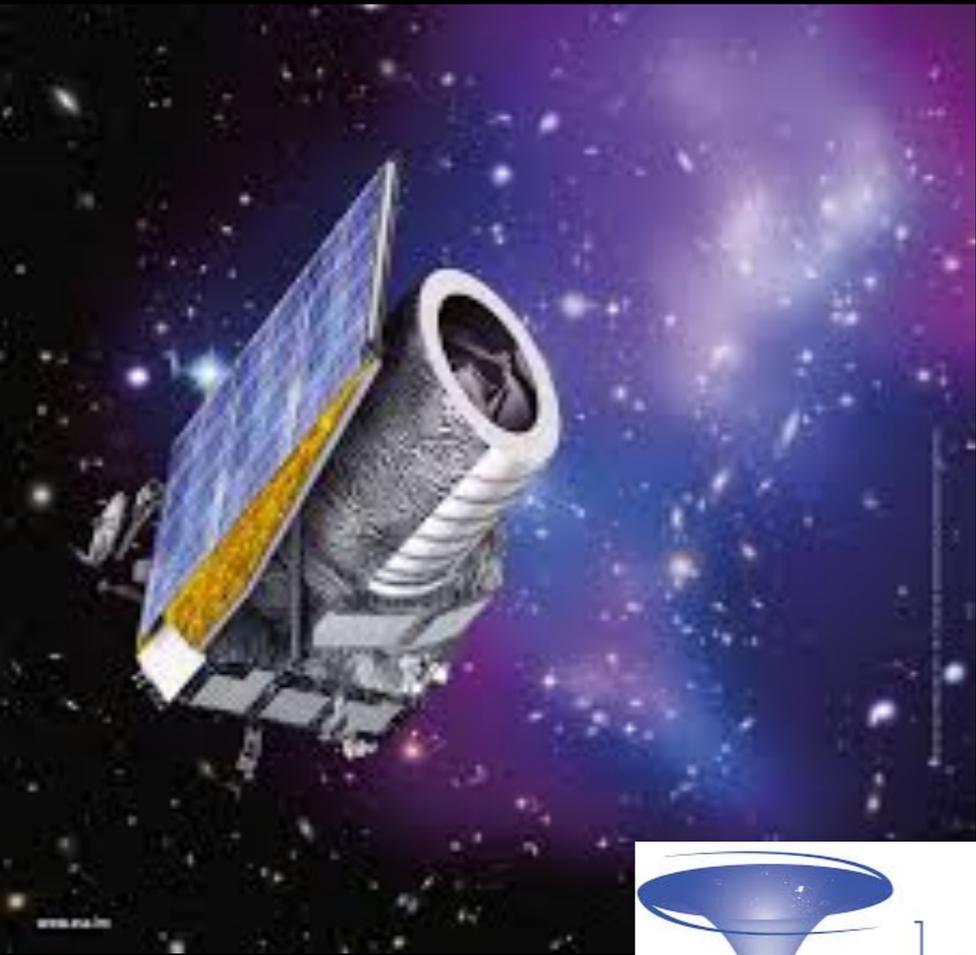


Credit: Ice Cube collaboration

# Aceleradores de partículas



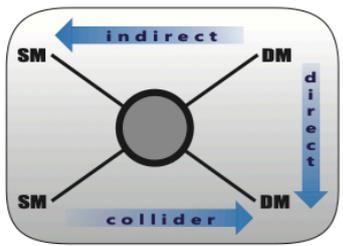
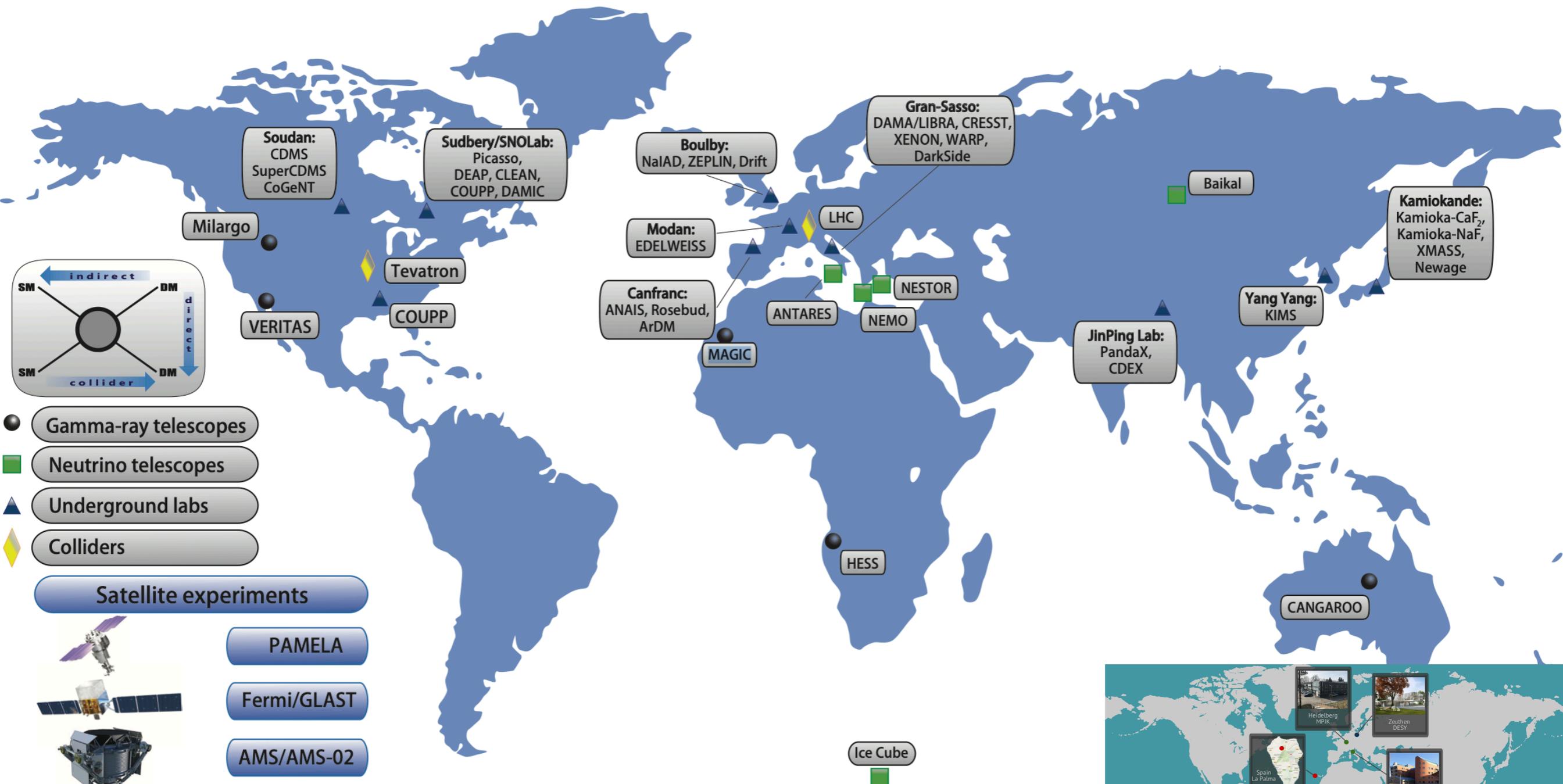


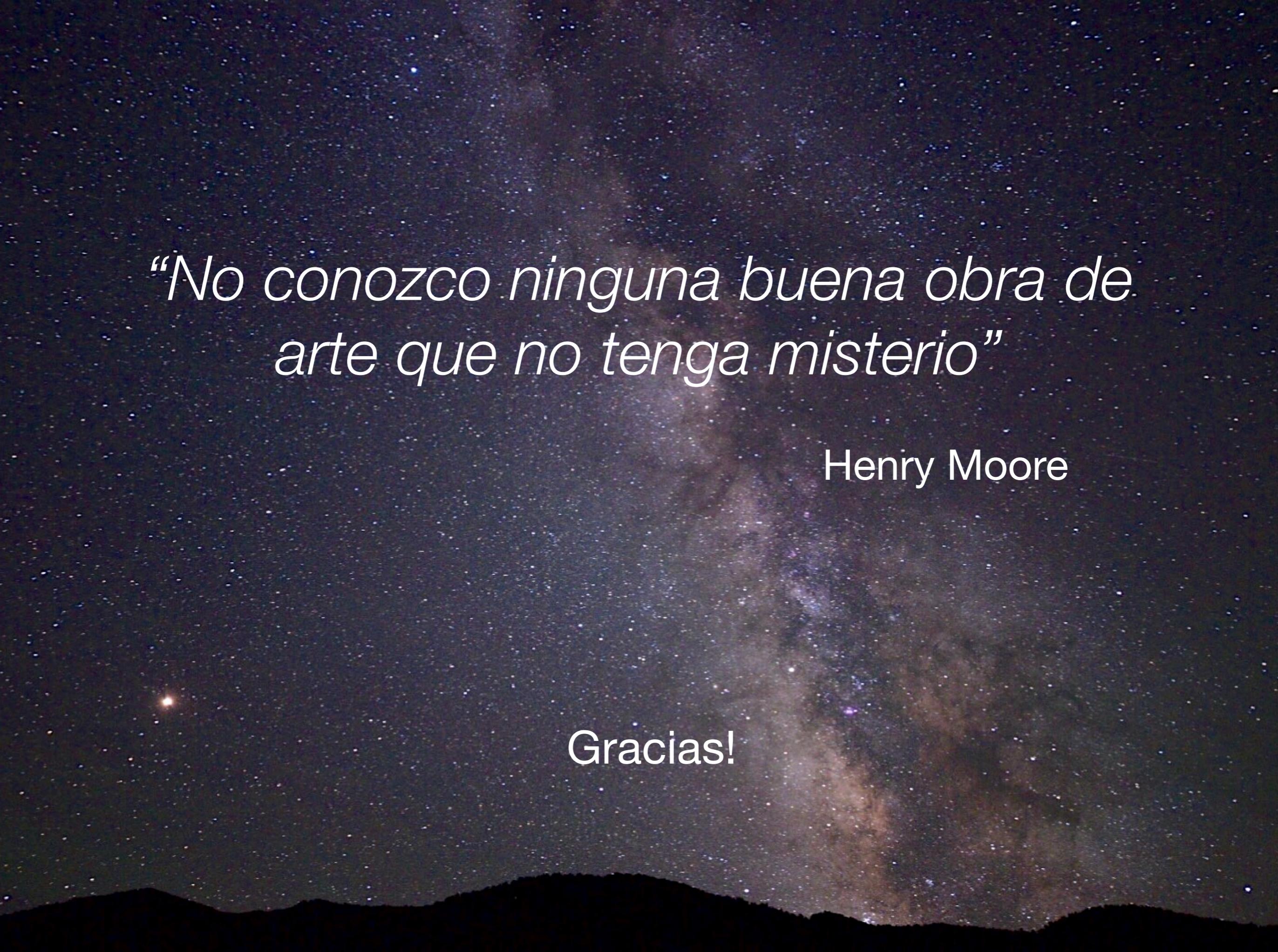


# Buscando y estudiando a la materia oscura



# Buscando y estudiando a la materia oscura





*“No conozco ninguna buena obra de arte que no tenga misterio”*

Henry Moore

Gracias!