

materia oscura

Astronomia & Cosmologia

Paolo Cremonese | 30/11/2022

overview

○ introduzione

- cos'è la cosmologia?

○ ne abbiamo bisogno?

- strutture
- galassie
- Bullet cluster

○ osservazioni

- machos
- wimps
- ???

○ what if...?

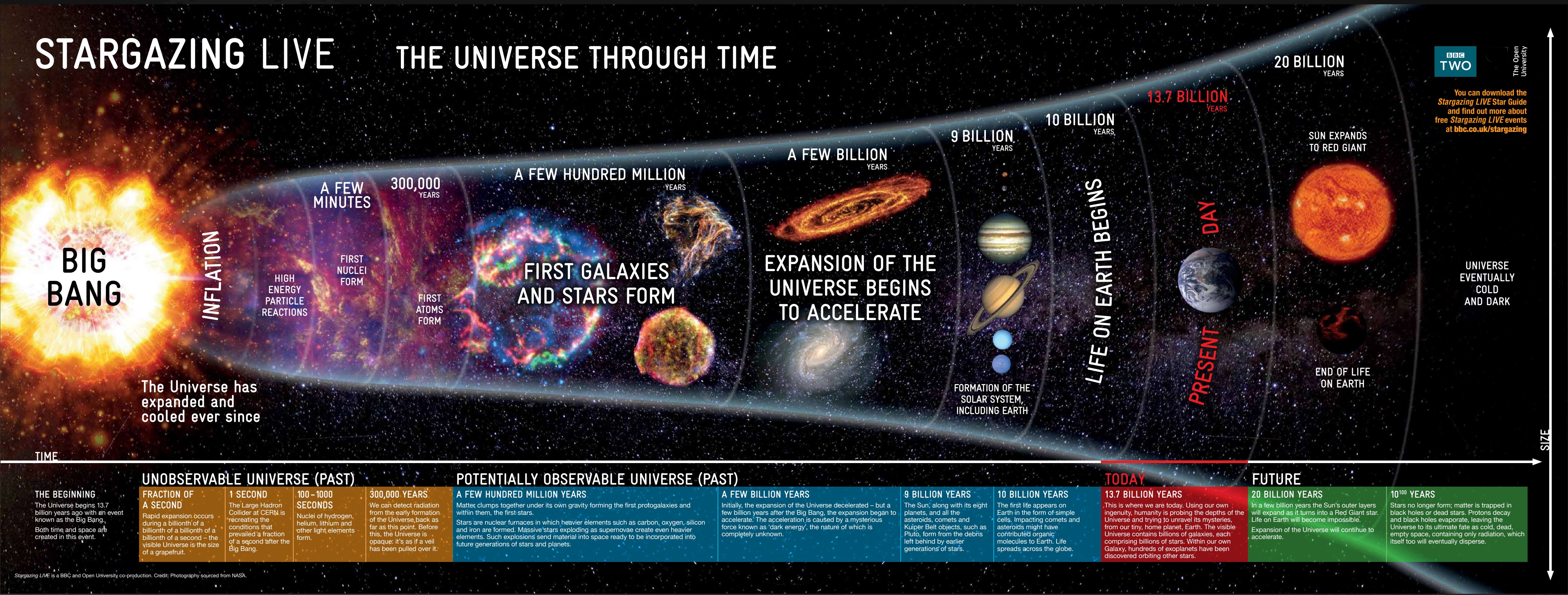
- teorie della gravità modificata

introduzione

Cosmologia

Cos'è?

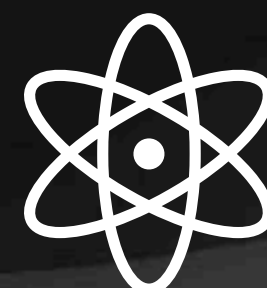

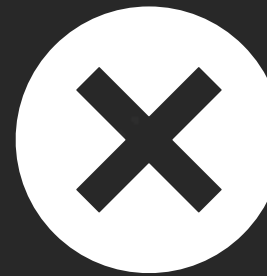
STARGAZING LIVE THE UNIVERSE THROUGH TIME



Stargazing LIVE is a BBC and Open University co-production. Credit: Photography sourced from NASA.

Cosmologia

Modello cosmologico Λ CDM

- ▶ Materia “normale” (5 %) 
- ▶ CDM (27 %) 
- ▶ Λ (68 %) 

ne abbiamo (davvero) bisogno?

#1 strutture

Λ CDM

► universo ha strutture



► CDM (27 %)

[e.g. [Liddle & Lyth 93](#)]

► è in espansione accelerata



► Λ (68 %)

[e.g. [Sahni & Starobinsky 99](#)]

#1 struttura

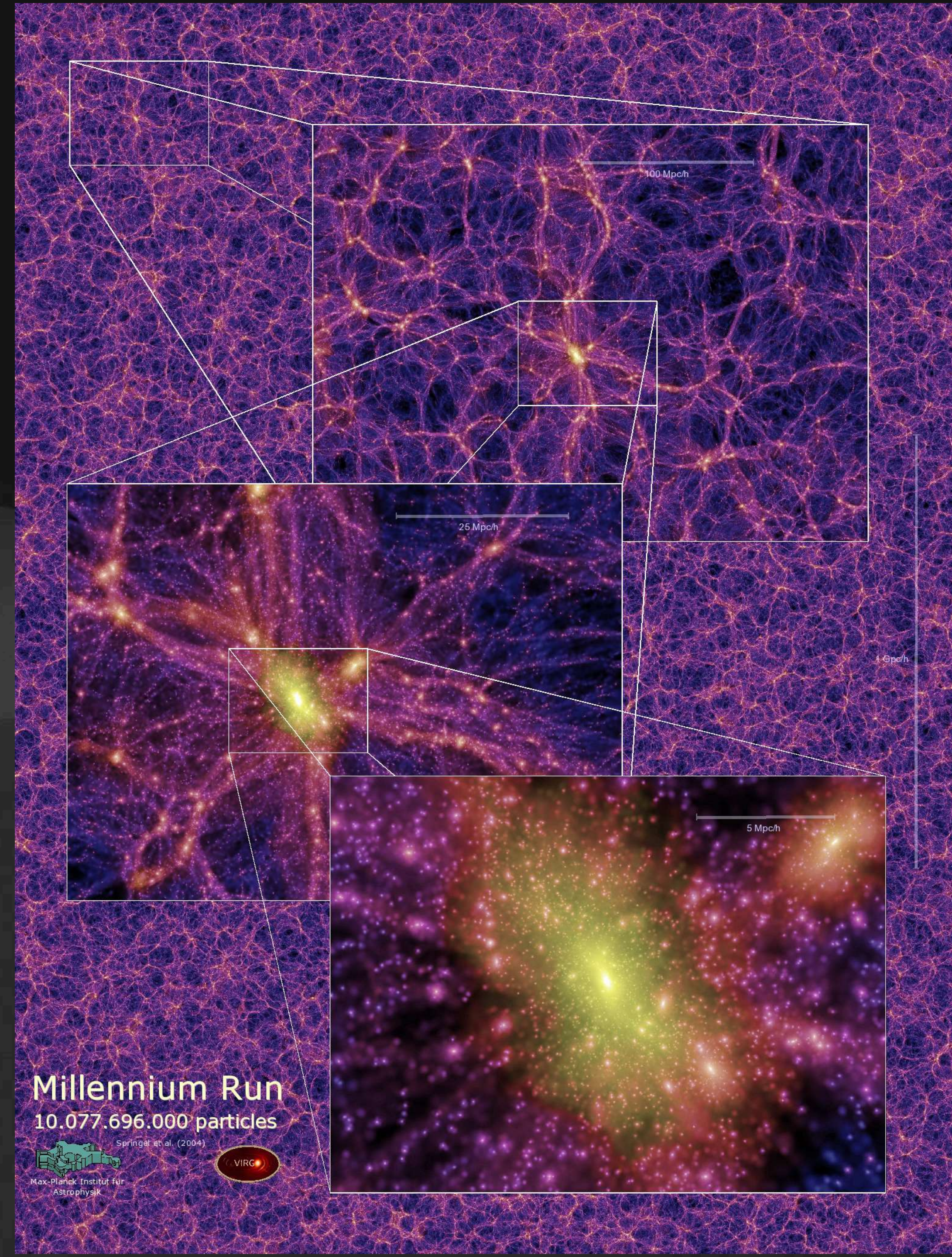
Λ CDM

- universo ha
strutture



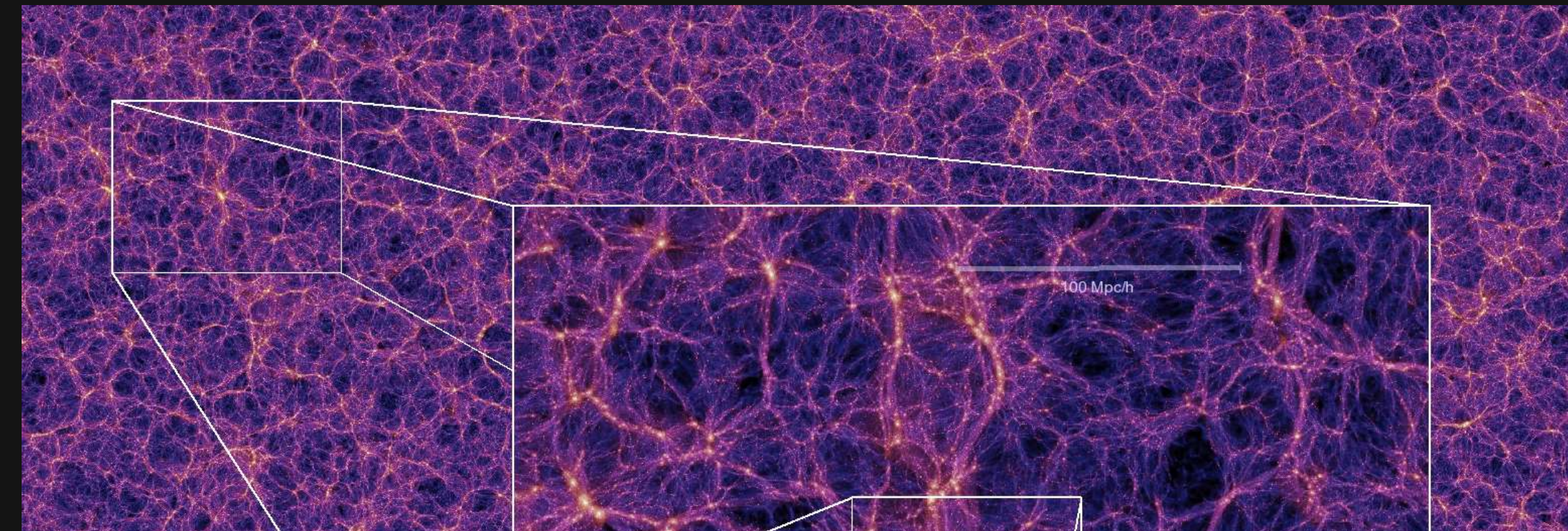
- CDM (27 %)

[e.g. [Liddle & Lyth 93](#)]



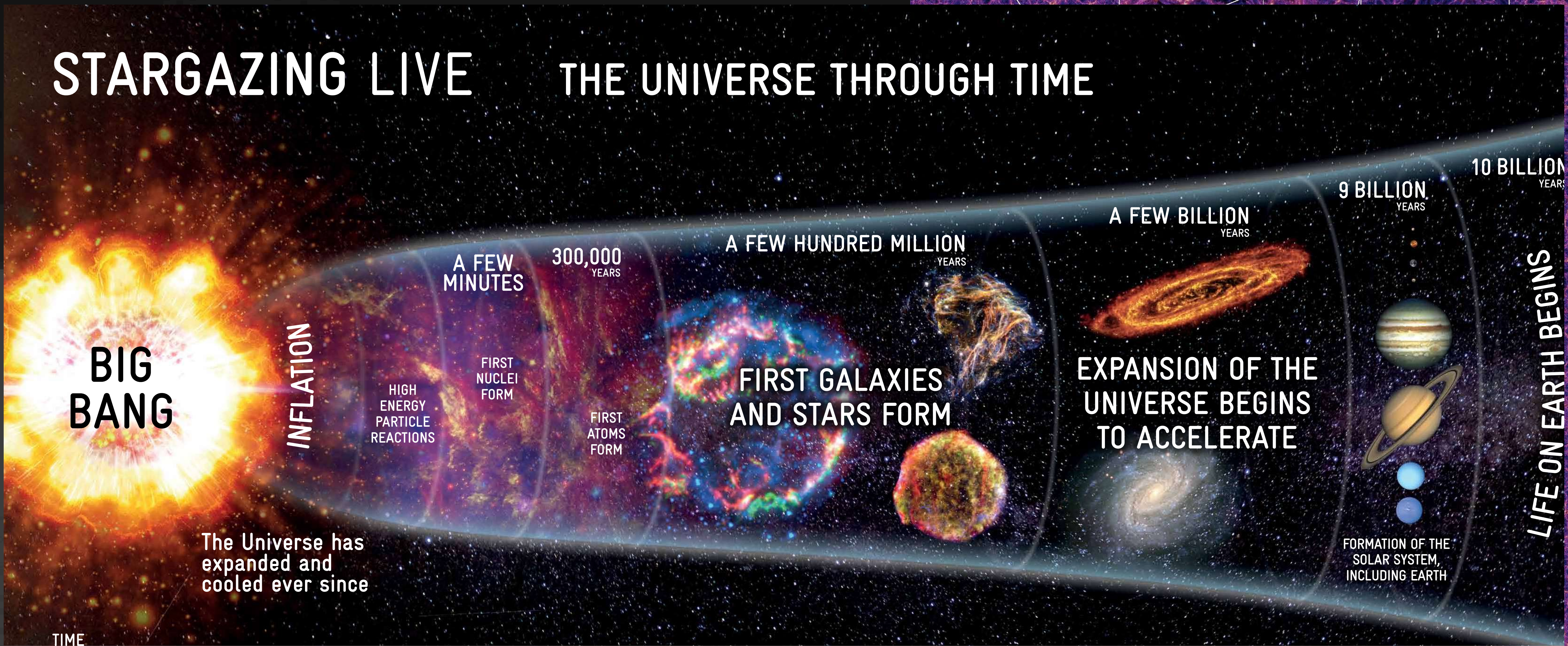
#1 structure

Λ CDM

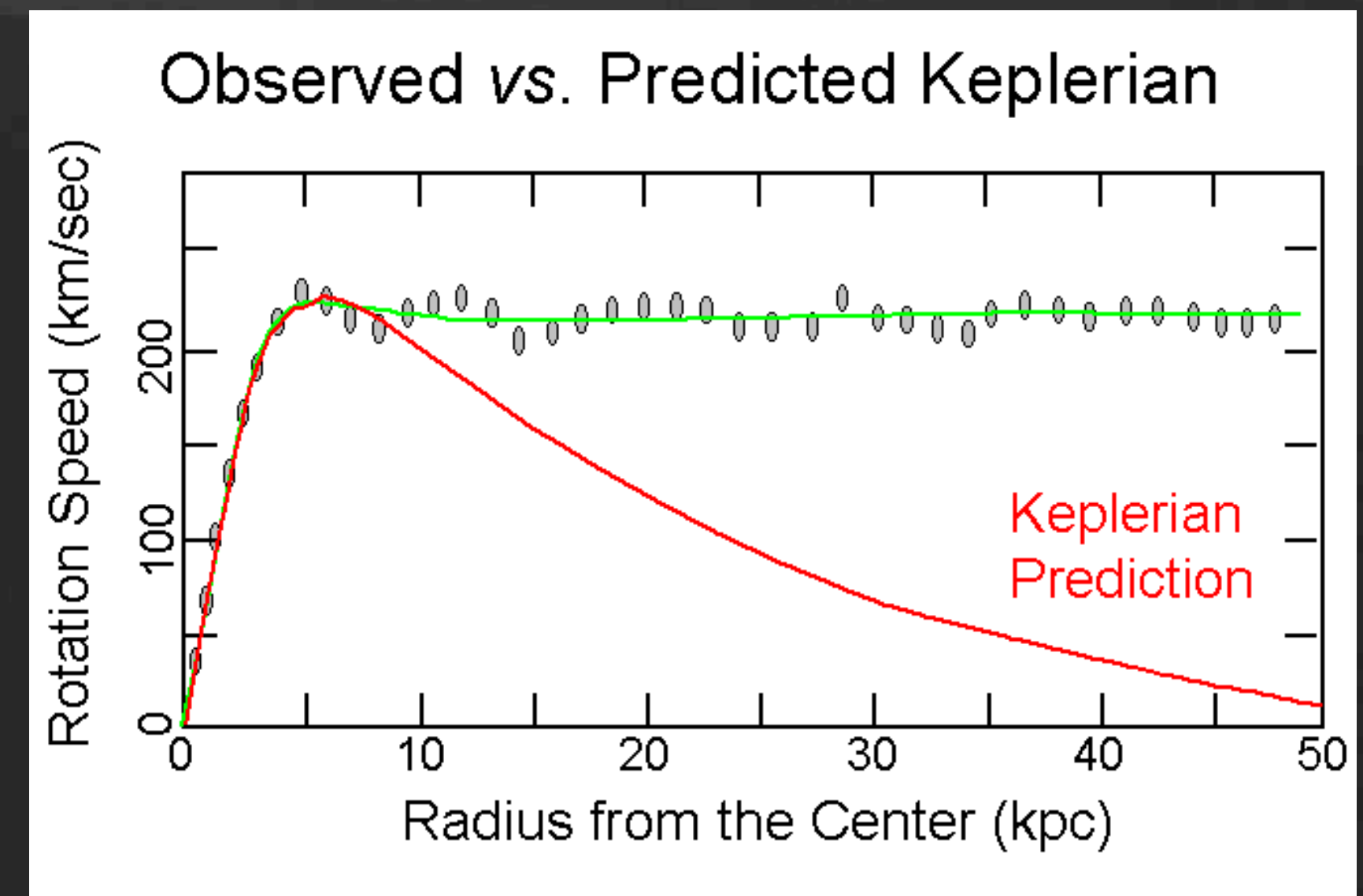
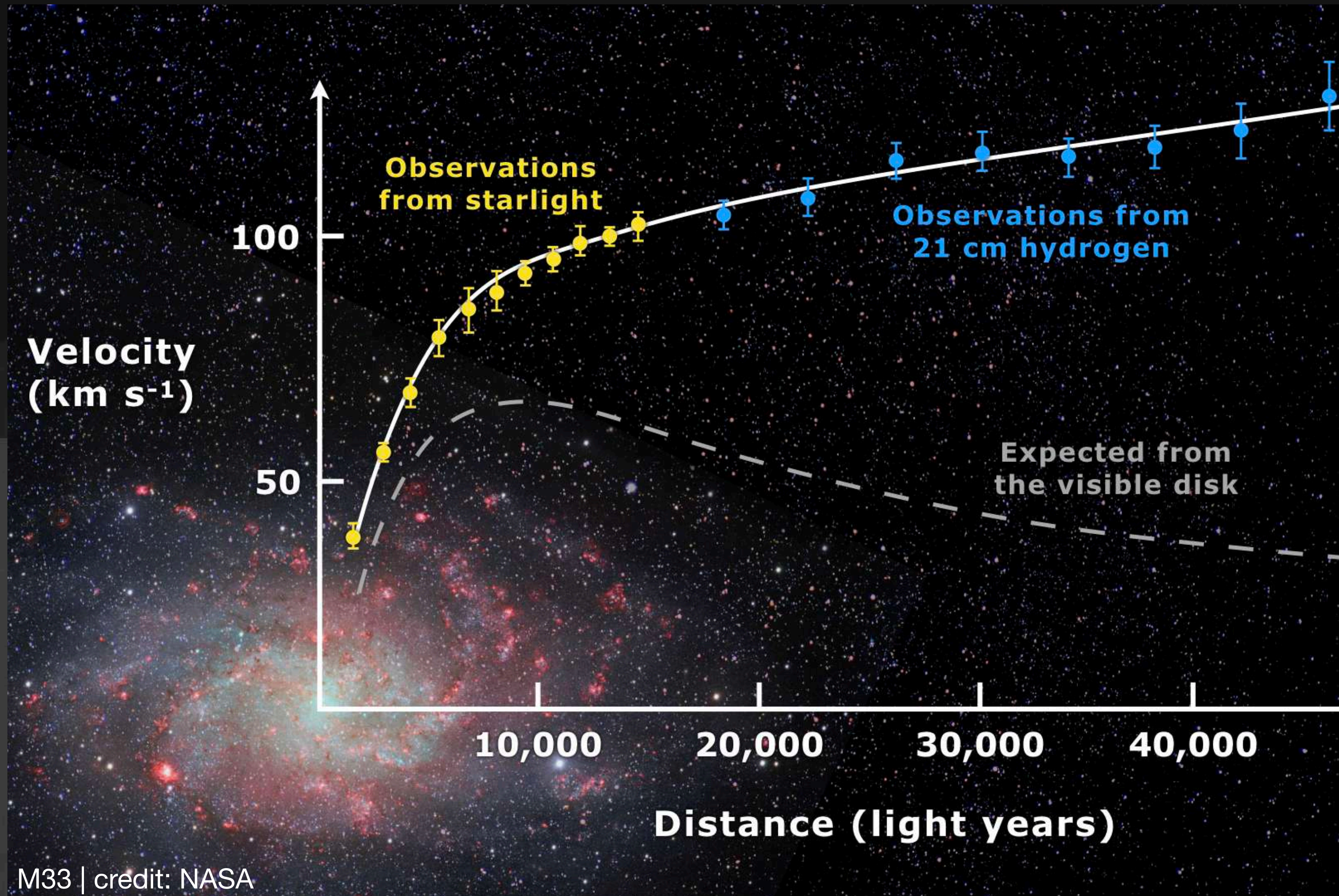


STARGAZING LIVE

THE UNIVERSE THROUGH TIME



#2 Galassie a Spirale



#3 Bullet Cluster

1E 0657-56

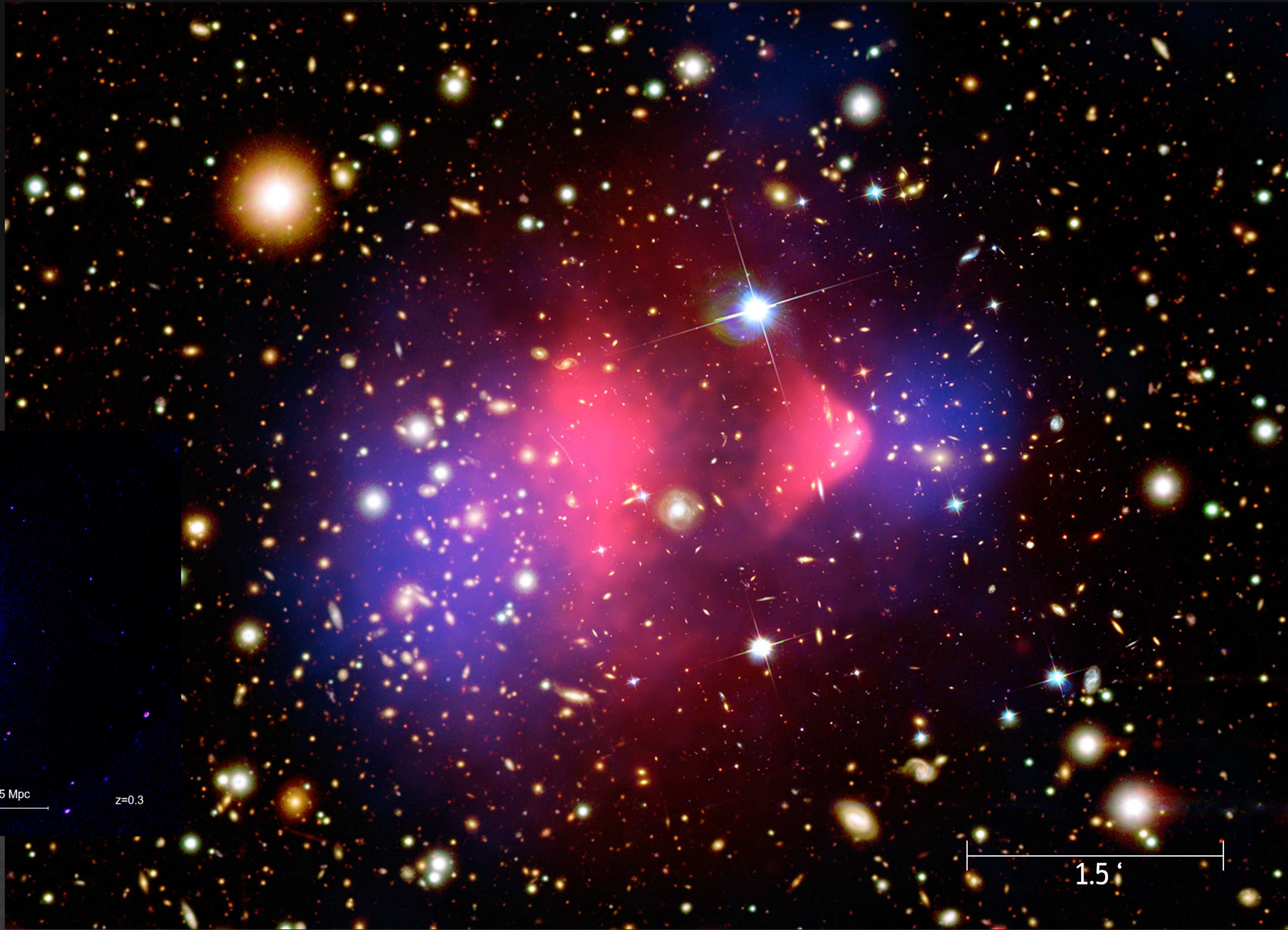
Chandra 0.5 Msec image

0.5 Mpc

$z=0.3$

credit: NASA

1.5'



“osservazioni”

osservazioni

cosa

- ▶ Assioni

$$10^{-21} < p_{DM} < 1 \text{ eV}$$

- ▶ WIMPS - Weakly Interactive Massive Particle

$$1 < p_{DM} < 10^{28} \text{ eV}$$

- ▶ MACHOS - Massive Compact Halos Objects

$$10^{28} \text{ eV} < p_{DM} \lesssim 1 \text{ M}_{\odot}$$

osservazioni come

▸ Indiretta: osservatori

- telescopi (x-ray)
- Super Kamiokande
- iceCube

▸ Diretta:

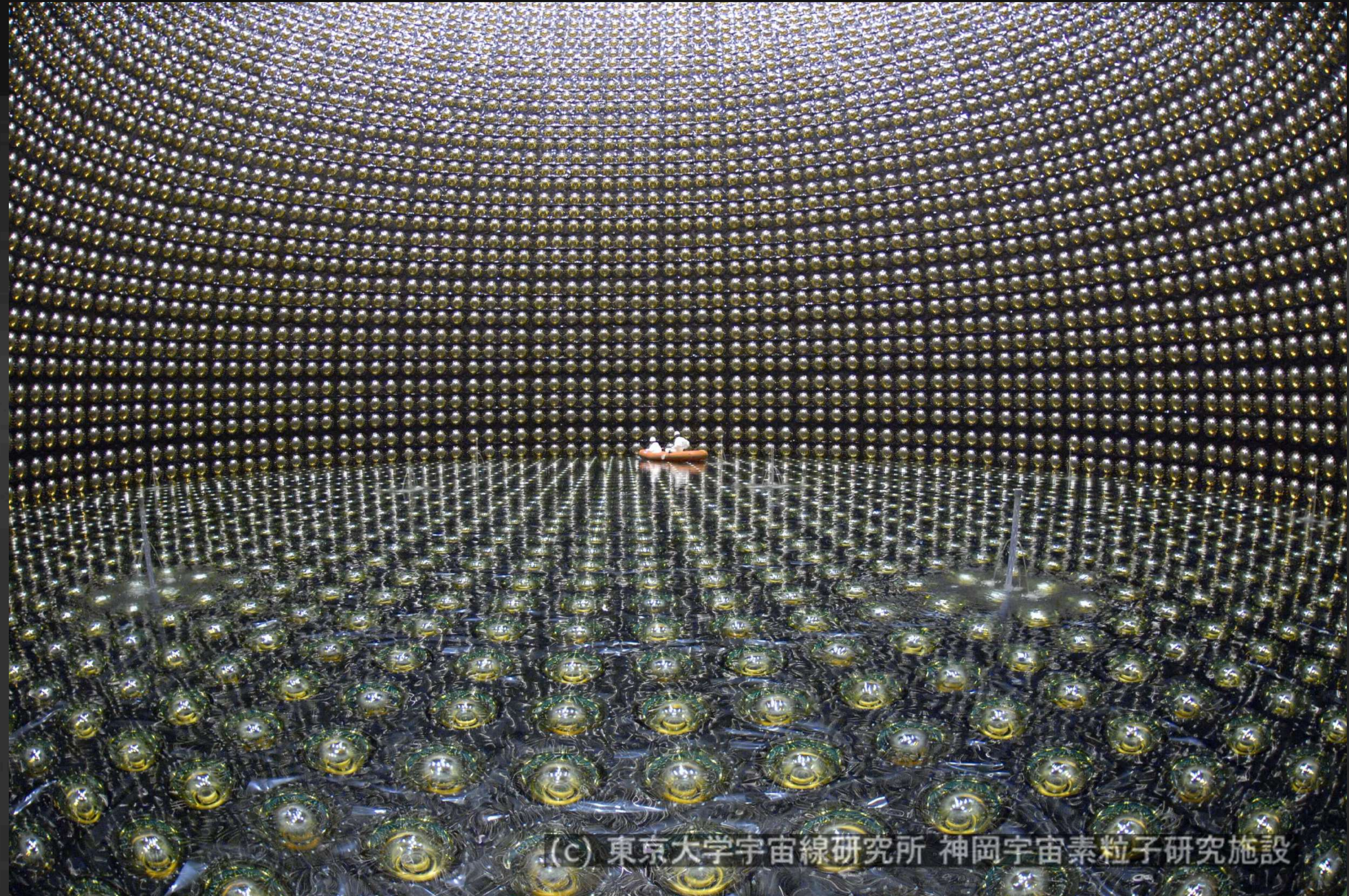
- LHC
- Crystal scintillators
- Axion Dark Matter Experiment

osservazioni indirette

- ▶ Indiretta: osservatori
 - telescopi (x-ray)
 - Super Kamiokande
 - iceCube
- ▶ modi
 - annichilazione
 - decadimento

osservazioni indirette

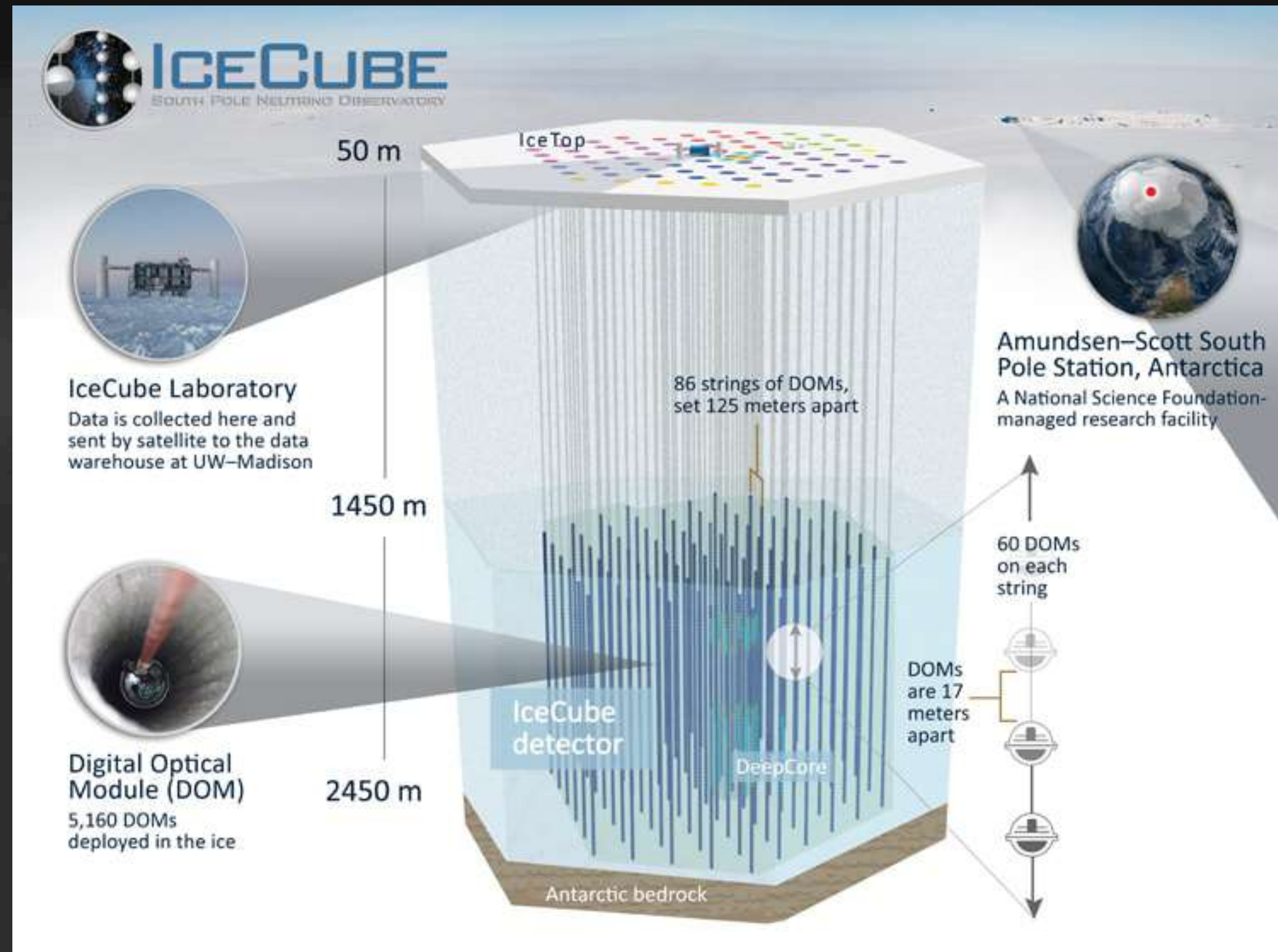
- ▶ Indiretta: osservatori
 - telescopi (x-ray)
 - Super Kamiokande
 - iceCube



(c) 東京大学宇宙線研究所 神岡宇宙素粒子研究施設

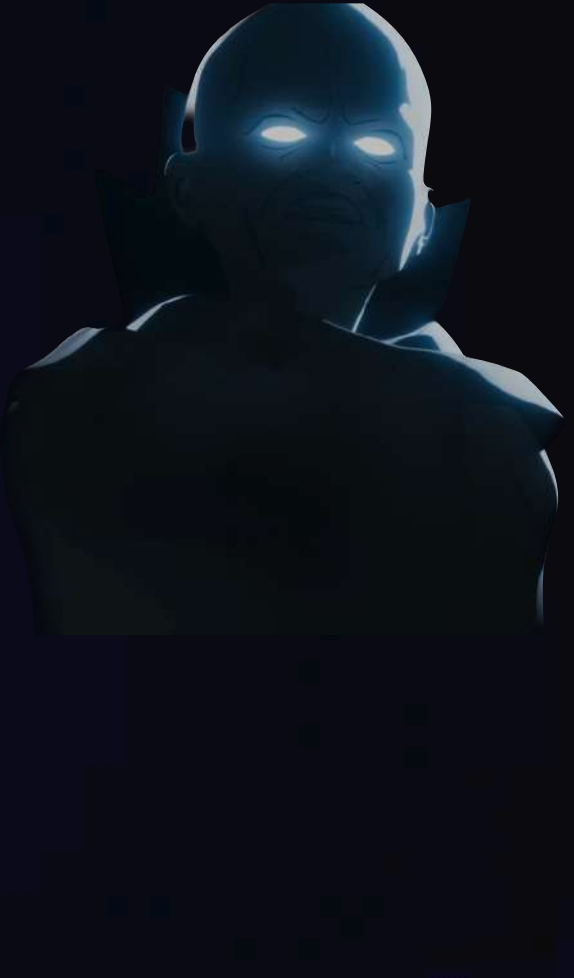
osservazioni indirette

- ▶ Indiretta: osservatori
 - telescopi (x-ray)
 - Super Kamiokande
 - iceCube



osservazioni dirette

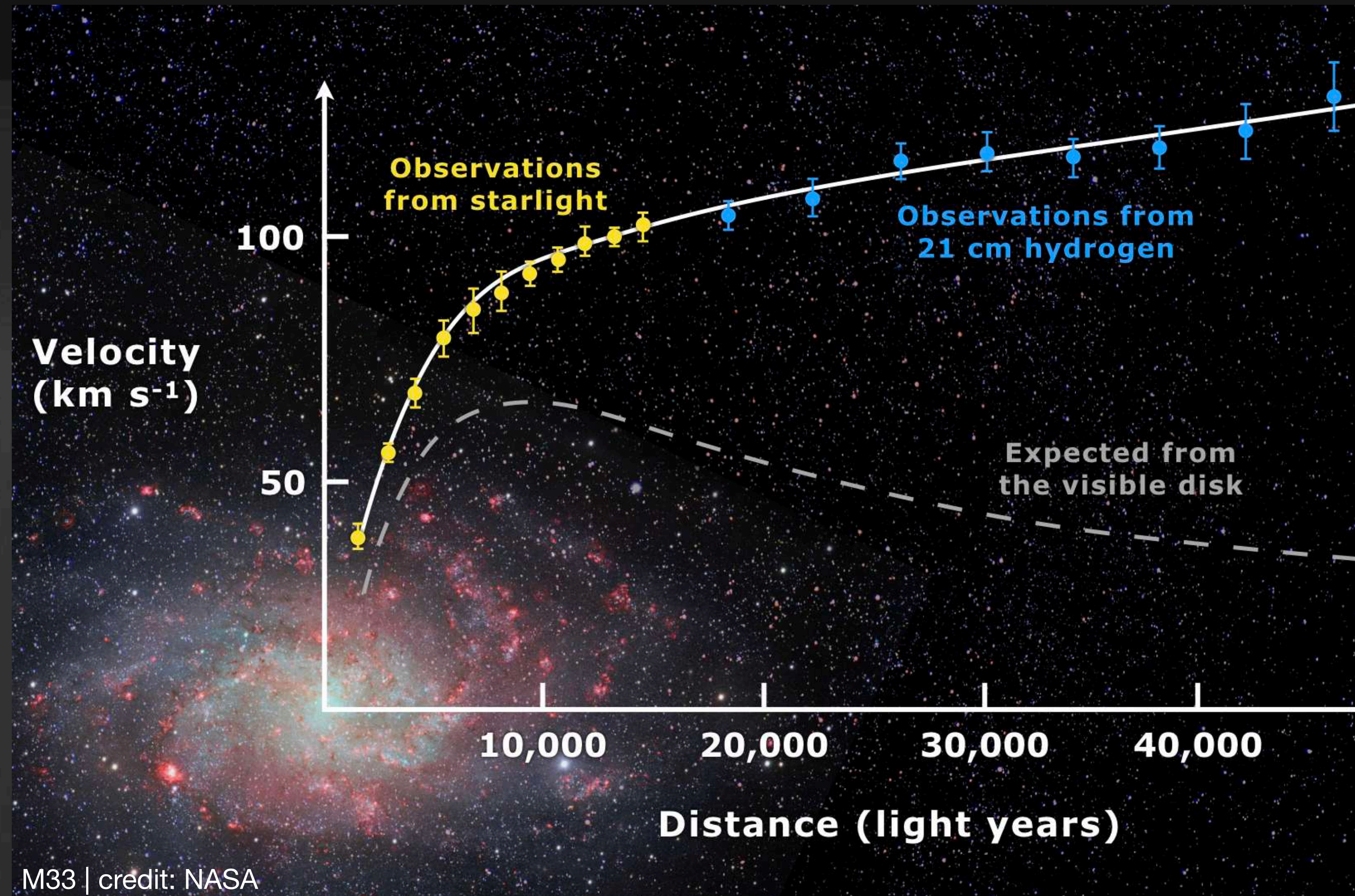
- ▶ Diretta:
 - LHC
 - Crystal scintillators
 - Axion Dark Matter Experiment
- ▶ modi
 - “osservazione” interazione
 - interazione DM con osservatori



what if...?

teorie della gravità modificata

- **MOND**
Modified Newtonian Dynamics



extras

extras

- ▶ Galassie senza materia oscura?? <https://www.nature.com/articles/d41586-022-01410-x>

- ▶ $\frac{H^2}{H_0^2} = \Omega_{0,R}a^{-4} + \Omega_{0,M}a^{-3} + \Omega_{0,k}a^{-2} + \Omega_{0,\Lambda}$ - 1st Friedmann eq

- ▶ $R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} (+\Lambda g_{\mu\nu}) = \kappa T_{\mu\nu}$ - Einstein field equations