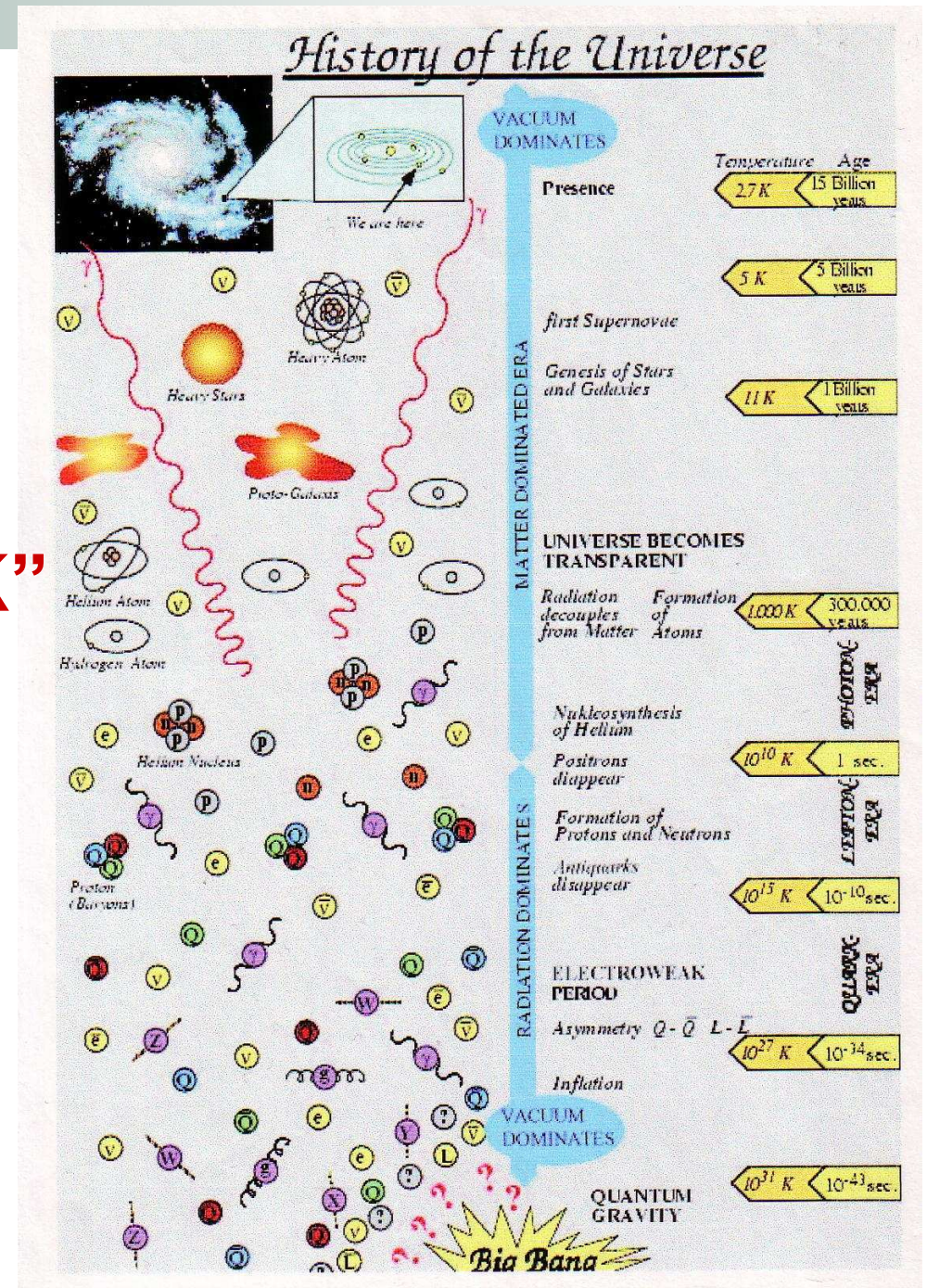


FIZIKALNA

KOZMOLOGIJA

XII. REZIME NAŠE "FK" KOZMOLOŠKE TURE





PITANJA S KOJIMA SMO POČELI OVAJ KOLEGIJ:

- **Starost, veličina i geometrija svemira?**
- **Kakav je početak i kraj svemira?**
- **Kakav je sastav svemira?**
- **Nastanak tvari i opaženih struktura?**

DANAŠNJE RAZUMIJEVANJE POVIJESTI SVEMIRA

(de Vega, astro-ph/0307477)

Od rane inflatorne ere

Time	Energy Scale 1 GeV = $1.16 \cdot 10^{13}$ K	Physical Phenomena	Era $1 + z = a(\text{today})/a(t)$ Scale Factor $a(t)$
$\sim 10^{-44}$ sec.	$\sim 10^{19}$ GeV	Quantum Gravity String Theory Inflation starts	$z > 10^{26+20} = 10^{46}$ $a(t) \sim e^{Ht}$ Inflationary Era
$\sim 10^{-30}$ sec.	$\sim 10^{12}$ GeV	Inflation Ends and	$z \sim 10^{20}$

preko stvaranja čestica i lakih elemenata

$\sim 10^{-10}$ sec.	$\sim 10^3$ GeV	Particle Creation Starts Reheating Transition GUT Phase Transition Hot Big Bang: Thermalization	$a(t) \sim \sqrt{t}$
	$\sim 10^2$ GeV	Electro-Weak Phase Transition Baryon Asymmetry Originates? Baryogenesis	Radiation Dominated
$\sim 10^{-4}$ sec. $\sim 10^{-2}$ sec.	~ 1 GeV ~ 0.1 GeV	Quark-hadron and Chiral Phase Transitions $\gamma, \nu, e, \bar{e}, n, p$ in thermal equilibrium	Era
1sec.	~ 1 MeV	Neutrinos decouple	
100sec.	~ 0.1 MeV	Nucleosynthesis Creation of Light Elements	$z \sim 10^4$

do stvaranja opaženih struktura

20000 years		Structure Formation Begins Onset of Gravitational Unstability	$a(t) \sim t^{2/3}$
10^5 years		Atoms Form	$z \sim 10^3$
		Photon Decoupling The Universe Becomes Transparent	Matter Dominated Era
10^9 years	first bound structures	Galaxy Formation	
		Solar system formation	Cold matter dominates but dark energy...
$1.4 \cdot 10^{10}$ years	$\sim 10^{-4} \text{eV}$	Today	$z = 1$



PITANJA VEZANA UZ RANU INFLATORNU ERU:

- **Što je pogonilo inflaciju i kako je ona završila?**
- **Priroda tamne energije i kako se mijenja u prostoru i vremenu?**
- **Priroda tamne tvari i njen utjecaj na evoluciju struktura u svemiru?**

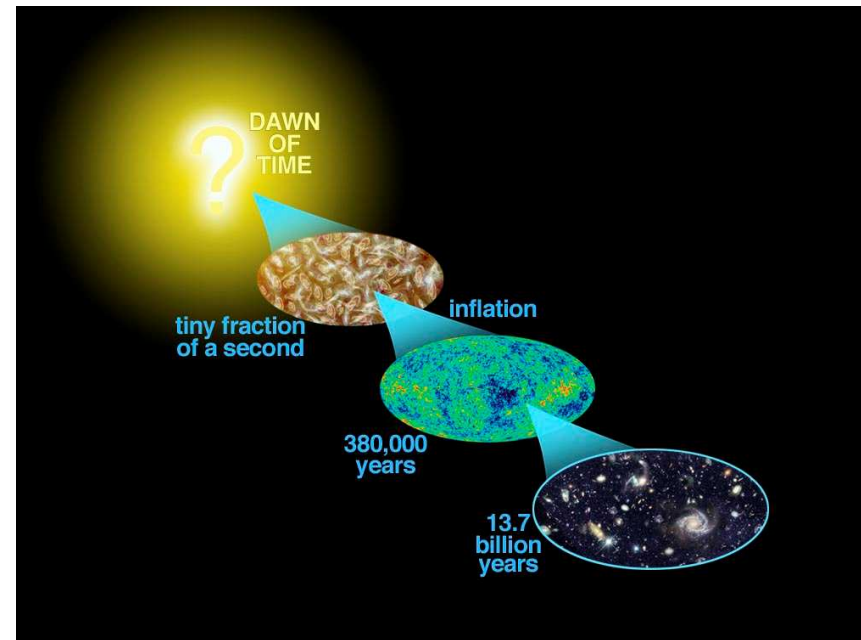
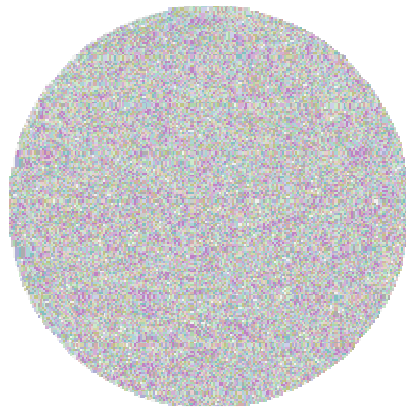


“FOSILI” KOJI NAM MOGU NEŠTO REĆI O INFLACIJI:

- **Perturbacija gustoća**
 - generira anizotropije CMBa putem Sachs-Wolfe efekta
 - ravni spektar fluktuacija potreban za formiranje galaktika (Harrison-Zeldovich)
- **Gravitacijski valovi**

Seminari

**Da bismo razumjeli “najveće”,
moramo poznavati “najmanje”**



**ASTRONOMSKI SVIJET KAO PRESLIKA
KVANTNOG SVIJETA RANOG SVEMIRA**

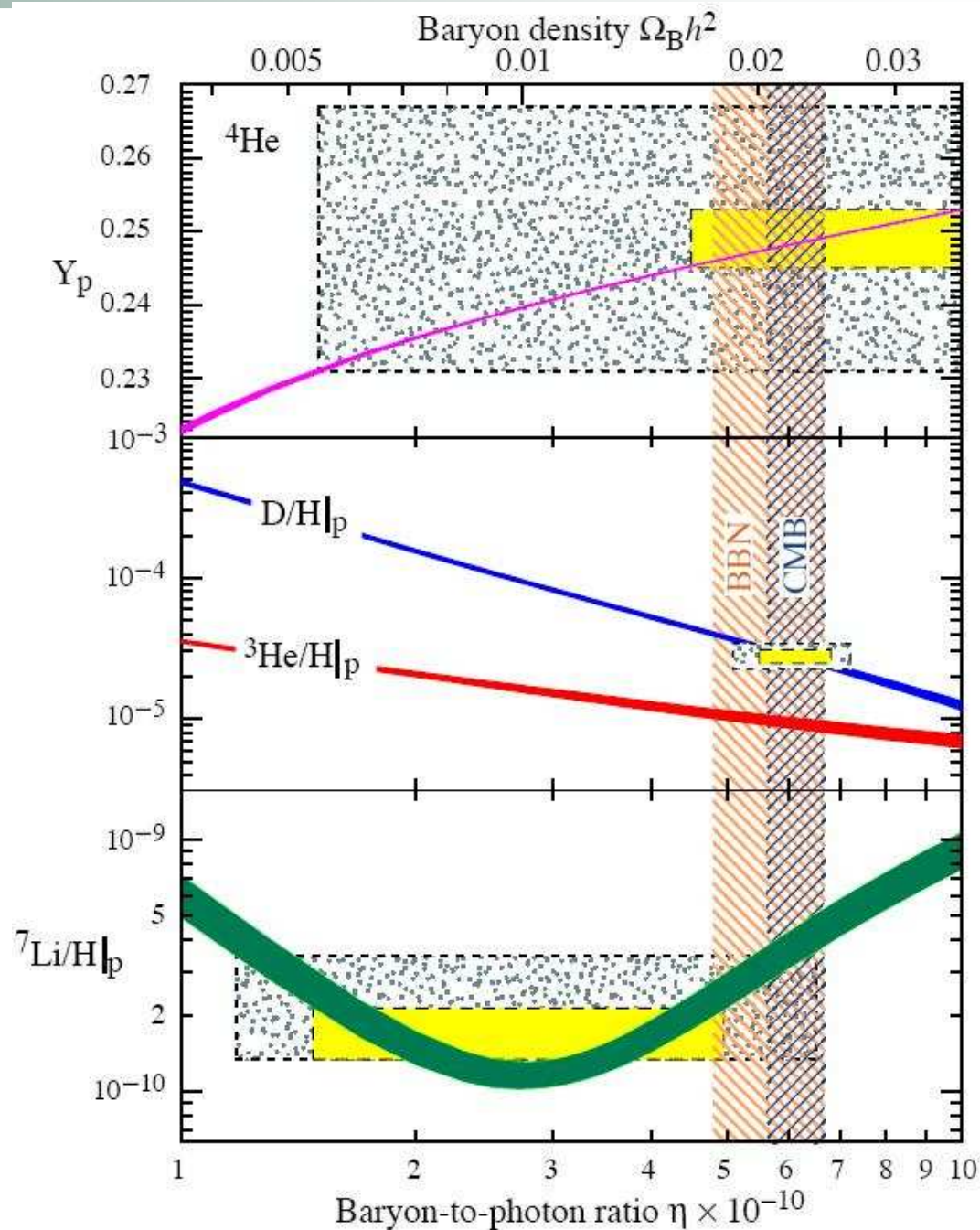


“ORIJENTIRI” KROZ KOJE PROLAZI SVEMIR NAKON PERIODA INFLACIJE:

- **Bariogeneza;**
- **Elektroslabi fazni prijelaz;**
- **QCD fazni prijelaz;**
- **Epoha zamrzavanja tamne tvari
(odvezivanje tamne tvari od plazme)**
- **Odvezivanje neutrina... nukleosinteza**

KOLIČINE PRVOTNO STVORENIH LAKIH ELEMENTATA

Seminar



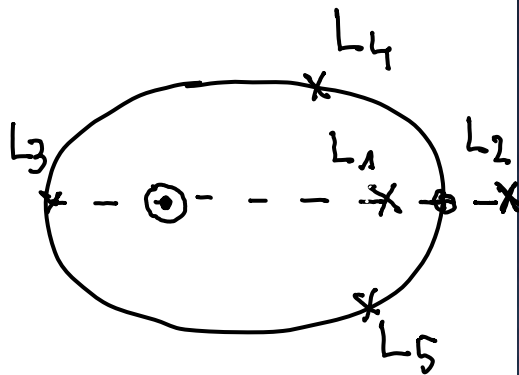


VIDLJIVI SVEMIR NAKON REKOMBINACIJE (predmet opažачke kozmologije) :

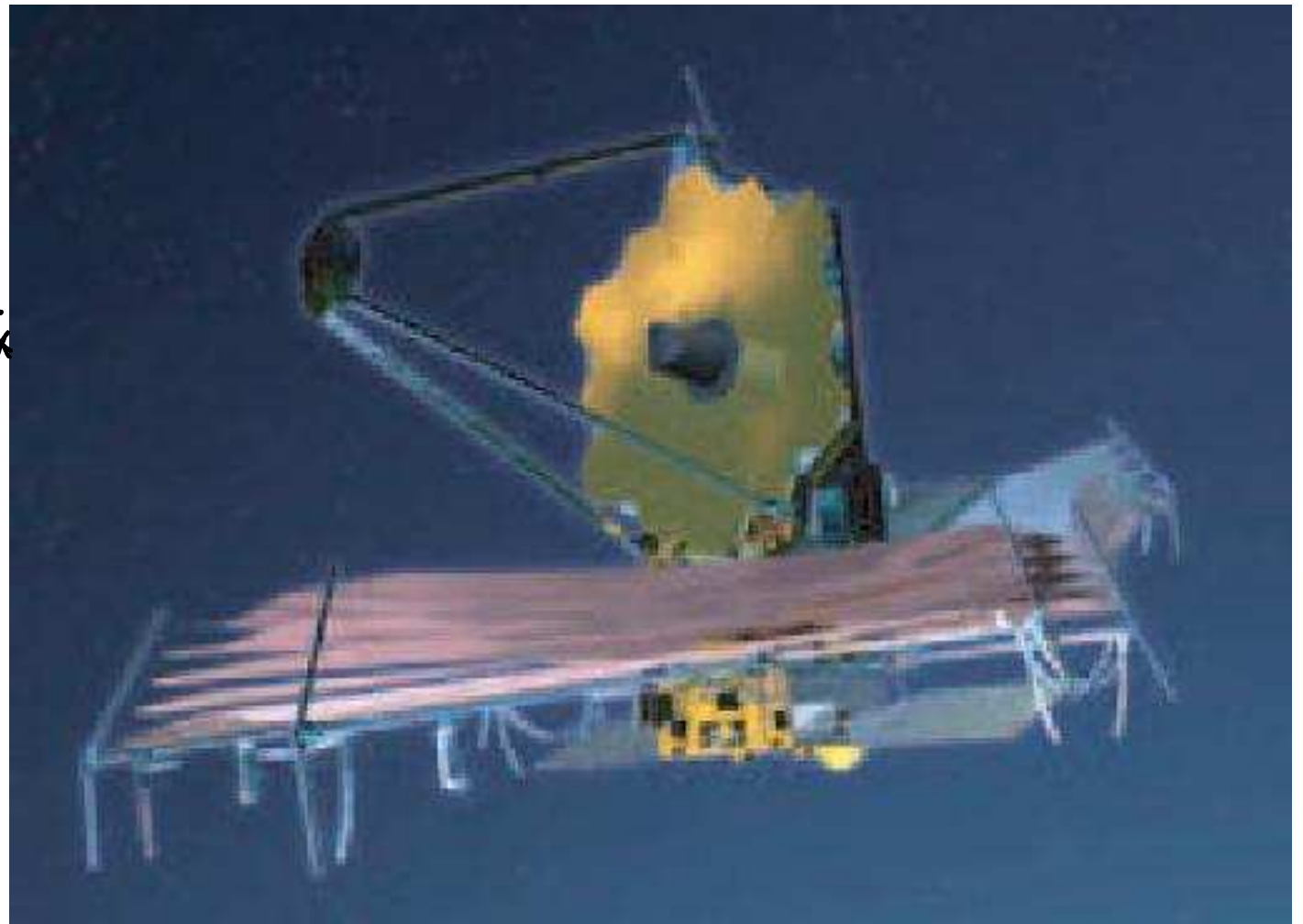
- Dostupna nam je “fotografija” iz ere rekombinacije (CMB),
- “Siva zona” između miliona i milijarde godina – **izučavanje neutralnog vodika (relikta rekombinacije) putem 21 cm linije**

JWST & GMT teleskopi (Loeb, astro-ph/0603360)

**JWST (James Webb Space Telescope) na 0.6-28 μm ,
NASA 2011 (www.jwst.nasa.gov) u 1.5 Mkm L2 točki**



L_2 WMAP
JWST



**GNT (Giant Magellan Telescope) promjera 8.4 m
(www.gmto.org) za opažanje 1. generacije galaktika**

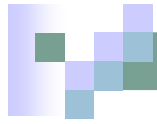




TAMNI SASTOJCI SVEMIRA

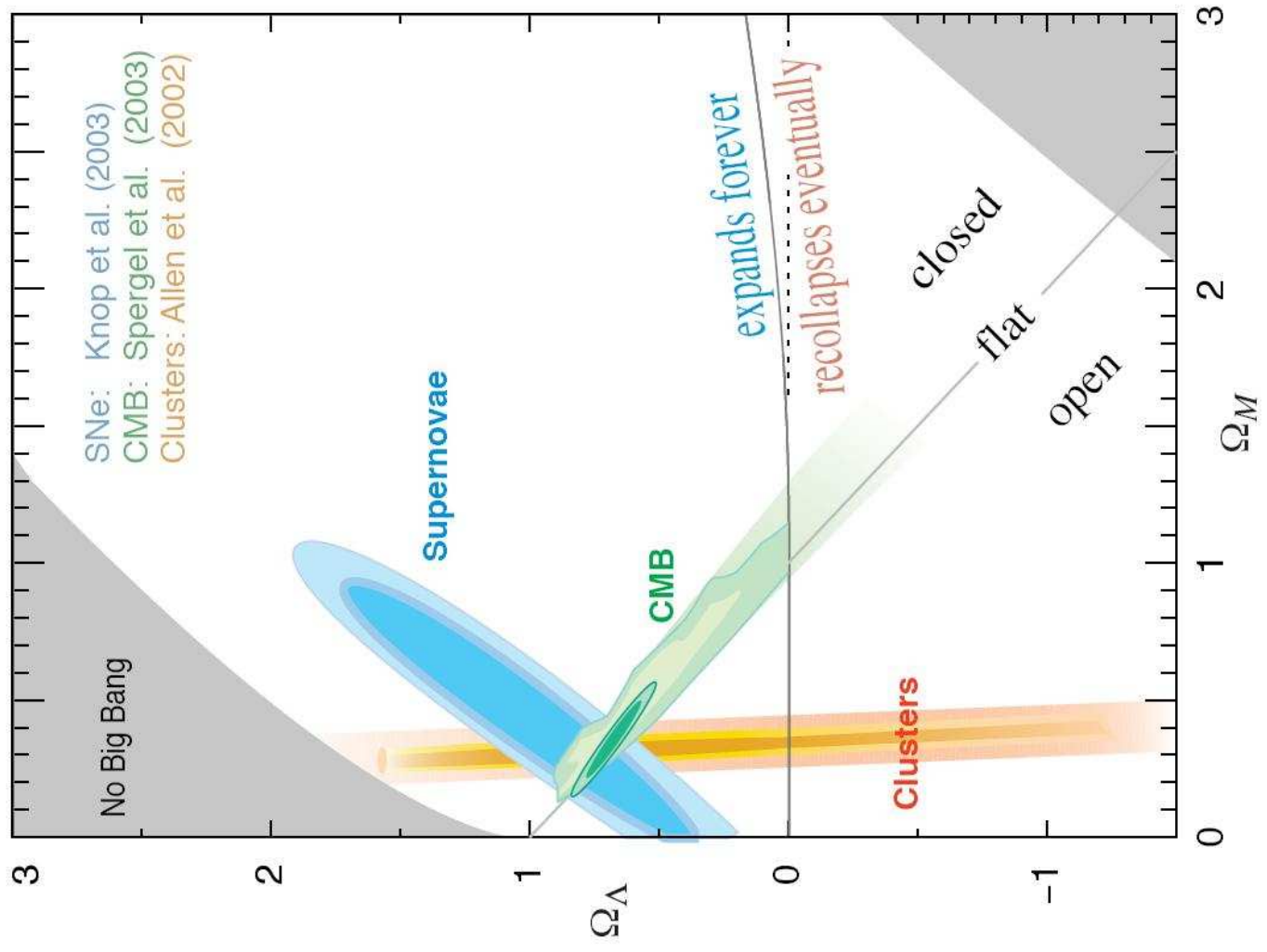
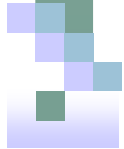
**(mogu se pratiti indirektno,
putem vidljivih sastojaka,
“tracers”):**

- **DM opažanjima u rendgenskom i vidljivom spektru**
- **Evolucija DE praćenjem SN Ia & “X-ray clustera” do $z=2$**

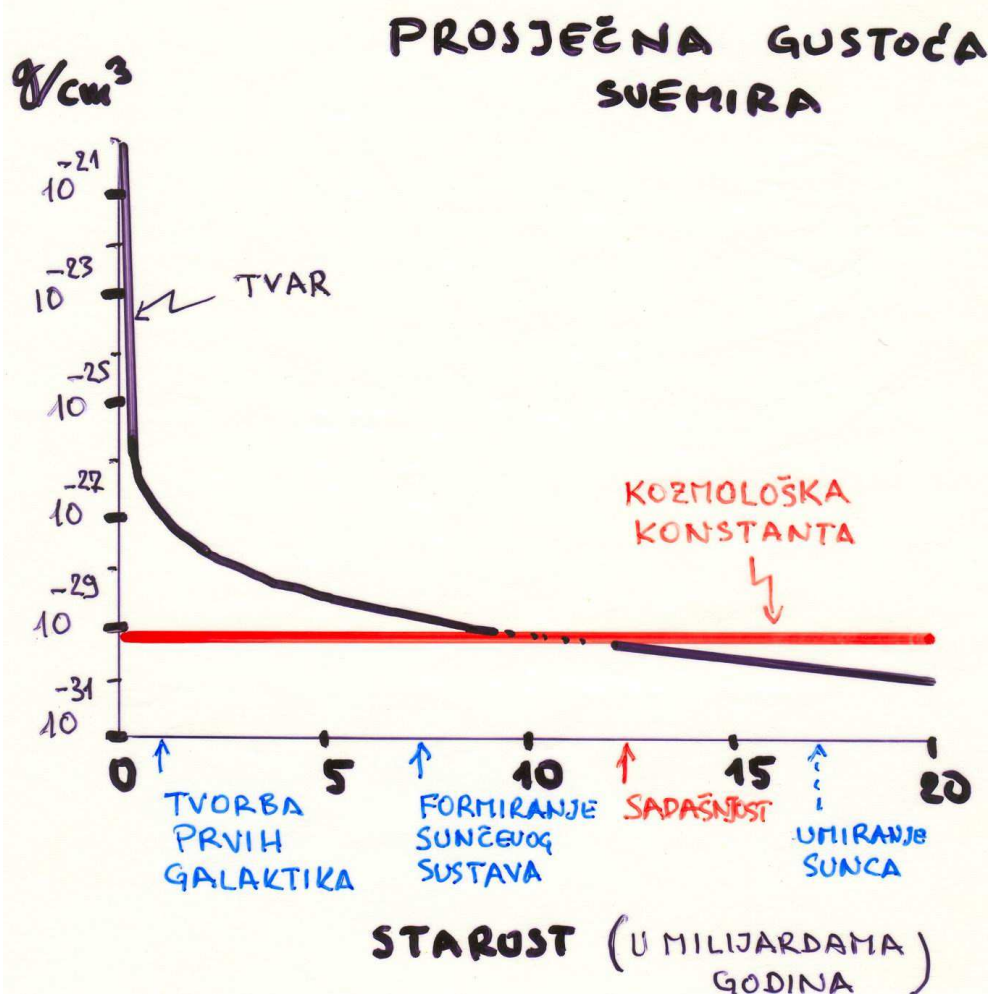


SPEKTAR PRVOTNIH FLUKTUACIJA U GUSTOĆI (na velikim skalama, preko 10 Mpc) :

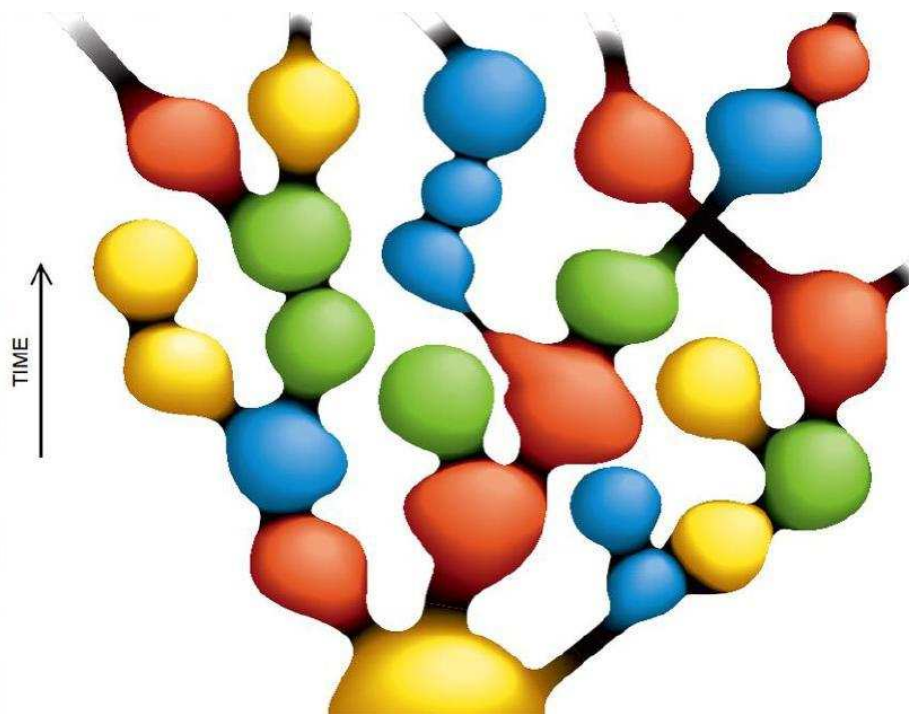
- **DM Poznat iz anizotropija CMBa, slabog fokusiranja i “Ly α šume”**



ERA KOZMIČKE KOINCIDENCIJE



MULTIVERSE?



INVENTAR KOZMIČKIH PARAMETARA

Hubble parameter	$h = 0.71^{+0.04}_{-0.03}$
Baryon density	$\Omega_B = 0.044 \pm 0.004$
Matter density	$\Omega_M = 0.27 \pm 0.04$
Dark energy density	$\Omega_\Lambda = 0.73 \pm 0.04$
Total energy density	$\Omega_{tot} = 1.02 \pm 0.02$
Neutrino density	$\Omega_\nu h^2 \leq 0.0076$ (95 % C.L.)
Dark energy equation of state	$w < -0.78$ (95 % C.L.)