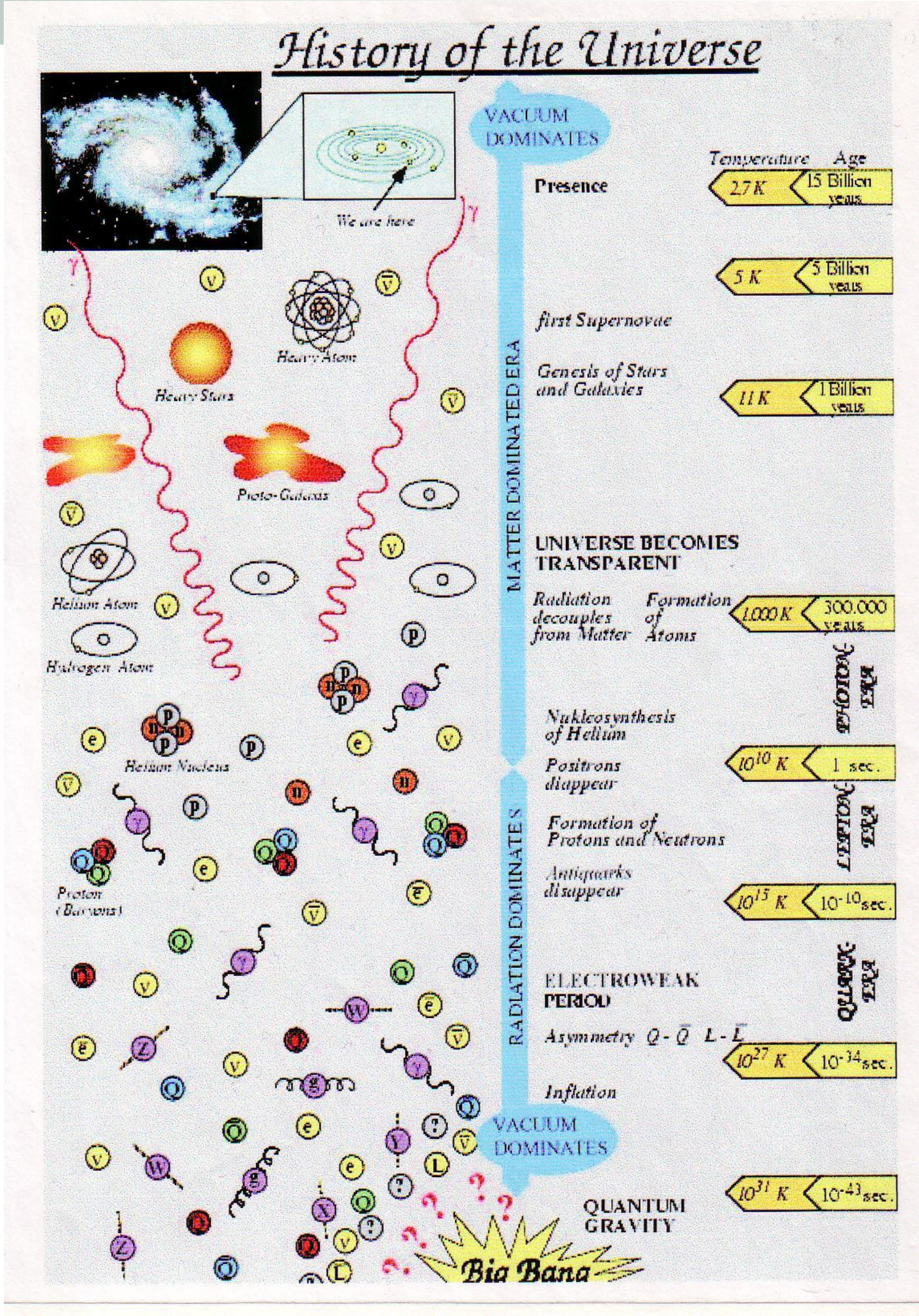
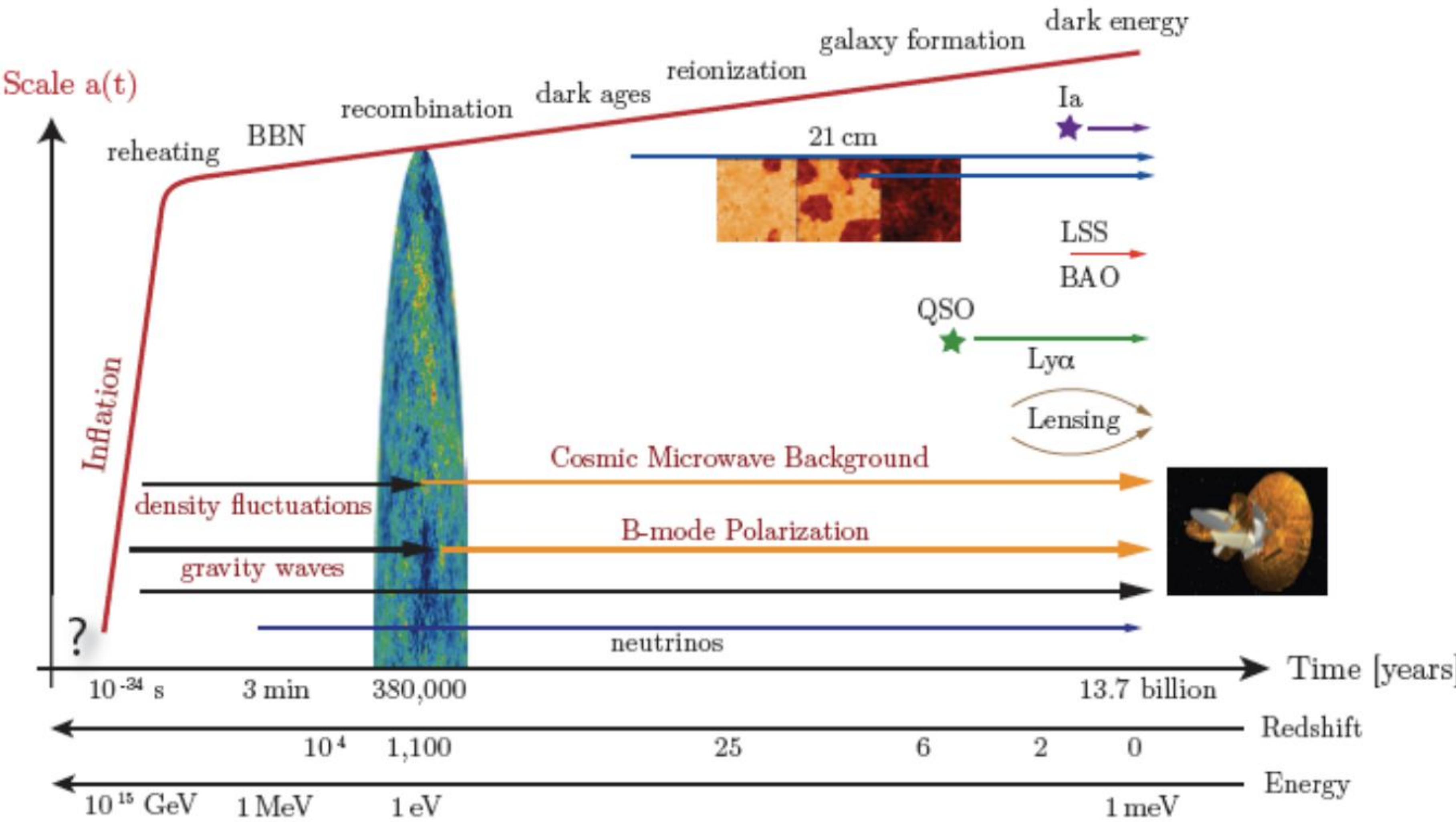
FIZIKALNA

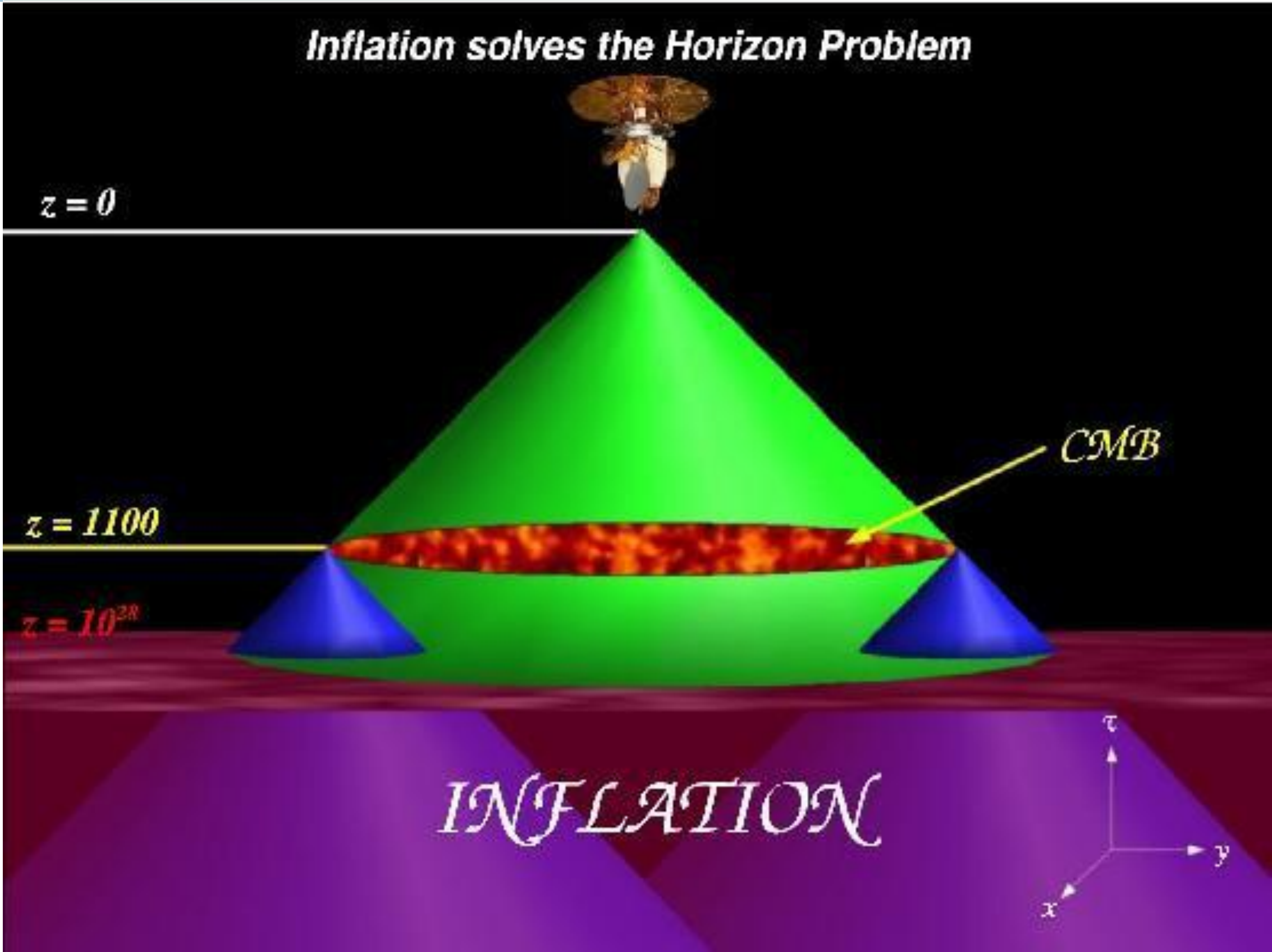
KOZMOLOGIJA

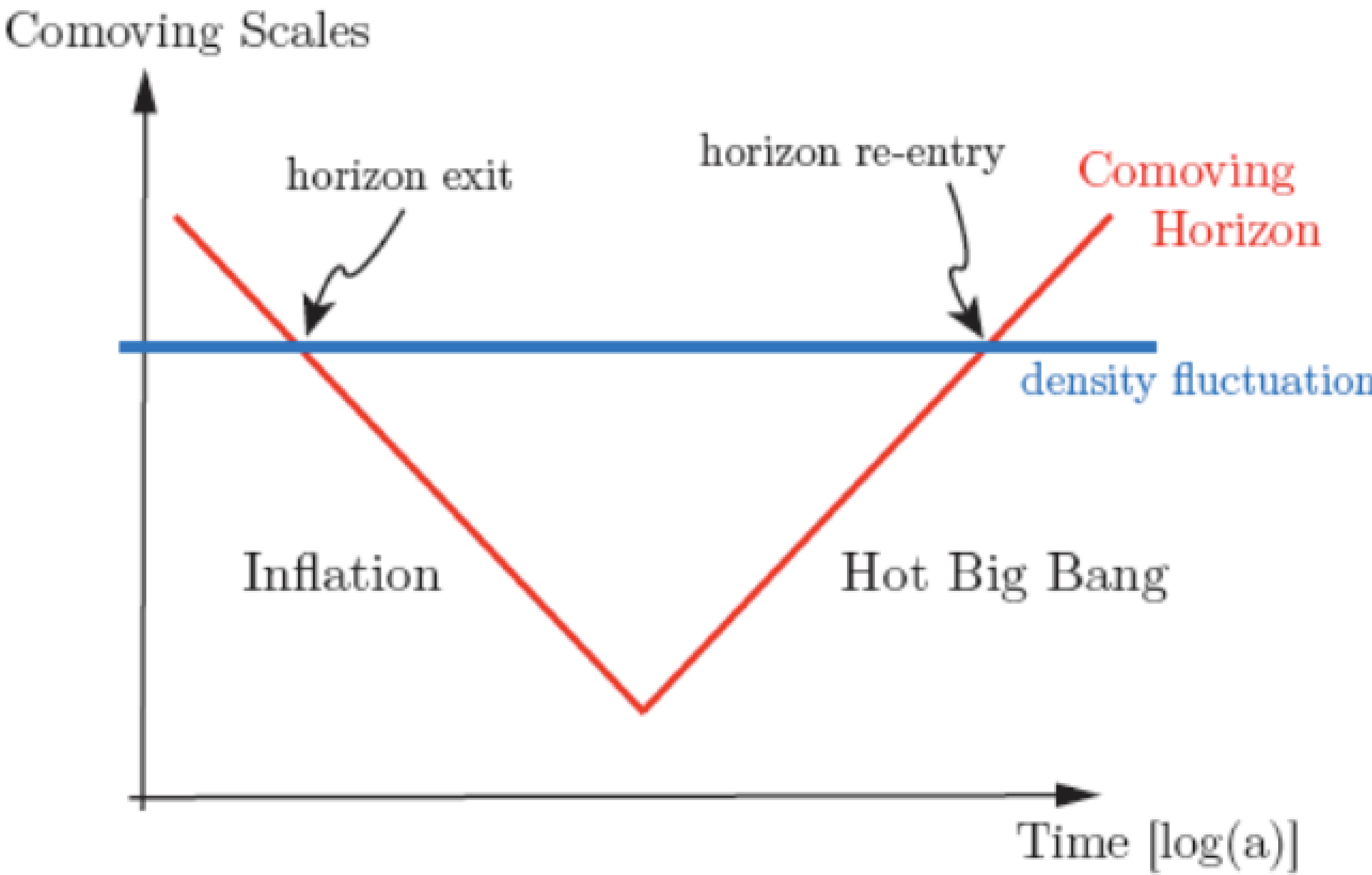
IX. INFLACIJA I SKALARNA POLJA U KOZMOLOGIJI



Prikaz POVIJESTI SVEMIRA




Inflation solves the Horizon Problem
z = 0
CMB
z = 1100
INFLATION


Comoving Scales
horizon exit
horizon re-entry
Comoving
Horizon
density fluctuation
Inflation
Hot Big Bang
Time [log(a)]

INFLACIJA rješava problem horizonta

during inflation the particle horizon grows exponential

$$R_H(t) = a(t)\int_{t_{\rm I}}^{t}\frac{dt'}{a(t')} = a_{\rm I}\, e^{H_{\rm I}(t-t_{\rm I})}\left(-\frac{1}{H_{\rm I}}\right)\left[e^{-H_{\rm I}(t-t_{\rm I})}\right]_{t_{\rm I}}^{t} \simeq \frac{a(t)}{H_{\rm I}},$$

while the Hubble radius remains constant

$$\text{HUBBLE RADIUS} = \frac{a}{\dot{a}} = H_{\rm I}^{-1},$$

and points that our causally disconnected today could have been in contact during inflation.

- **Starobinsky ’79**
- **Guth “stara” ‘81**
- **Linde “nova”**

RAVNOST, Ω = 1 kao najprecizniji poznata vrijednost

- **U usporedbi s mjerenjem WMAPa**

$$\Omega = 1.02 \pm 0.02$$

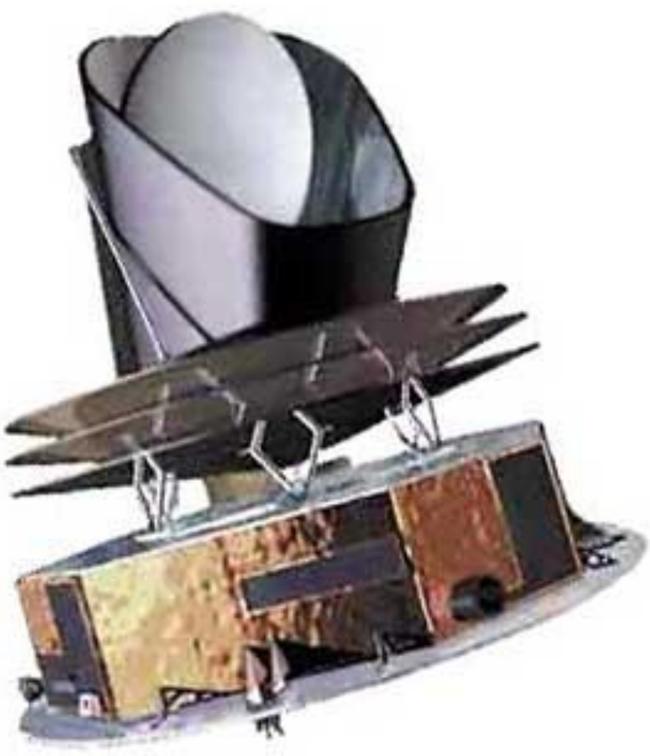
U inflacijskom periodu *)

$$|1 - \Omega(t)| \propto e^{-2Ht}$$

*) osiguranom jedn. stanja $p < -\frac{1}{3}\rho c^2$

$\omega < -1/3$

ESA lansirala Herschel Space Laboratory i PLANCK Satelite



INFLACIJA se oslanja na tvar s repulzivnom gravitacijom

- **Podvostručenje svemira svakih 10^-37 sek, uz gustoću repulzivne tvari koja se ne smanjuje pri ekspanziji**
- **Repulzivna tvar je nestabilna –raspada se nakon 10^-35 sek; svemir manji od protona naraste do centimetra**
- **Kandidati za pogonitelja inflacije?**

VAKUUMSKA ENERGIJA

vakuumska očekivajuća vrij. tenzora energije - impulsa

$$T_{\mu\nu}^{vac} = \langle 0 | T_{\mu\nu} | 0 \rangle = \rho_{vac} c^2 \eta_{\mu\nu}$$

podudara se s izrazom za fluid

$$T_{\mu\nu} = (p + \rho c^2) u_\mu u_\nu - p \eta_{\mu\nu}$$

ukoliko $p = -\rho c^2$

INDUCIRANA KOZMOLOŠKA KONSTANTA

$$G_{\mu\nu} + \lambda g_{\mu\nu} = -\frac{8\pi}{c^4} G_N T_{\mu\nu}$$

uz supstituciju

$$T_{\mu\nu} \rightarrow T_{\mu\nu} + \underbrace{\langle 0 | T_{\mu\nu} | 0 \rangle}_{g_{\mu\nu} \Lambda_{ind}}$$

daje efektivnu c.c.:

$$\lambda_{eff} = \lambda + \frac{8\pi}{c^4} G_N \Lambda_{ind}$$

U prirodnim jedinicama

$[\Lambda] = E^4$ - mjerena gustoća energije vakuuma $\sim \mathcal{O}(10^{-47})\ \mathrm{GeV}^4$

$L = \int \mathfrak{L}\, d^3x, \quad \mathfrak{L}$ lagrangian density

Klein Gordon field $\phi(x)$

$$\mathfrak{L} = \underbrace{\left(\partial_\mu \phi(x)\right)^\dagger \partial^\mu \phi(x)}_{T} - \underbrace{m^2 \phi(x)^\dagger \phi(x)}_{V}$$

Manifestly Lorentz invariant

Classical path :

$$\delta S = 0 \quad \Rightarrow \quad \frac{\partial \mathfrak{L}}{\partial \phi} - \partial^\mu \frac{\partial \mathfrak{L}}{\partial(\partial^\mu \phi)} = 0$$

Euler Lagrange equation

$$\Rightarrow \quad \boxed{(\partial_\mu \partial^\mu + m^2)\psi = 0}$$

Klein Gordon equation

SKALARNO POLJE

$$\mathcal{L} = \frac{1}{2}\left[(\partial_\mu \phi)(\partial^\mu \phi) - \mu^2 \phi^2\right]$$

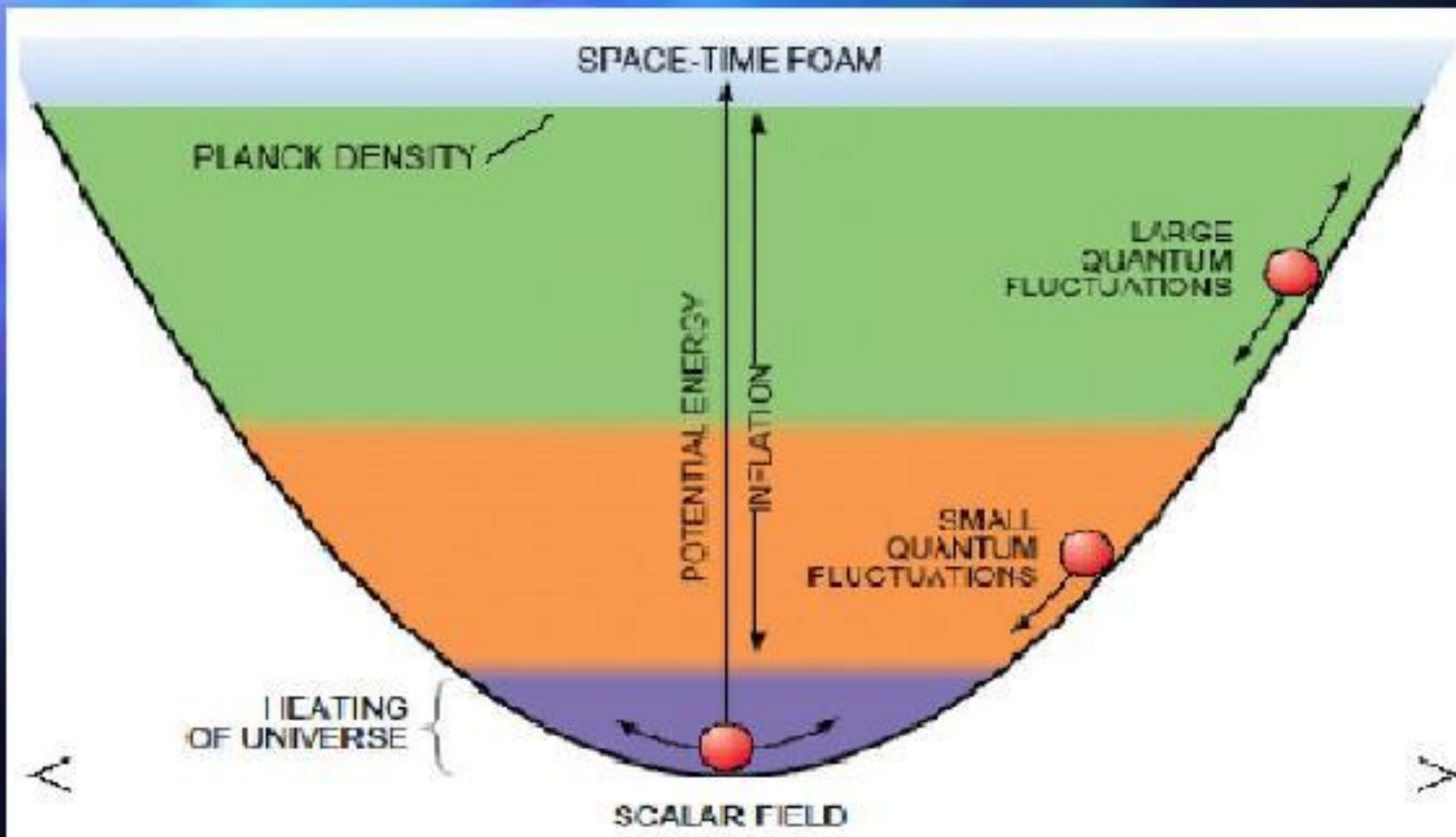
$$T^{\mu\nu} = \partial^\mu \phi \, \partial^\nu \phi - g^{\mu\nu} \mathcal{L}$$

$$T^{00} \Rightarrow \rho_\phi$$

$$T^{ij} \Rightarrow \delta^{ij} p_\phi$$

Inflation as a theory of a harmonic oscillator

$$V(\phi) = \frac{m^2}{2}\phi^2$$



H.O. s (promjenljivim) trenjem

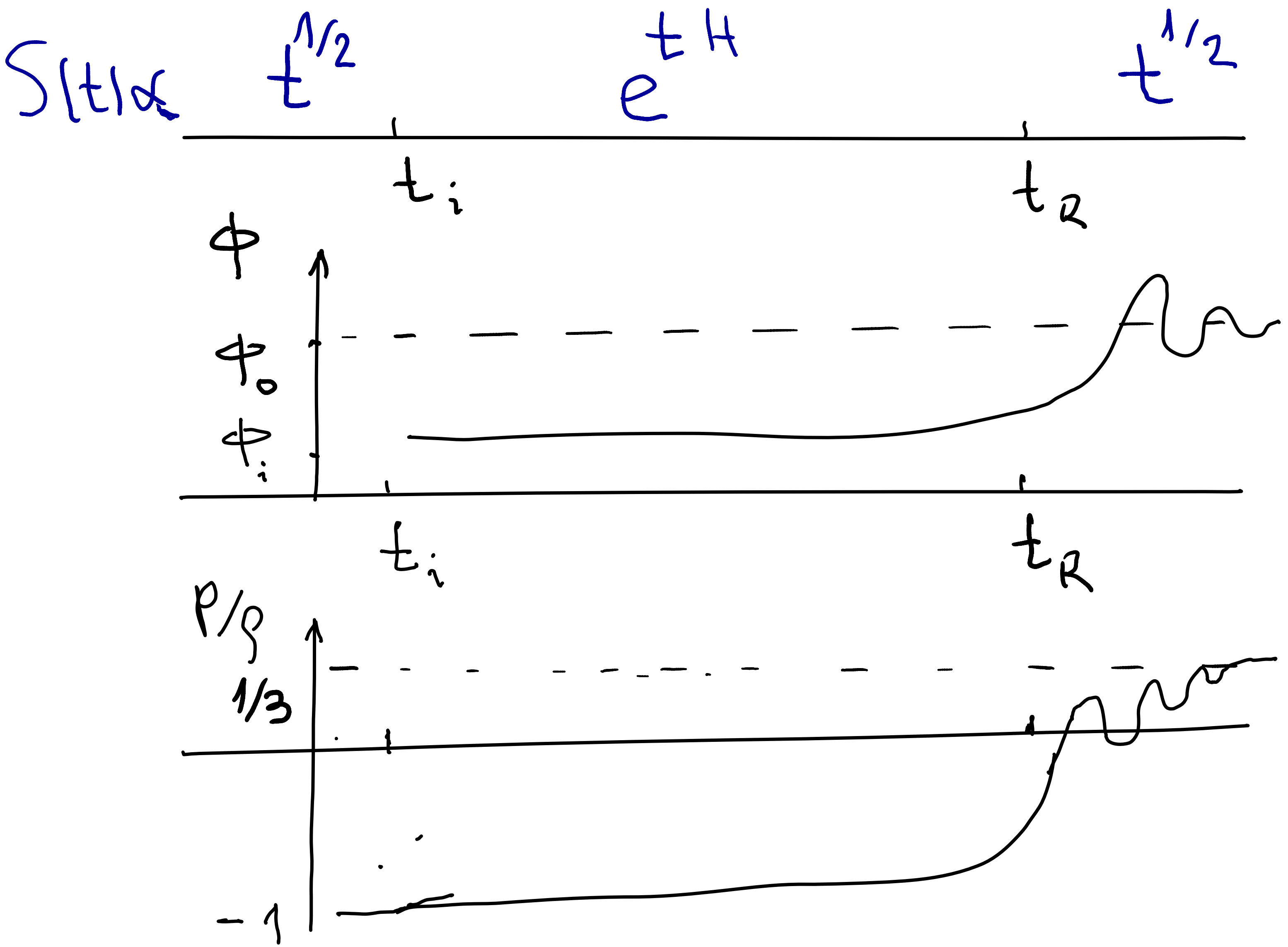
- **OPĆENITO**

$$\ddot{\phi} + 3H\dot{\phi} - \nabla^2\phi + \frac{dV}{d\phi} = 0$$

- **SPORO KOTRLJANJE**

$$3H\dot{\phi} = -dV/d\phi$$

SAŽETAK IDEJE INFLACIJE



SKALARNO POLJE PROIZVODI OSIM INFLACIJE I SVU TVAR U SVEMIRU

- **PRIJELAZ U ISTINSKI VAKUUM ZAUSTAVLJA INFLACIJU I PONOVNO ZAGRIJAVA (podgrijava) SVEMIR (engl. reheating)**
- **BRZO-OSCILIRAJUĆE POLJE STVARA PAROVE ČESTICA (SCHWINGEROV MEHANIZAM)**