

# ASTROFIZIKA ZA VELIKE KROZ MATEMATIKU ZA MALE

## 1.dio

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**KOZMOLOGIJA** opisuje porijeklo i evoluciju Svemira u cjelini  
U prošlosti fokusirala se na pitanje središta i ruba Svemira

**RAZVOJ MODERNE CIVILIZACIJE:**

Baziran na prodorima u kozmologiji – revolucionarni odmak od mitskih i religioznih objašnjenja u domenu znanosti!

**DANAS:**

Prostor i vrijeme su svojstva Svemira, a ne nešto u čemu Svemir postoji  
Vrijeme nije postojali prije početka Svemira.  
Svemir nema centar niti rub.

NAJVEĆE PITANJE MODERNE  
ZNANOSTI POSTAVLJA  
KOZOMOLGIJA:

**Od čega se  
sastoji 95%  
Svemira?!**



# Beskonačnost Svemira

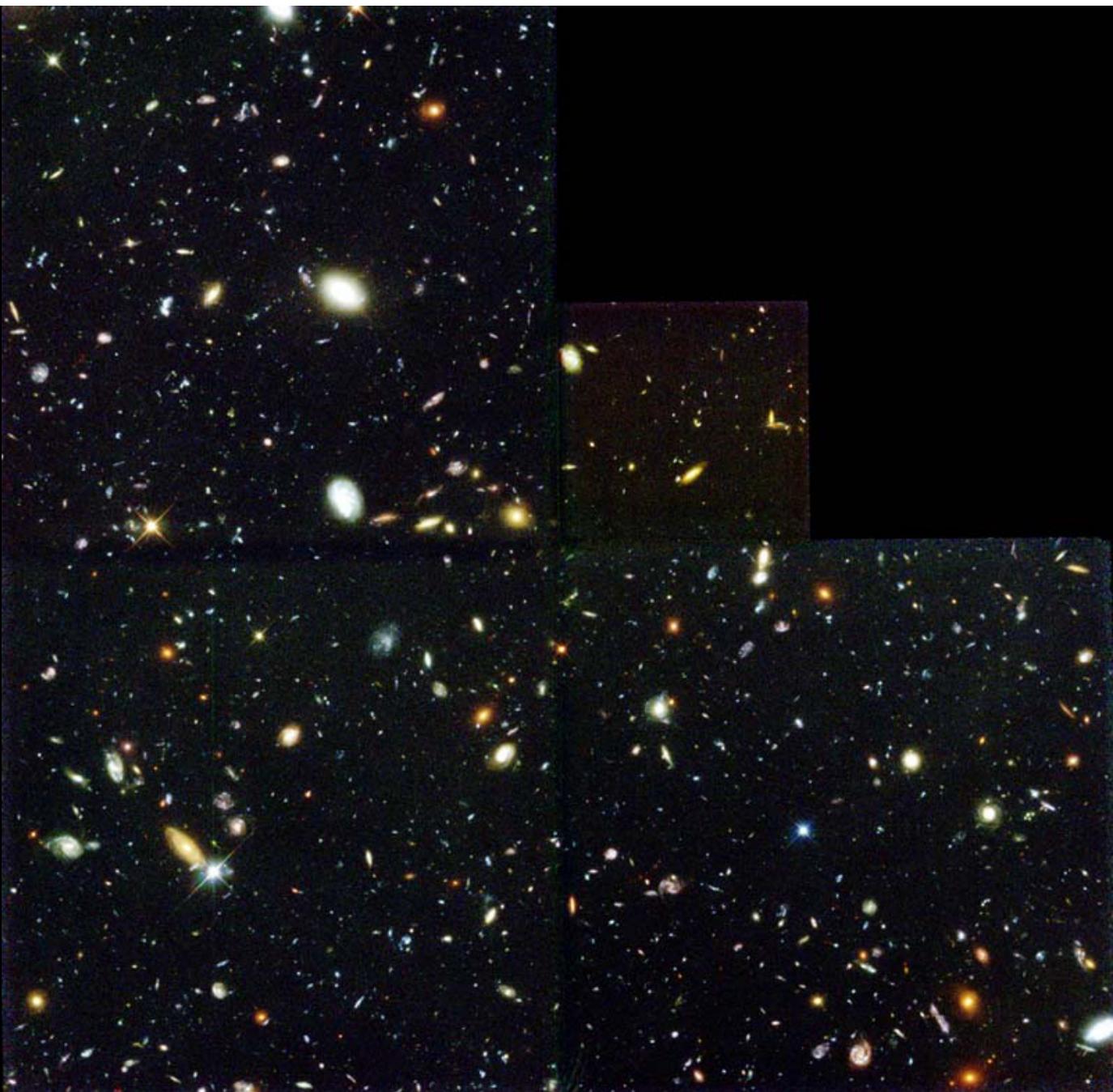
**Titus Lucretius Carus, 99-55.B.C.:**

uvijek mora biti “nešto iza” → Svemir je beskonačan

**Heinrich Wilhelm Olbers, 1823.:**

Ako je Svemir beskonačan, kuda god da pogledamo vidjet ćemo zvijezdu i čitavo nebo bi sjalo poput Sunca!

**ODGOVOR:** Svemir ne može biti beskonačno star – u protivnom ne bi imali tamno noćno nebo!!

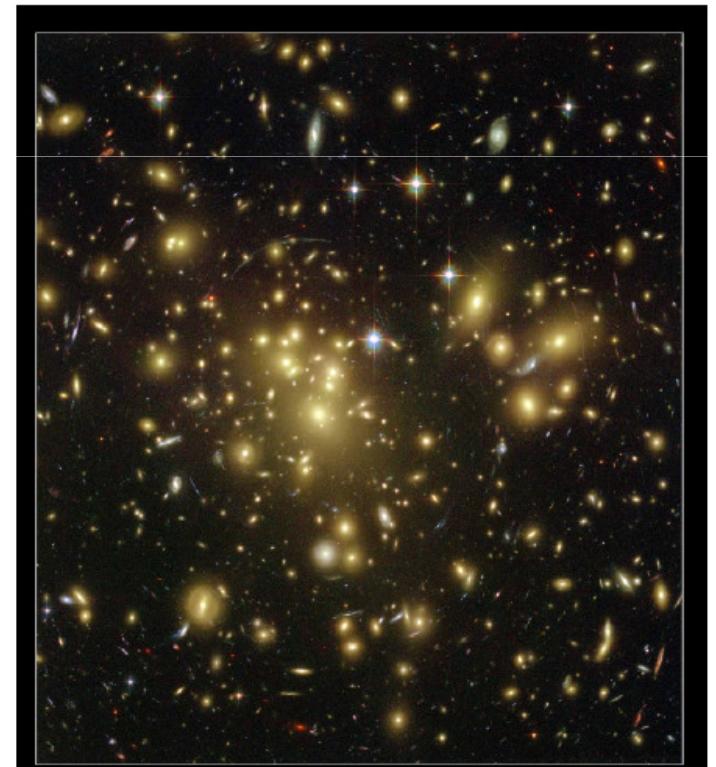
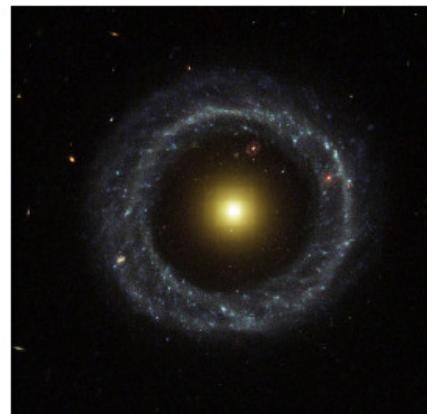
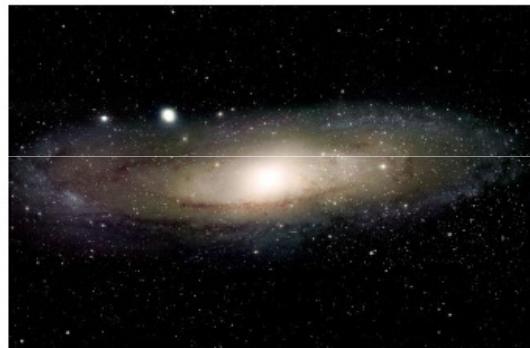


**Hubble Deep Field**

ST Scl OPO January 15, 1996 R. Williams and the HDF Team (ST Scl) and NASA

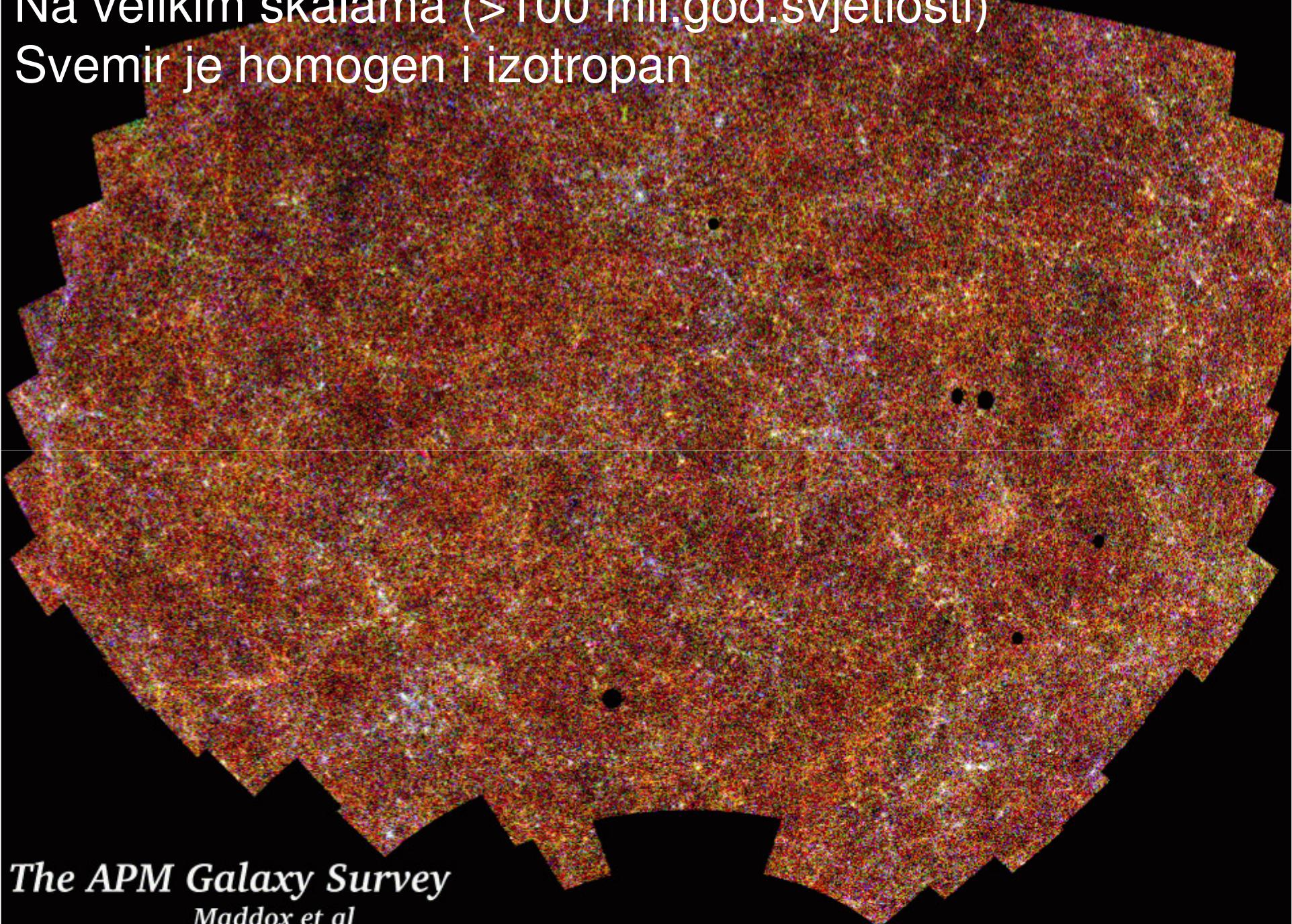
**HST WFPC2**

Na malim skalama Svemir izgleda vrlo kompleksan i nehomogen

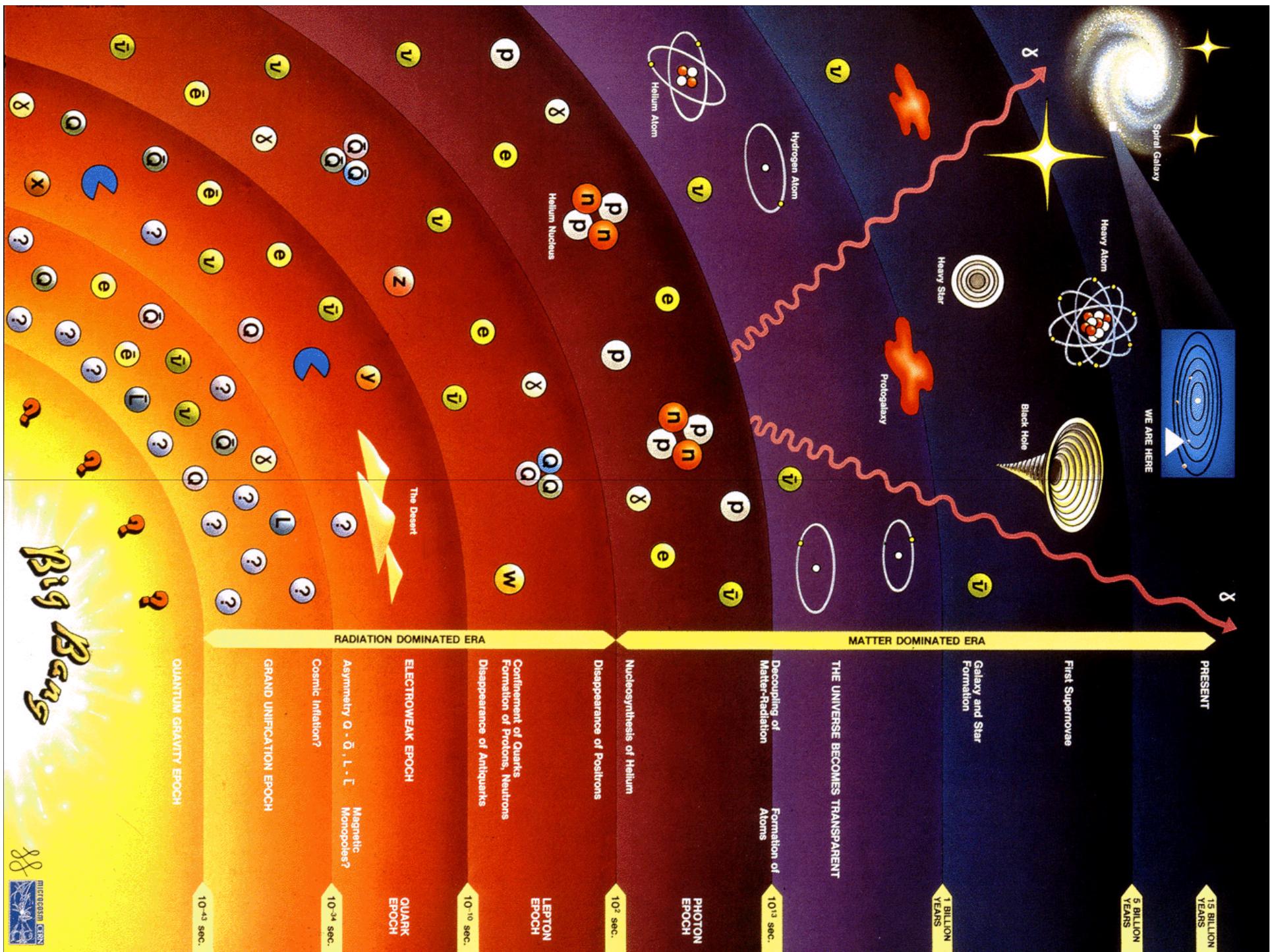


Galaxy Cluster Abell 1689  
Hubble Space Telescope • Advanced Camera for Surveys

Na velikim skalama ( $>100$  mil.god.svjetlosti)  
Svemir je homogen i izotropan



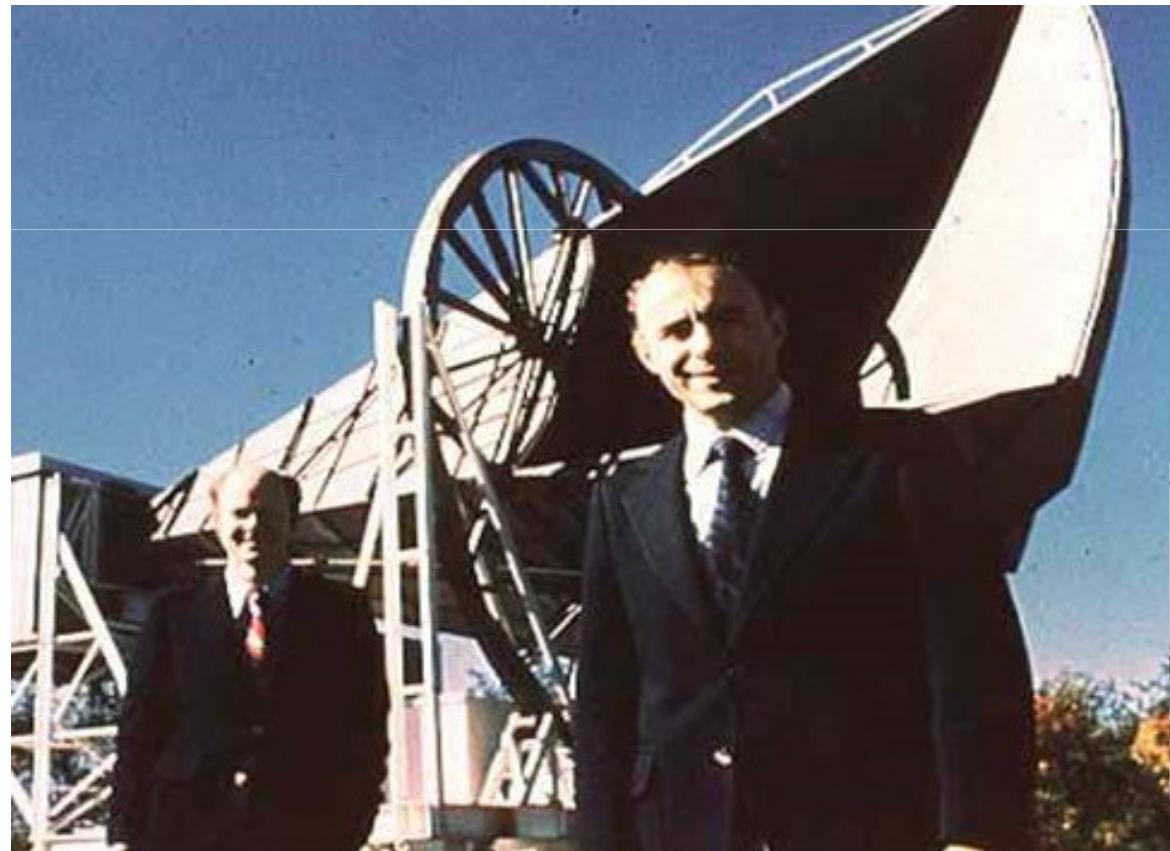
*The APM Galaxy Survey*  
*Maddox et al*

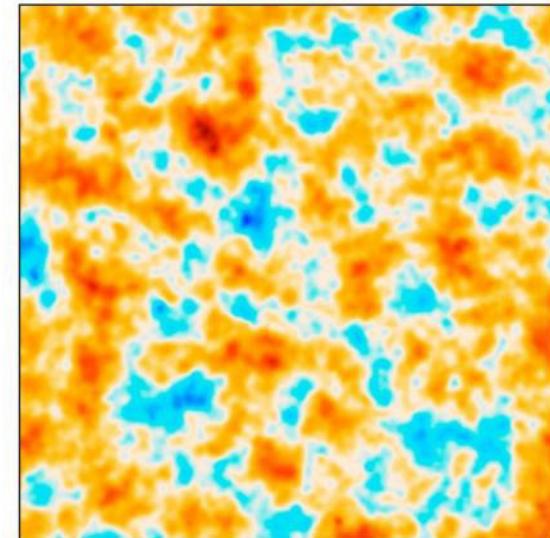
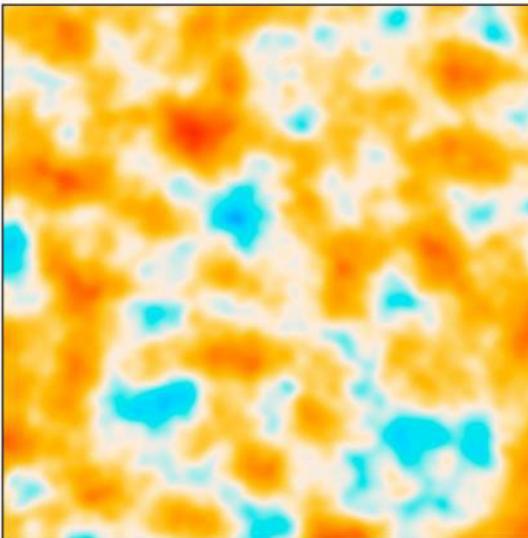
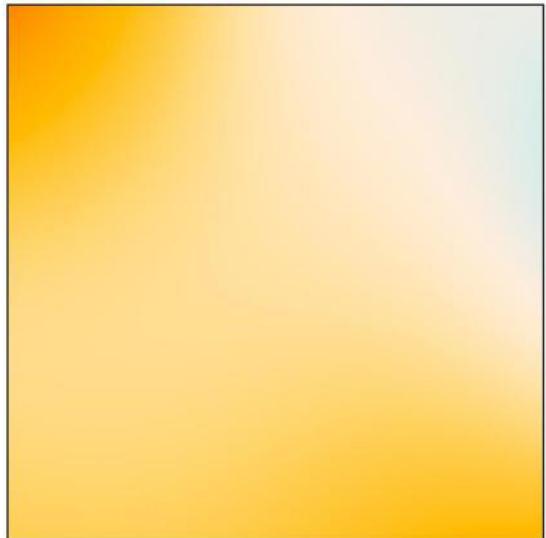
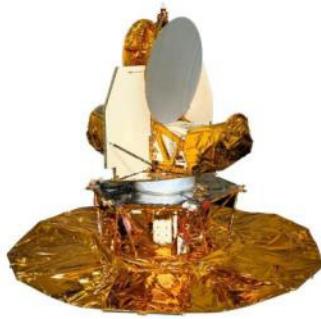


**1963: Arno PENZIAS & Robert WILSON**

Otkrivaju pozadinsko mikrovalno zračenje

Takvo zračenje je ostatak Big Banga i bilo je predviđeno još 1948., te ponovo početkom 1960-ih.





COBE

Godina  
lansiranja:

1989

WMAP

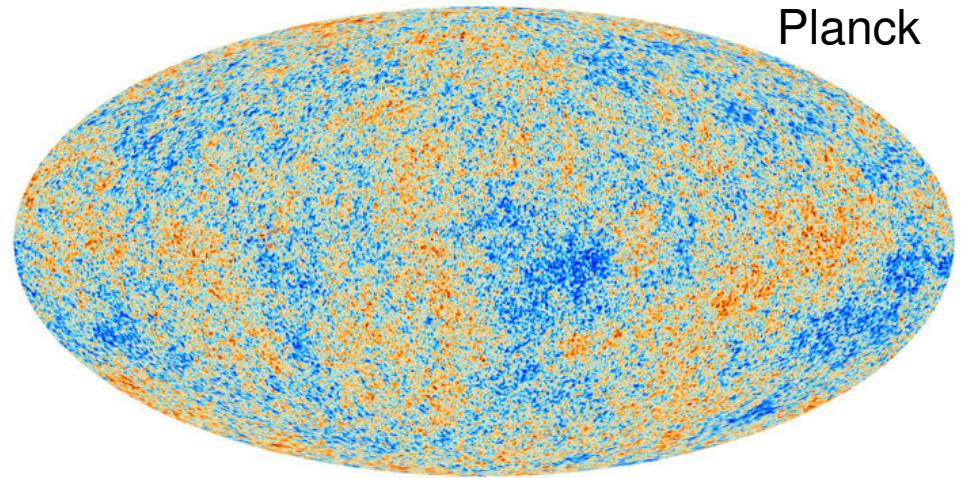
2001

Planck

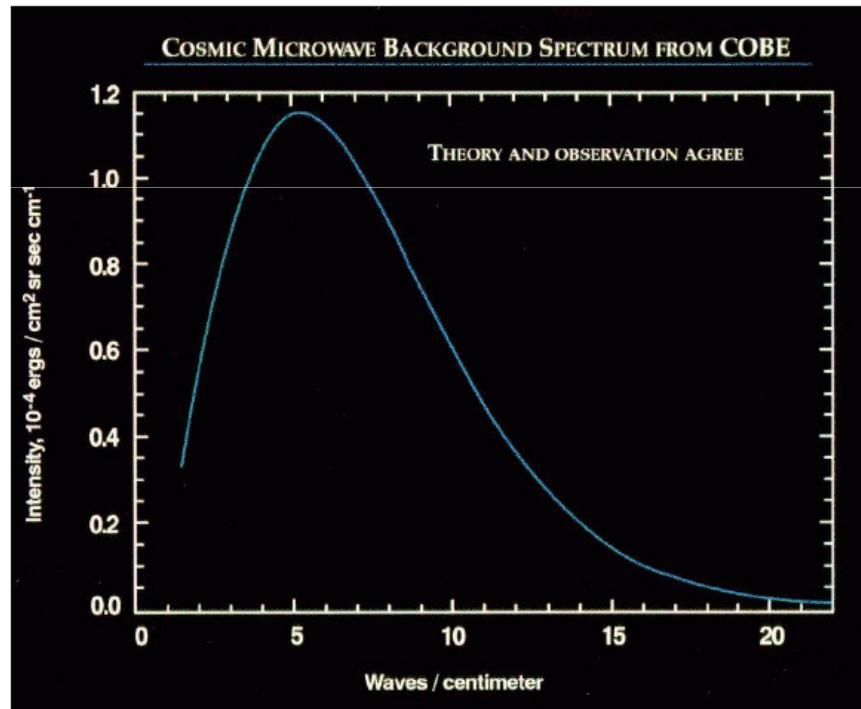
2009

Fotoni koji su stvoreni anihilacijom materije i antimaterije i postali vidljivi 300,000g nakon Big Banga – zbog rastezanja Svemira ti fotoni su danas u mikrovalnom području – mapiranje čitavog neba pomoću svemirskih teleskopas

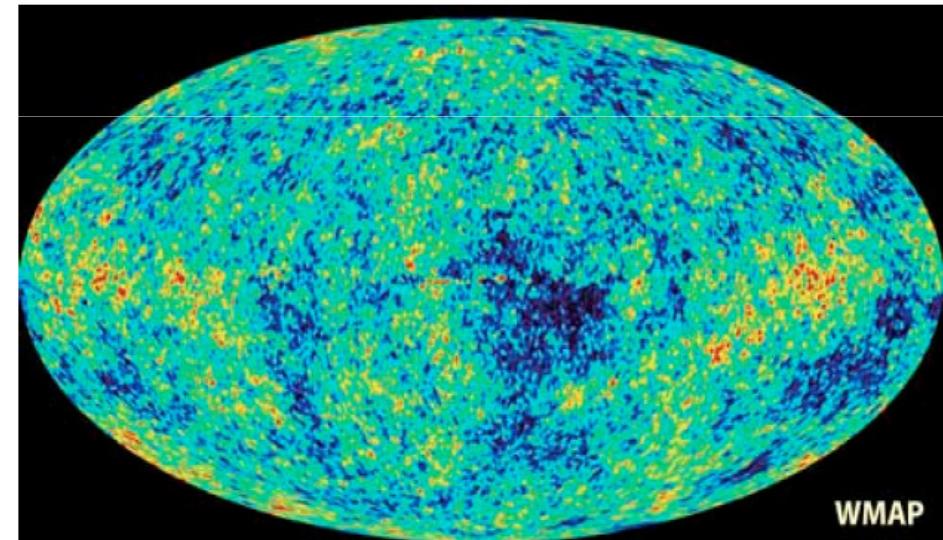
Planck



Perfect black body radiation



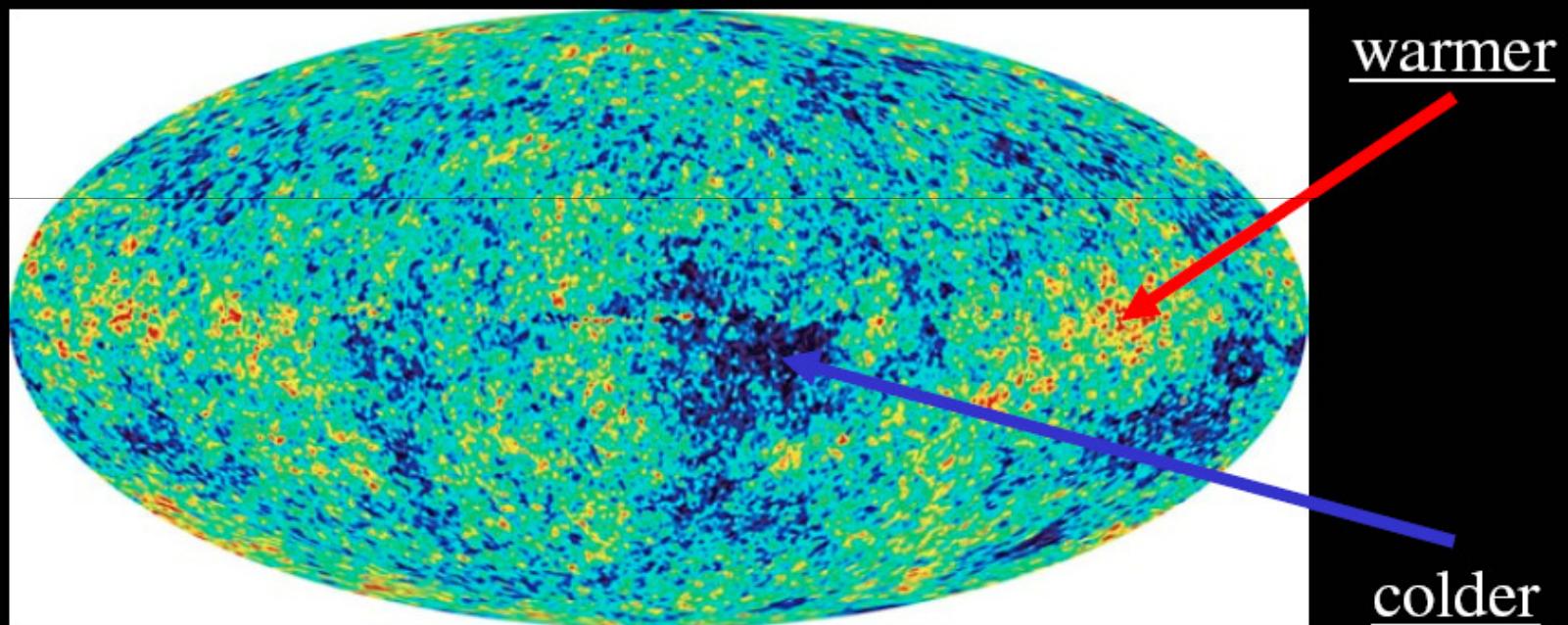
$$T = 2.728 \text{ K}$$



$$\frac{\delta T}{T} \approx 0.00001$$

## The WMAP Mission

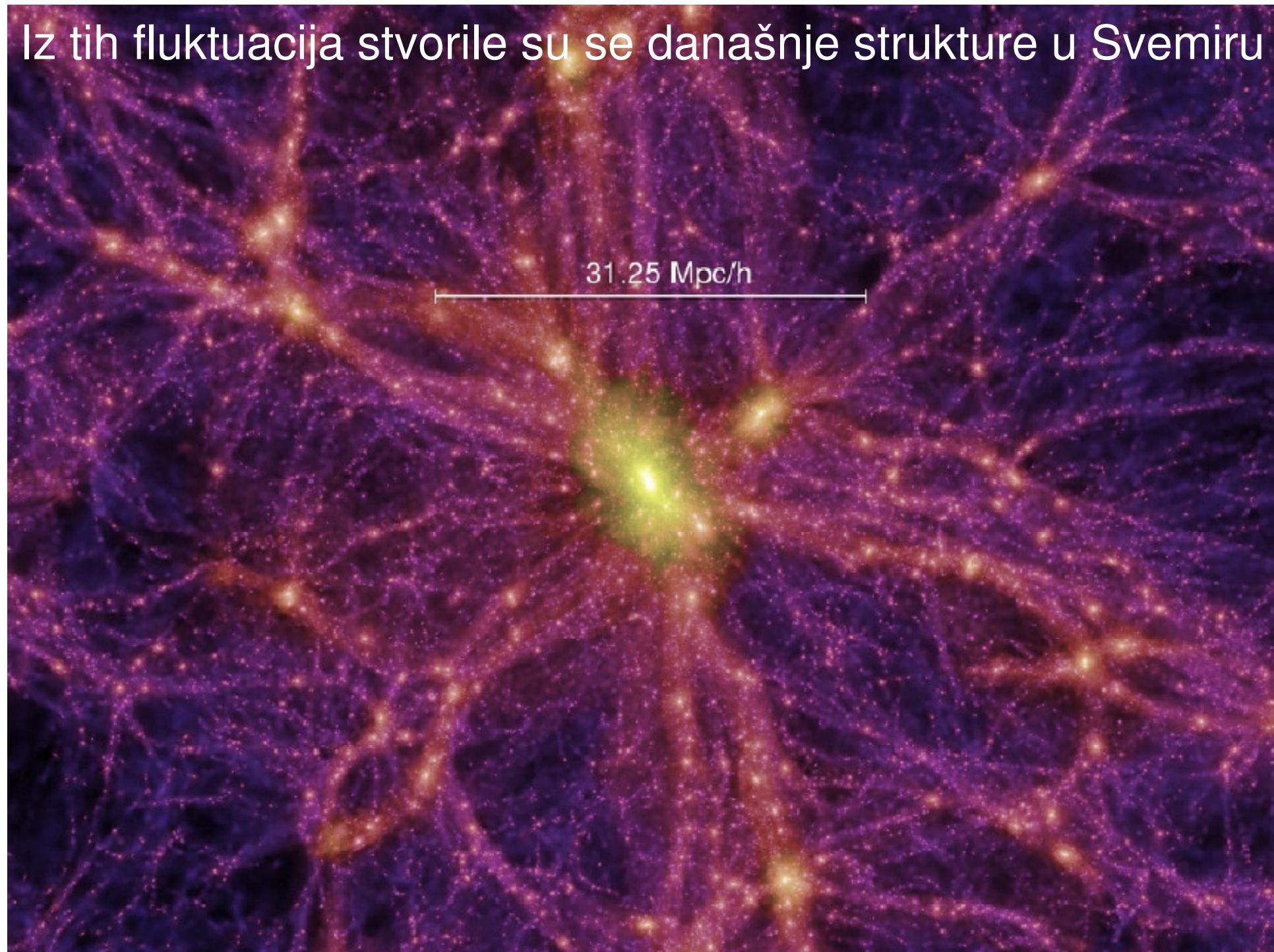
WMAP found tiny temperature and density perturbations in the visible matter **380000 years** after then Big Bang.



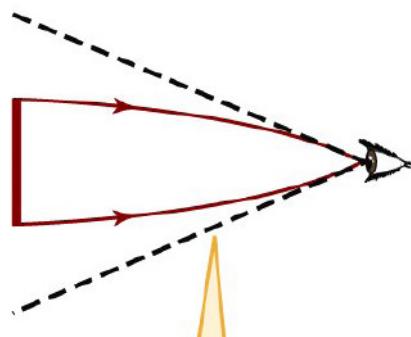
Tiny density fluctuations:

$$\delta\rho/\rho = 0.00001$$

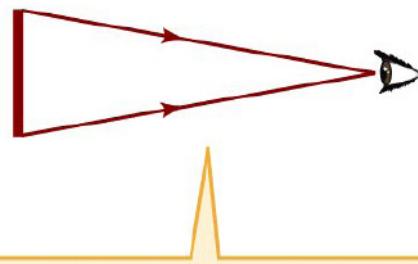
Iz tih fluktuacija stvorile su se današnje strukture u Svemiru



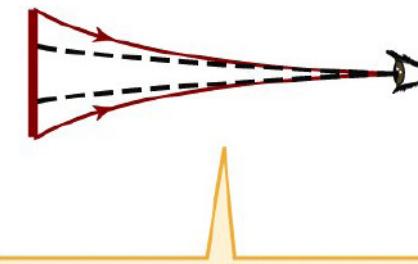
# Od čega se sastoji Svemir? Slike pozadinskog zračenja nam to otkrivaju!!



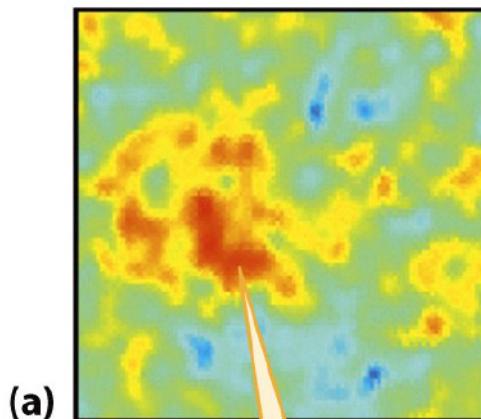
“Zatvoren” svemir  
zakrivljuje zrake svjetla  
jednu prema drugoj...



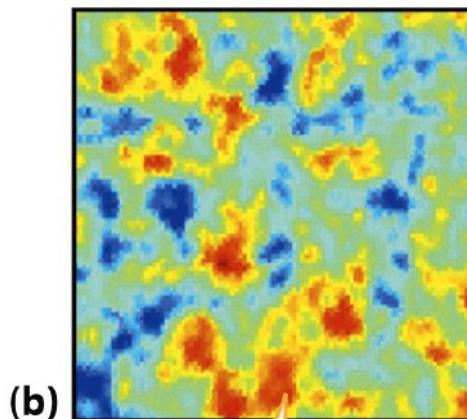
“Ravan” svemir ne  
zakrivljuje putanju  
zraka svjetlosti...



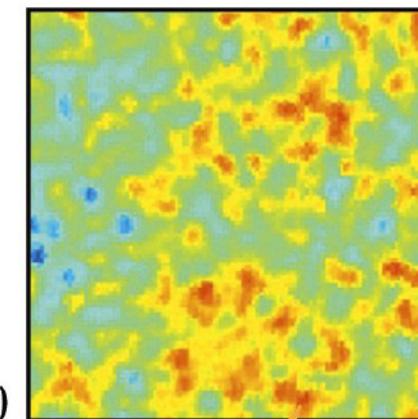
“Otvoren” svemir  
zakrivljuje zrake svjetla  
jednu od druge...



... što stvara slike mrlja  
većim nego što jesu.

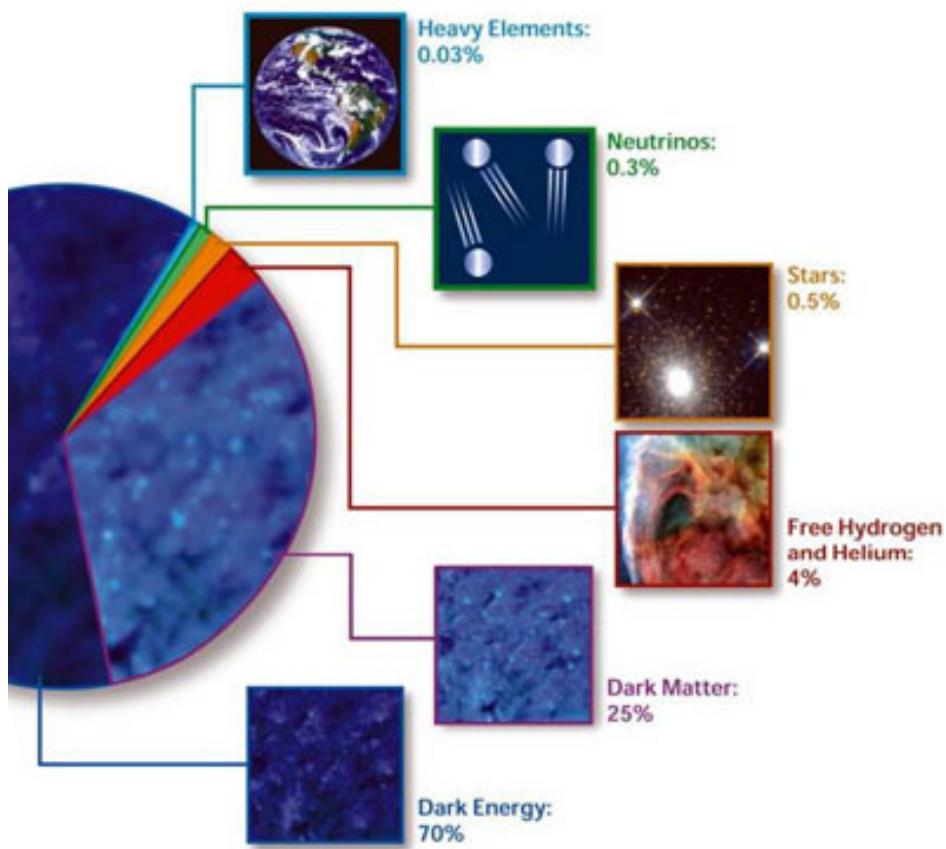


... što ne deformira  
slike mrlja.

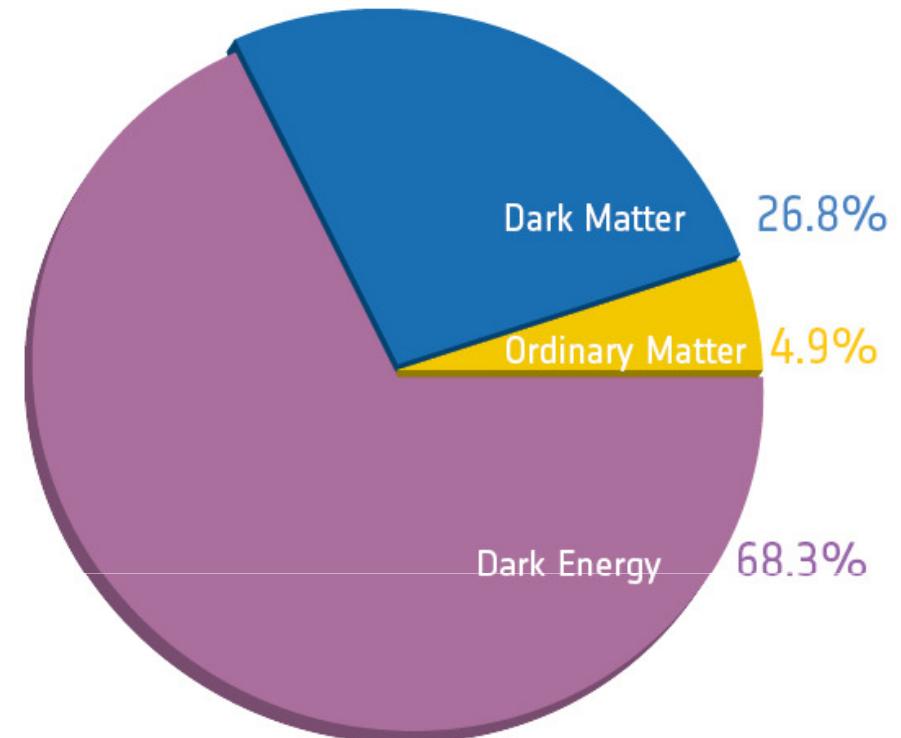


... što stvara slike mrlja  
manjima nego što jesu.

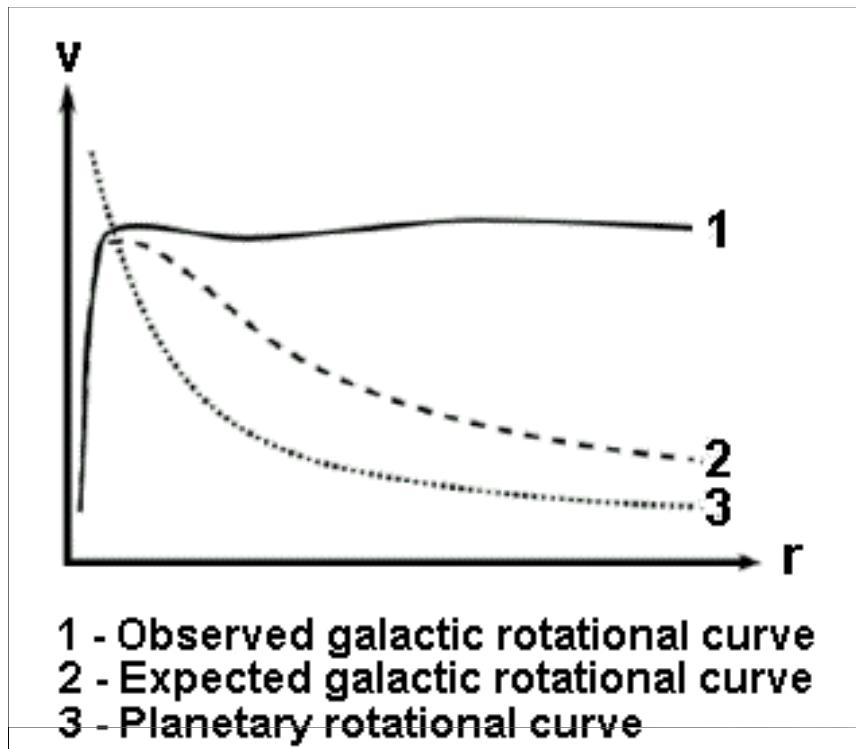
## COMPOSITION OF THE COSMOS



Before Planck



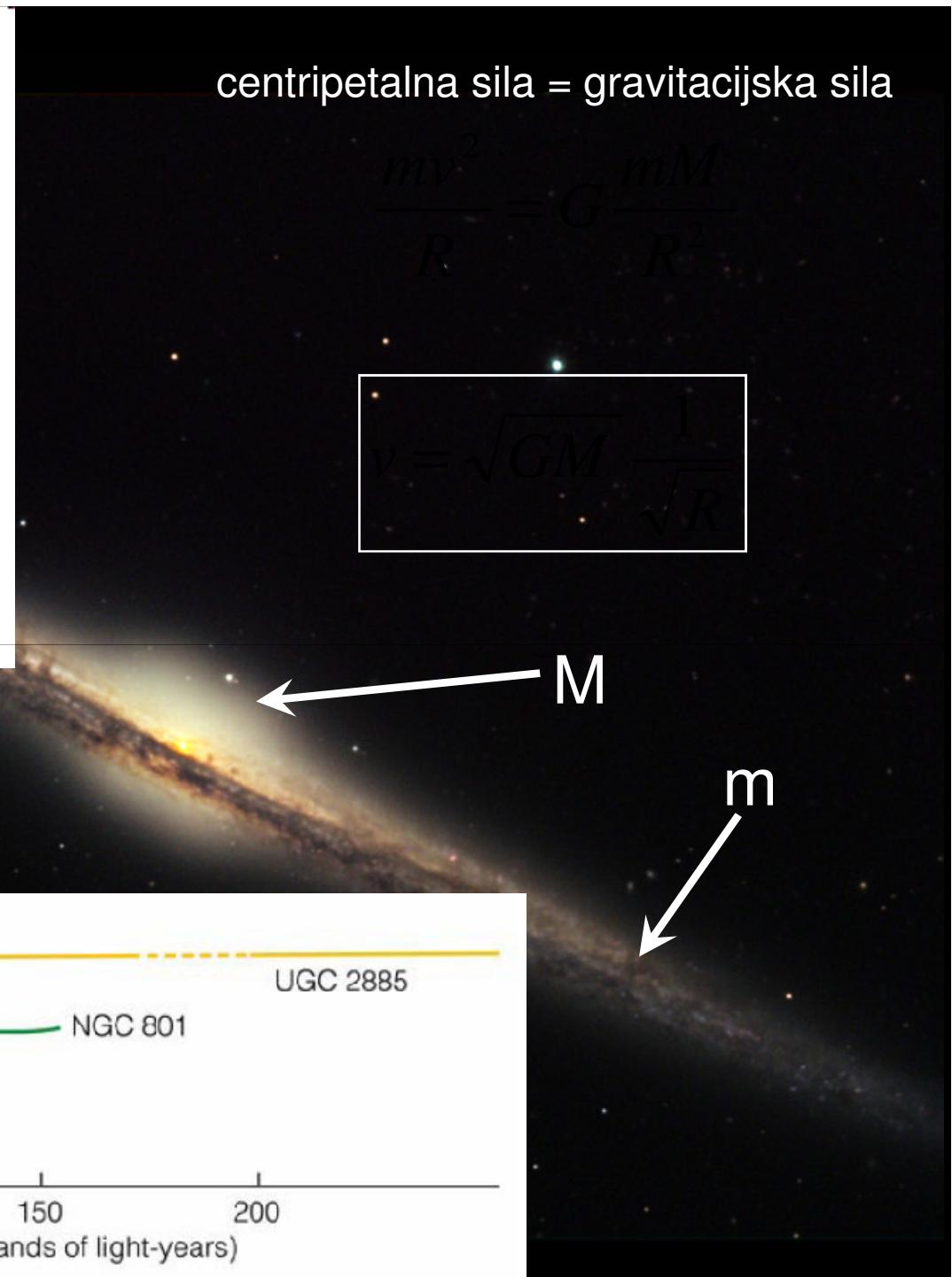
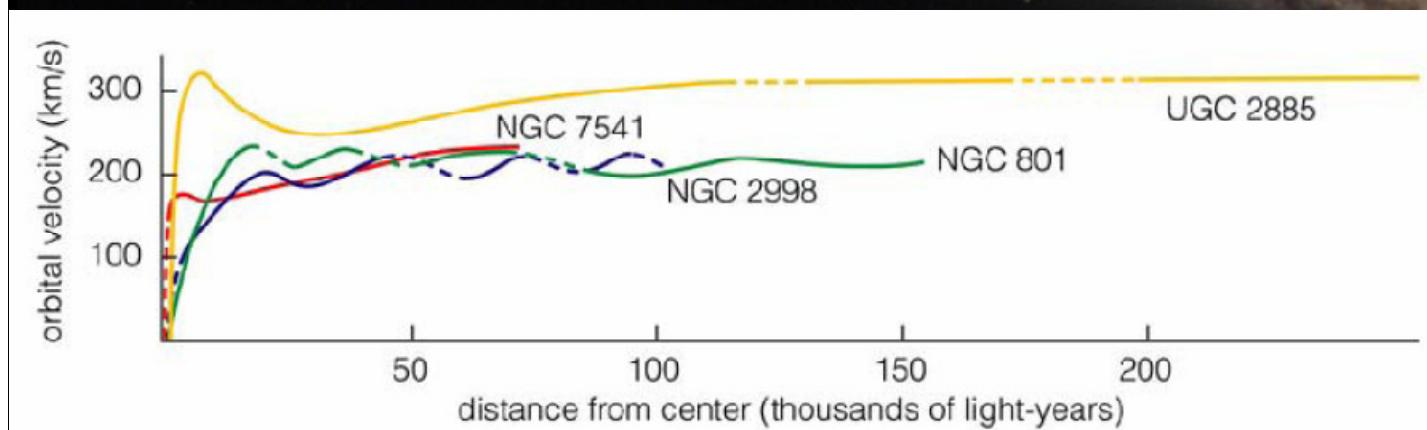
After Planck



centripetalna sila = gravitacijska sila

$$\frac{mv^2}{R} = G \frac{mM}{R^2}$$

$$v = \sqrt{GM} \quad \frac{1}{\sqrt{R}}$$



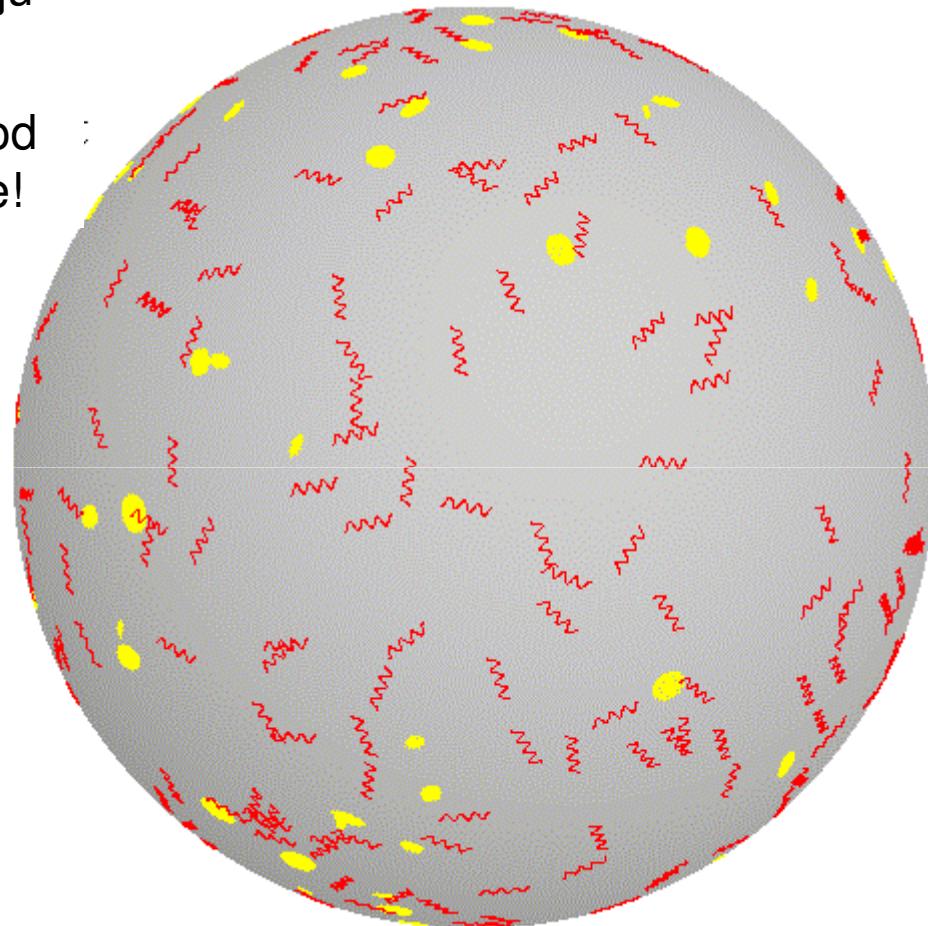
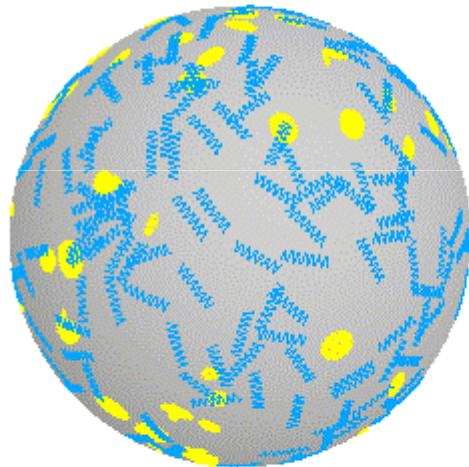
## *The Hubble Expansion*

JESMO LI U CENTRU SVEMIRJA?!

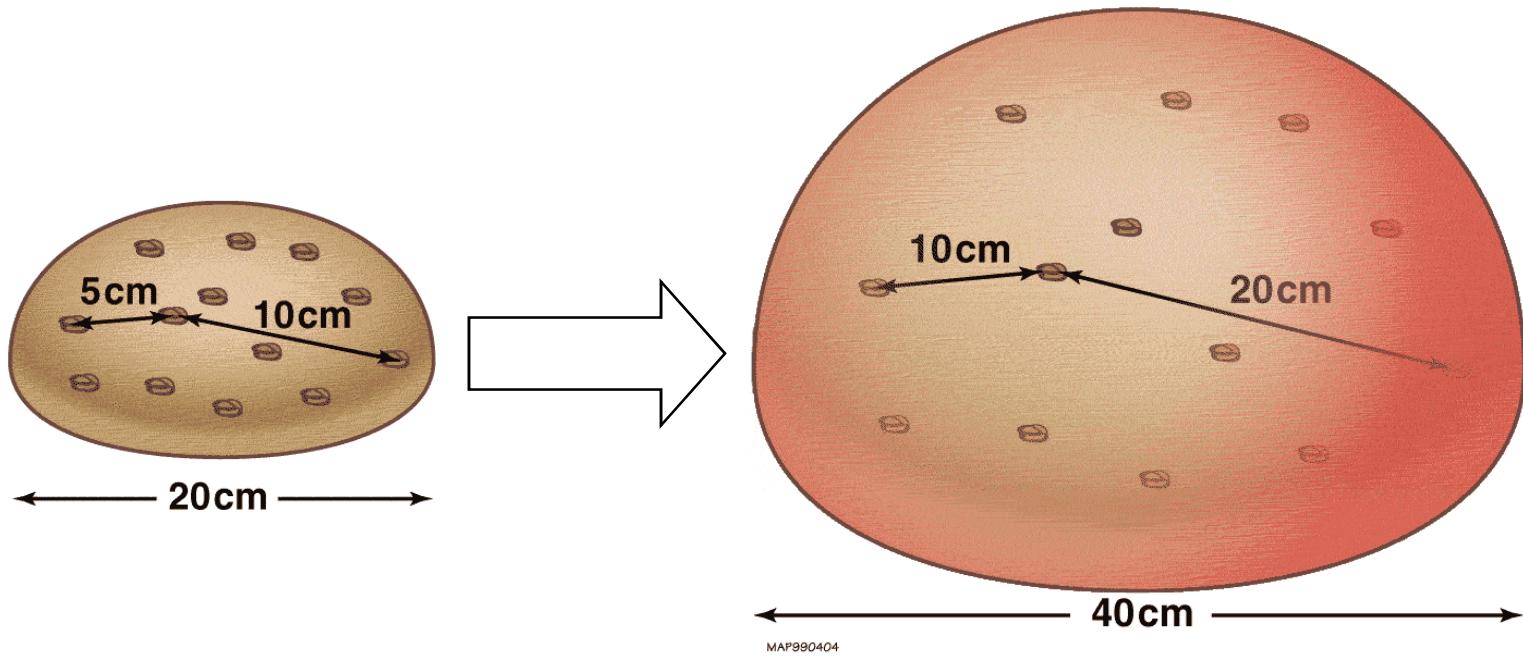


Fotoni zauvijek lete i imaju crveni pomak.

Galaksije se odmiču jedna od druge, ali ostaju iste veličine!



Prostor između galaksija se "rasteže" na način da prostor mijenja svoja svojstva. Dakle, Svemir se ne rasteže u "nešto", nego samo mijenja svojstvo "skale" koju korisimo za mjerjenja udaljenosti

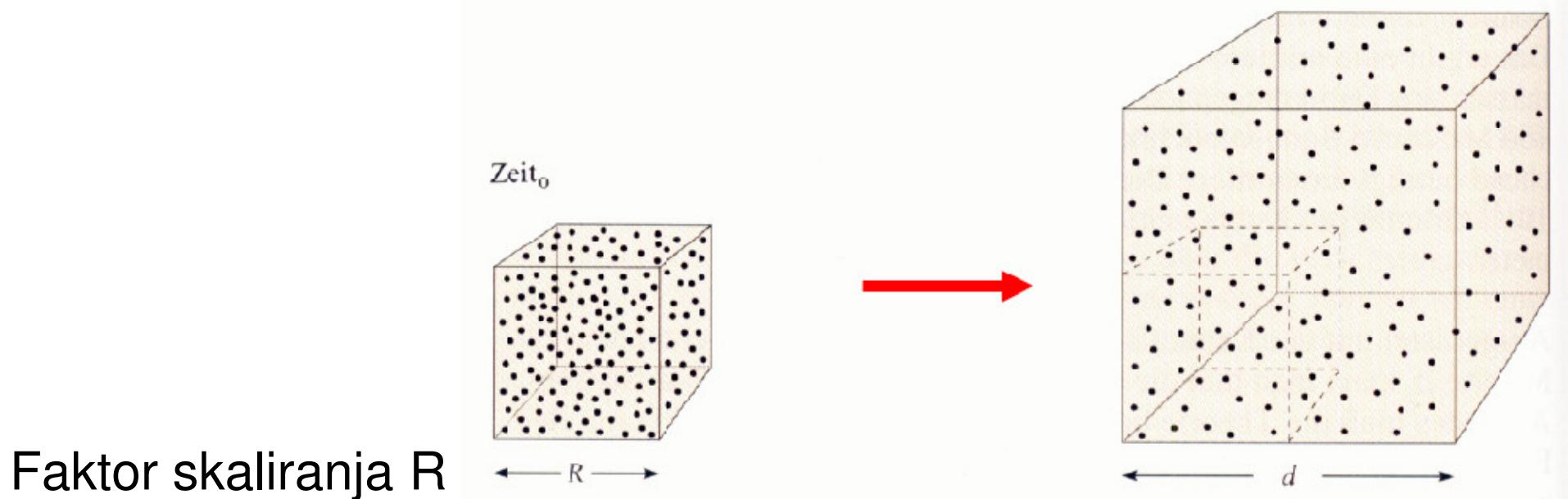


The diagram shows a horizontal chain of three particles (1, 2, 3) with separation  $d$ . A downward arrow labeled  $T$  indicates an applied force. Below it, a second chain of three particles is shown with separation  $2d$ , also under a force  $T$ .

$$V_{21} = (2d - d)/T = d/T$$

$$V_{31} = (4d - 2d)/T = 2d/T \quad \left. \right\} V \propto d$$

$V = Hd$



Relativna udaljenost između točaka:  $r/R = r_0/R_0$

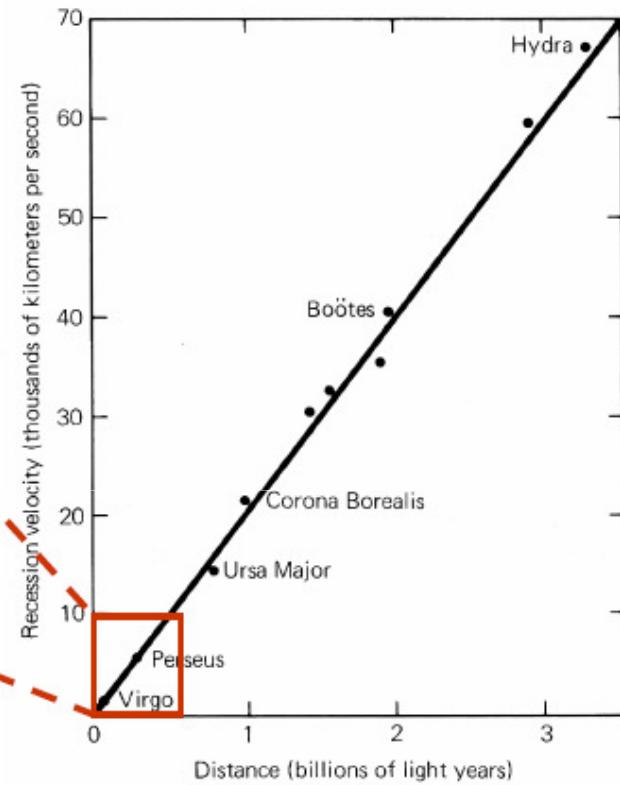
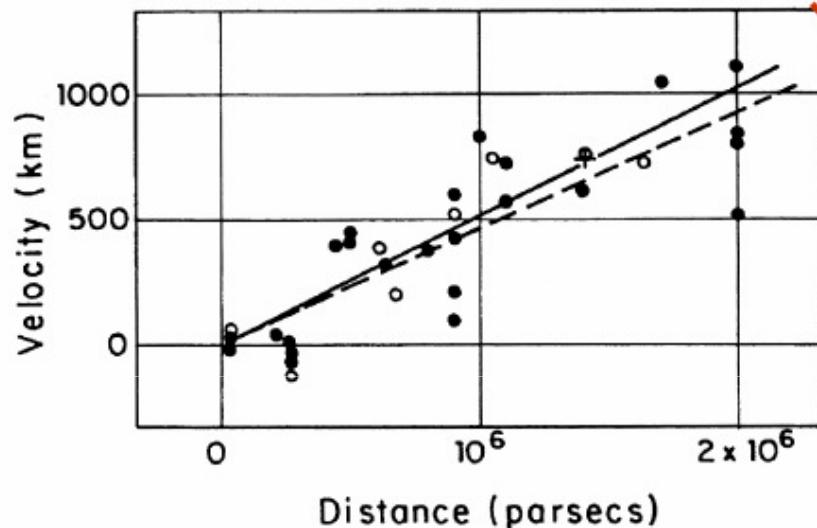
Uzmimo da je danas  $R_0=1 \rightarrow V=dr/dt=r_0 dR/dt$   
 Homogeni svemir zahtjeva  $V=H r = H R r_0$

$$H = dR/dt / R$$

Hubbleova konstanta je mjera brzine kojom  
 Svemir povećava svoju prostranu skalu



Hubble (1929)



The Hubble constant today is usually written as

$$H_0 = H(t_0)$$

Note, that **H** is *not* necessarily a constant in time!

$$H_0 = 67.80 \pm 0.77 \text{ (km/s)/Mpc}$$

LINEAR SCALE OF UNIVERSE RELATIVE TO TODAY

## RELATIVE BRIGHTNESS OF SUPERNOVAE

