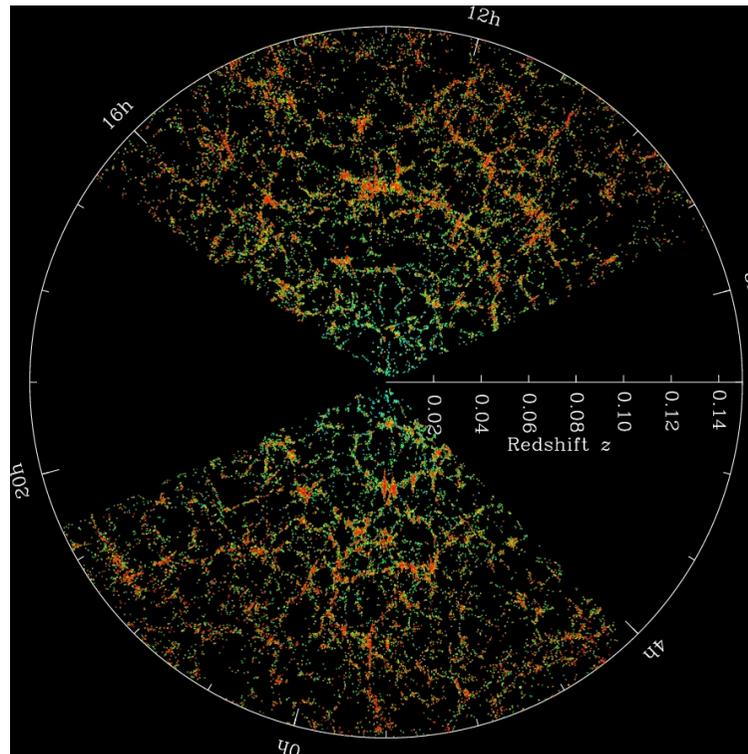


# Prostorska porazdelitev galaksij



Hubblovo ultra globoko polje

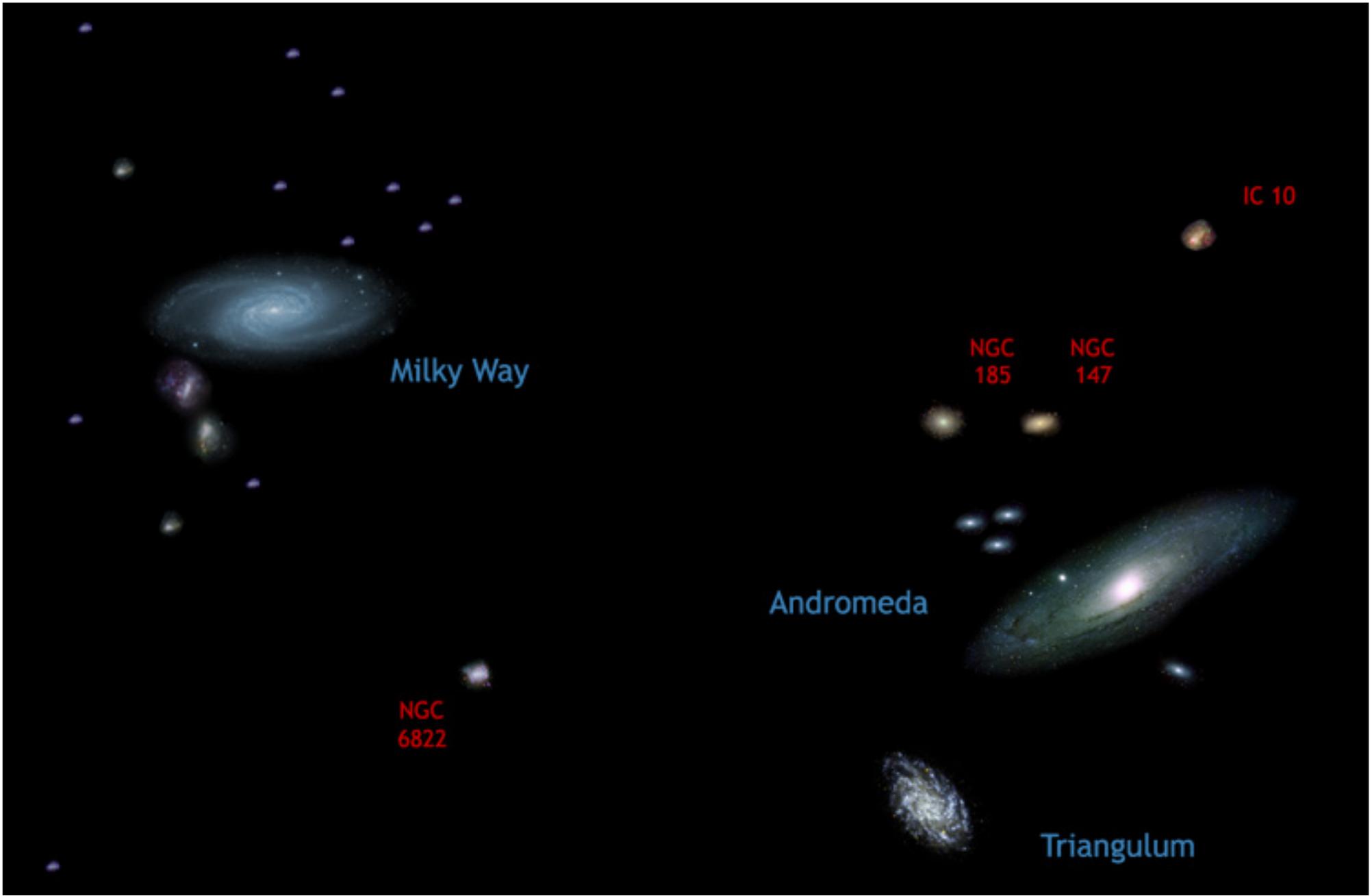


# skupine, jate, nadjate

- skupine galaksij (groups) (<50 g.)
- jate galaksij (clusters):  $\approx 2$  Mpc (nekaj 10 – okrog 1000 g.)
- nadjate galaksij (superclusters): nekaj 10 Mpc
- 3D mreža: filamenti in plahte (sheets), praznine (voids)
- galaksije, ki niso v jatah: "field galaxies"

# Lokalna skupina galaksij





Milky Way

IC 10

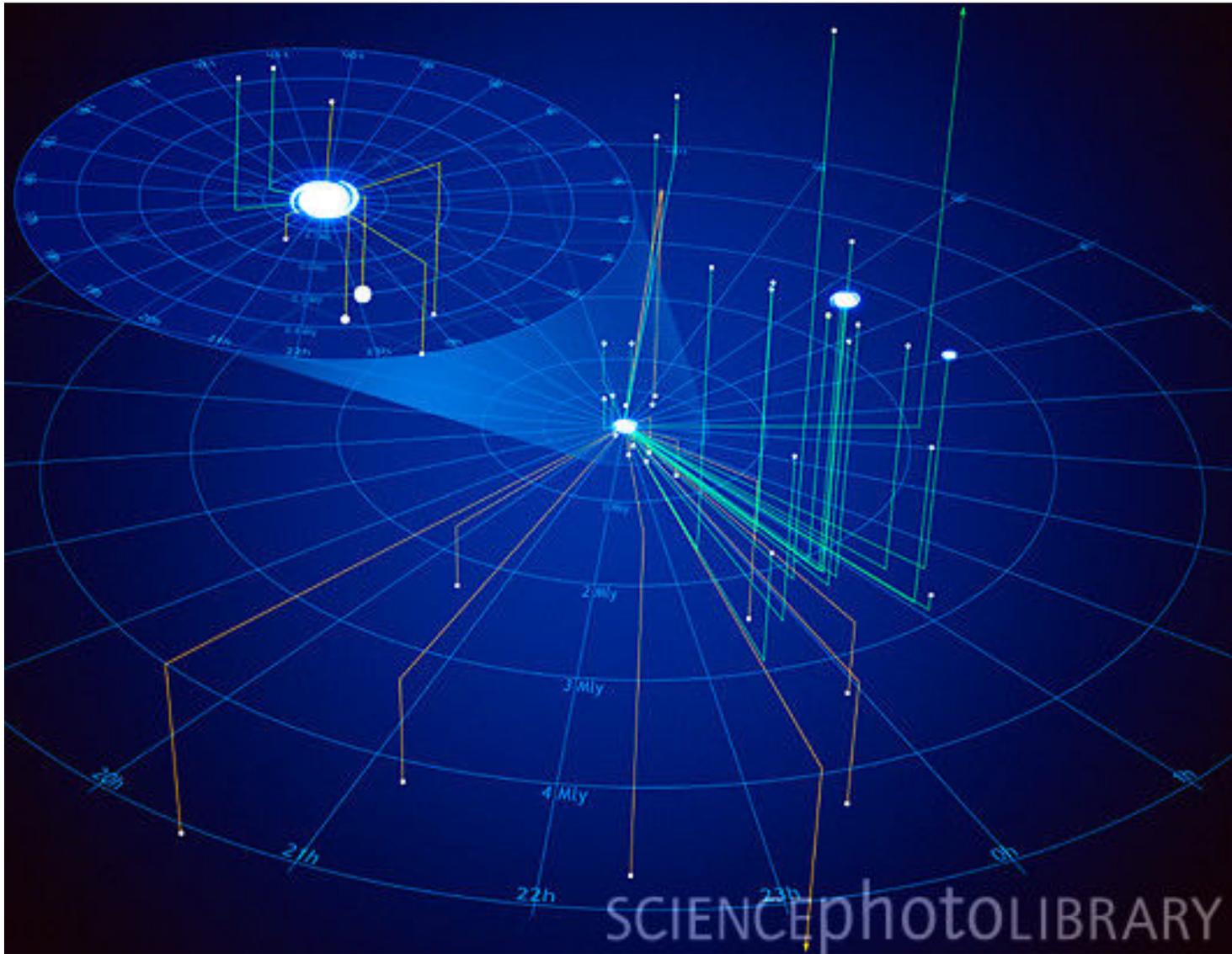
NGC  
185

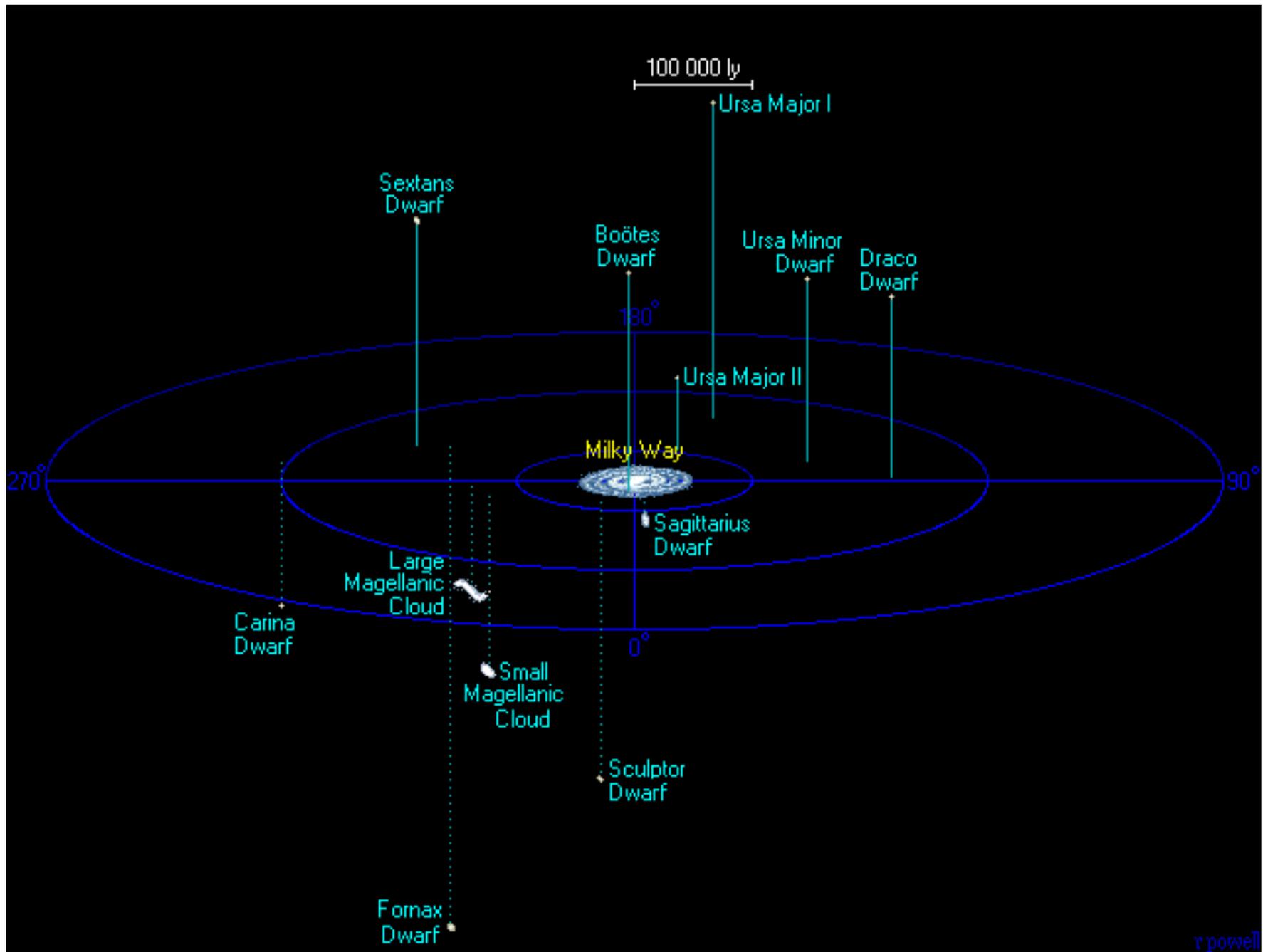
NGC  
147

Andromeda

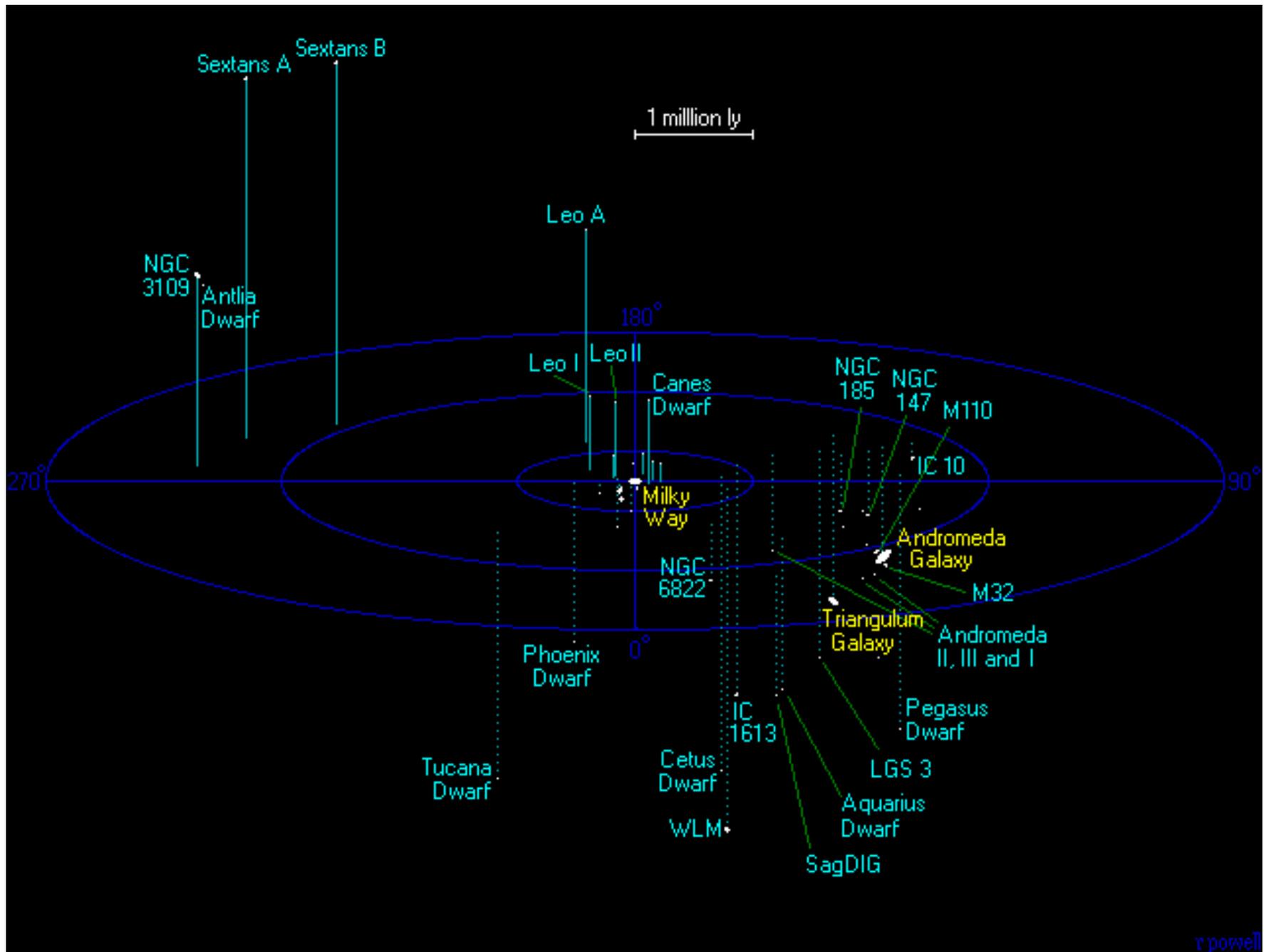
NGC  
6822

Triangulum





0.5 Mlyr



r powell

5 Mlyr



# jate galaksij

- podobne po velikosti: nekaj Mpc
- bogate jate – več galaksij
- vidimo na posnetkih:



Coma cluster – jata v Berenikinih kodrih: 100 Mpc daleč, E g.

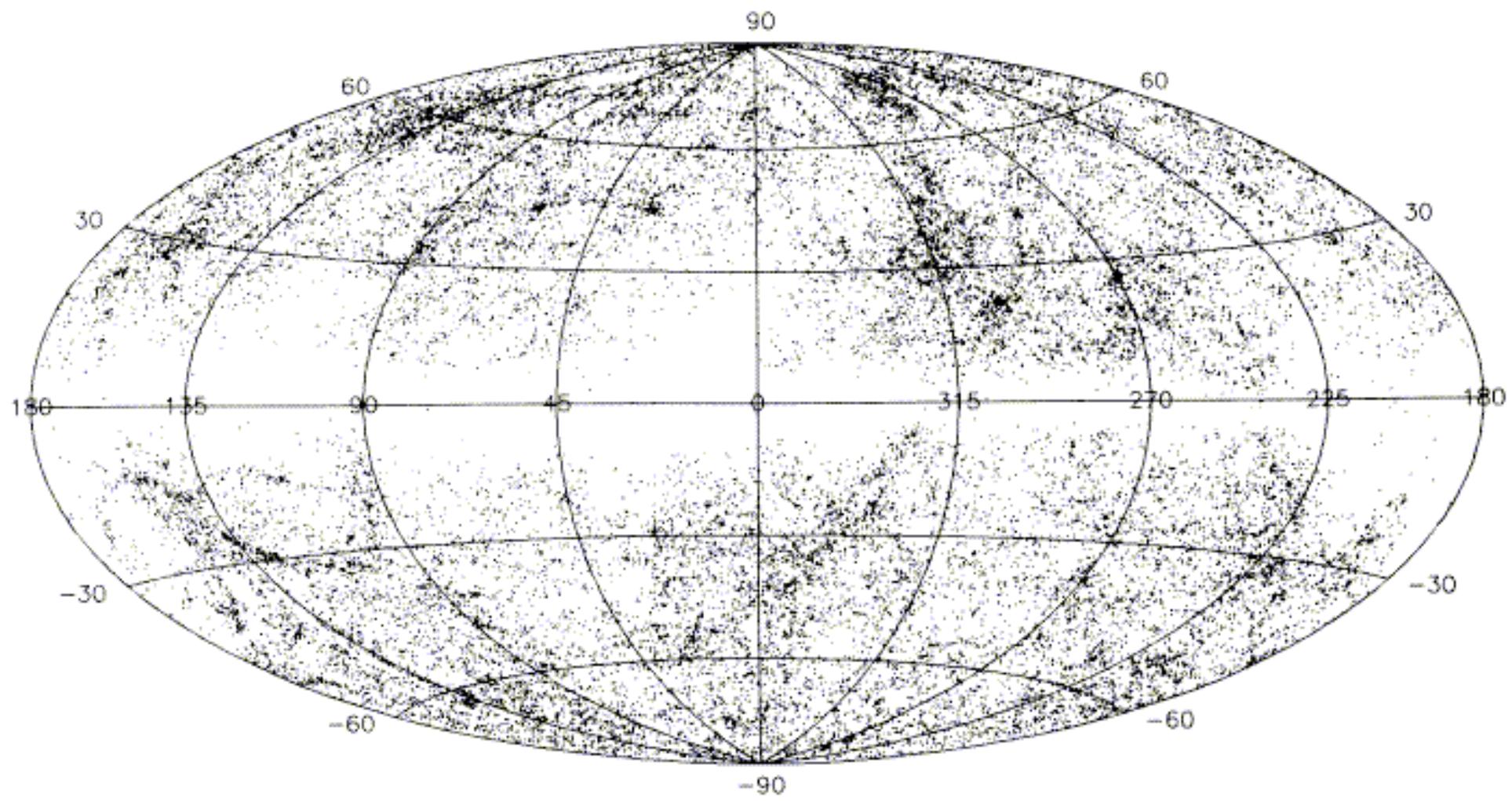


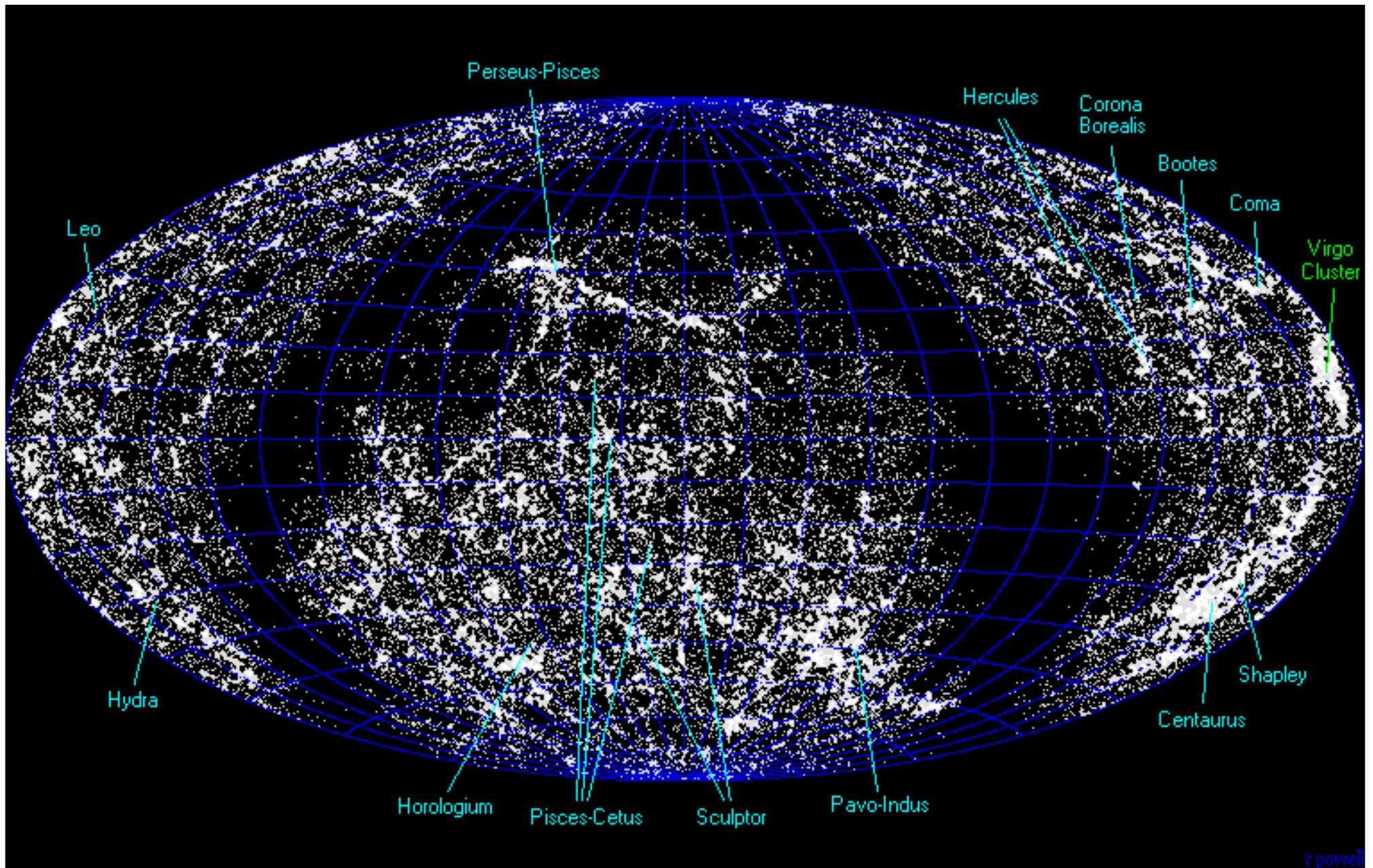
Virgo cluster - jata v Devici: 20 Mpc, E in S g.

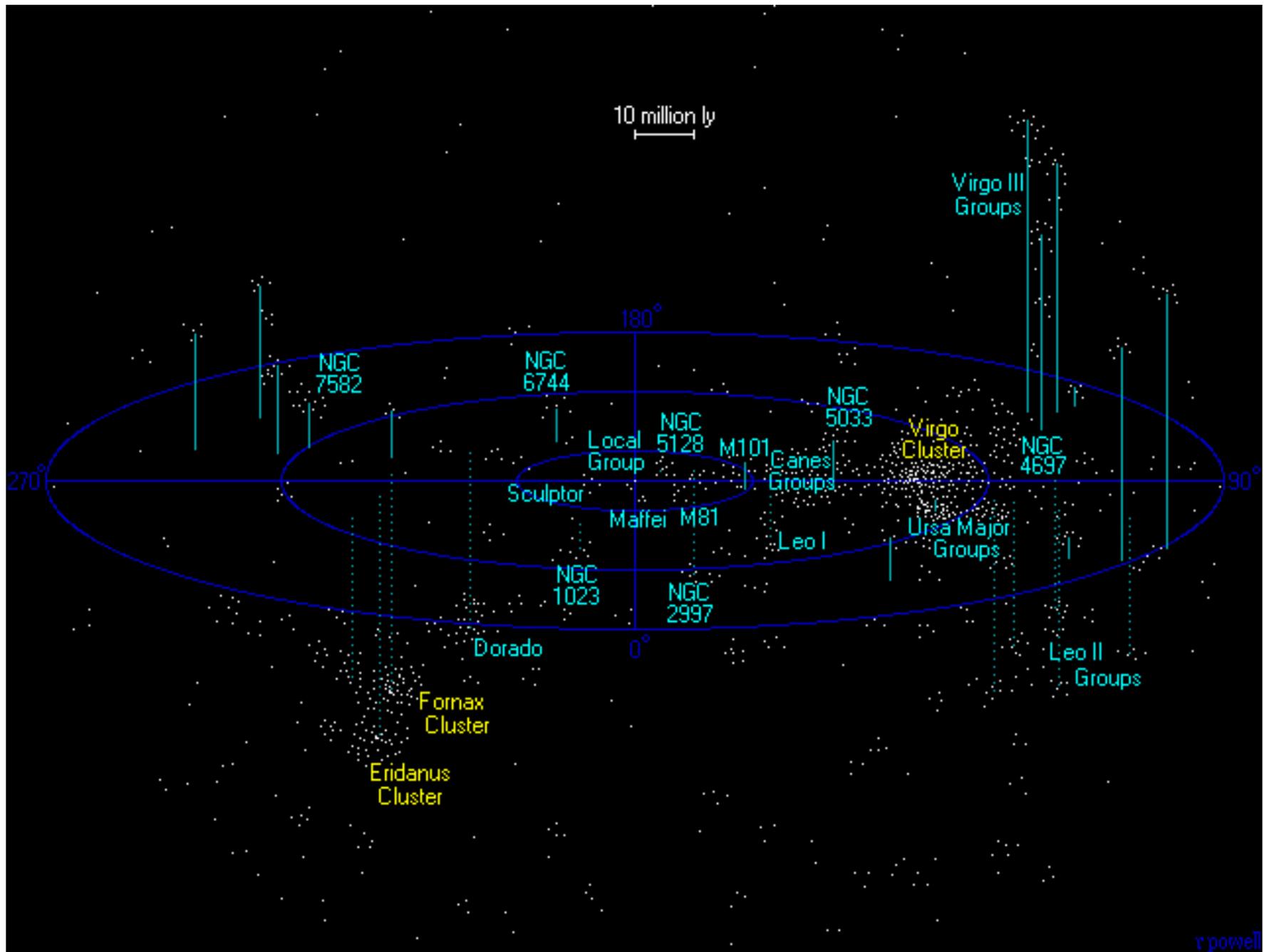
# George Ogden Abell (1927-1983)

- katalog: 2712 jat
- Mount Palomar Observatory
- fotografske plošče  $6^\circ \times 6^\circ$ ,
- 75% neba
- primerjal lastnosti jat
- Abellov radij: 2 Mpc oz. 6.5 Mlyr
- regularne, iregularne
- porazdelitev po nebu in po prostoru

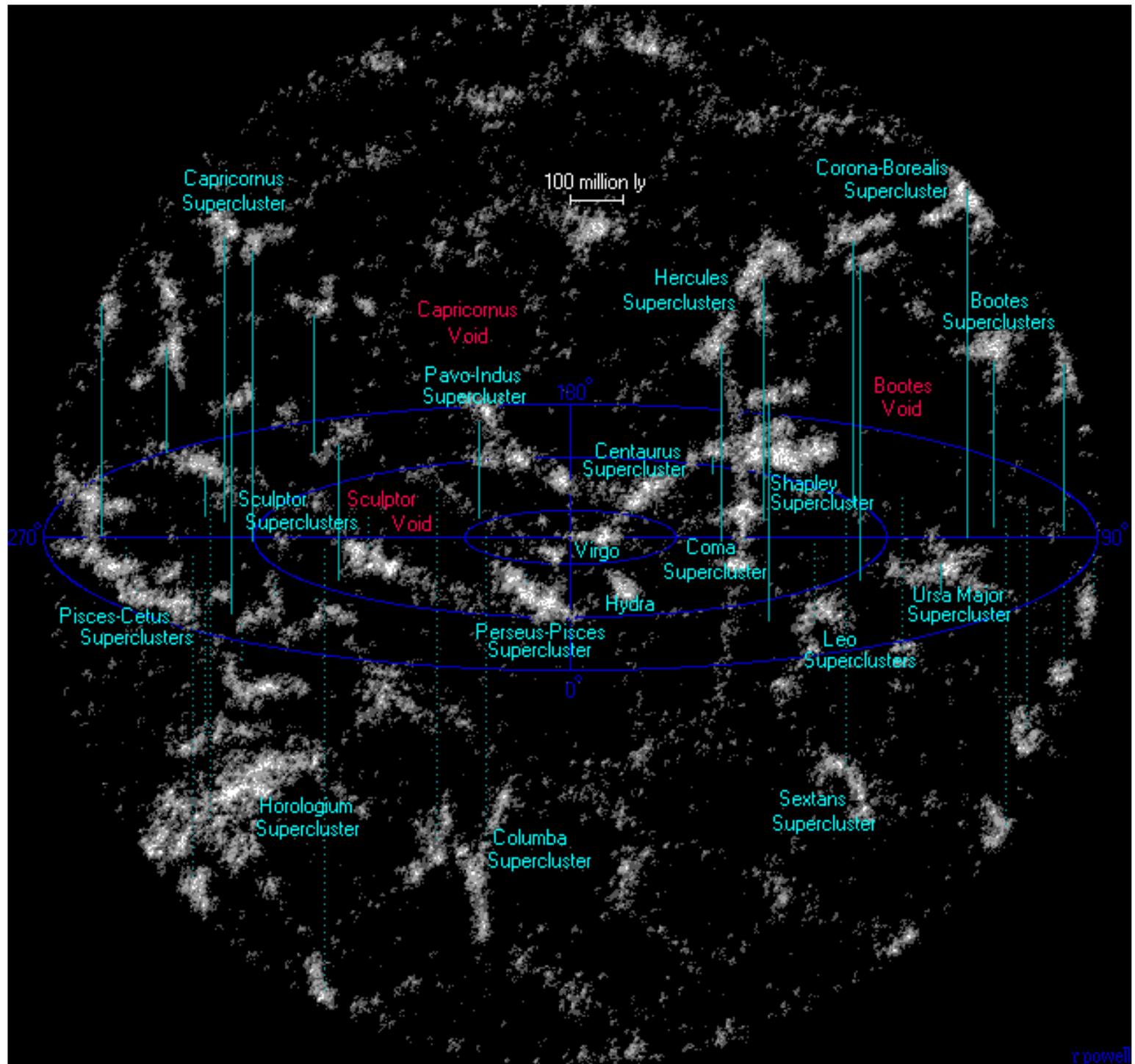




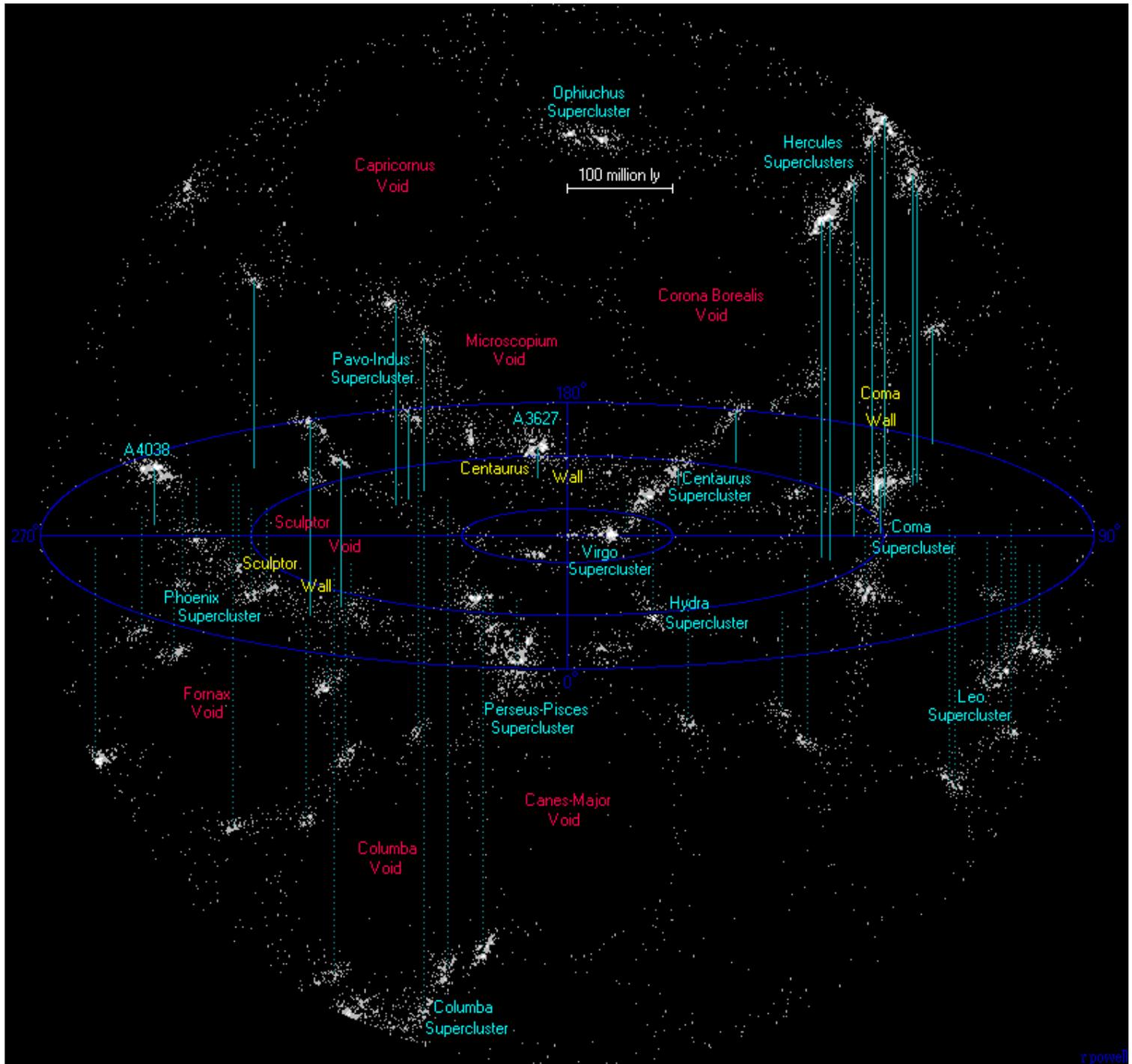




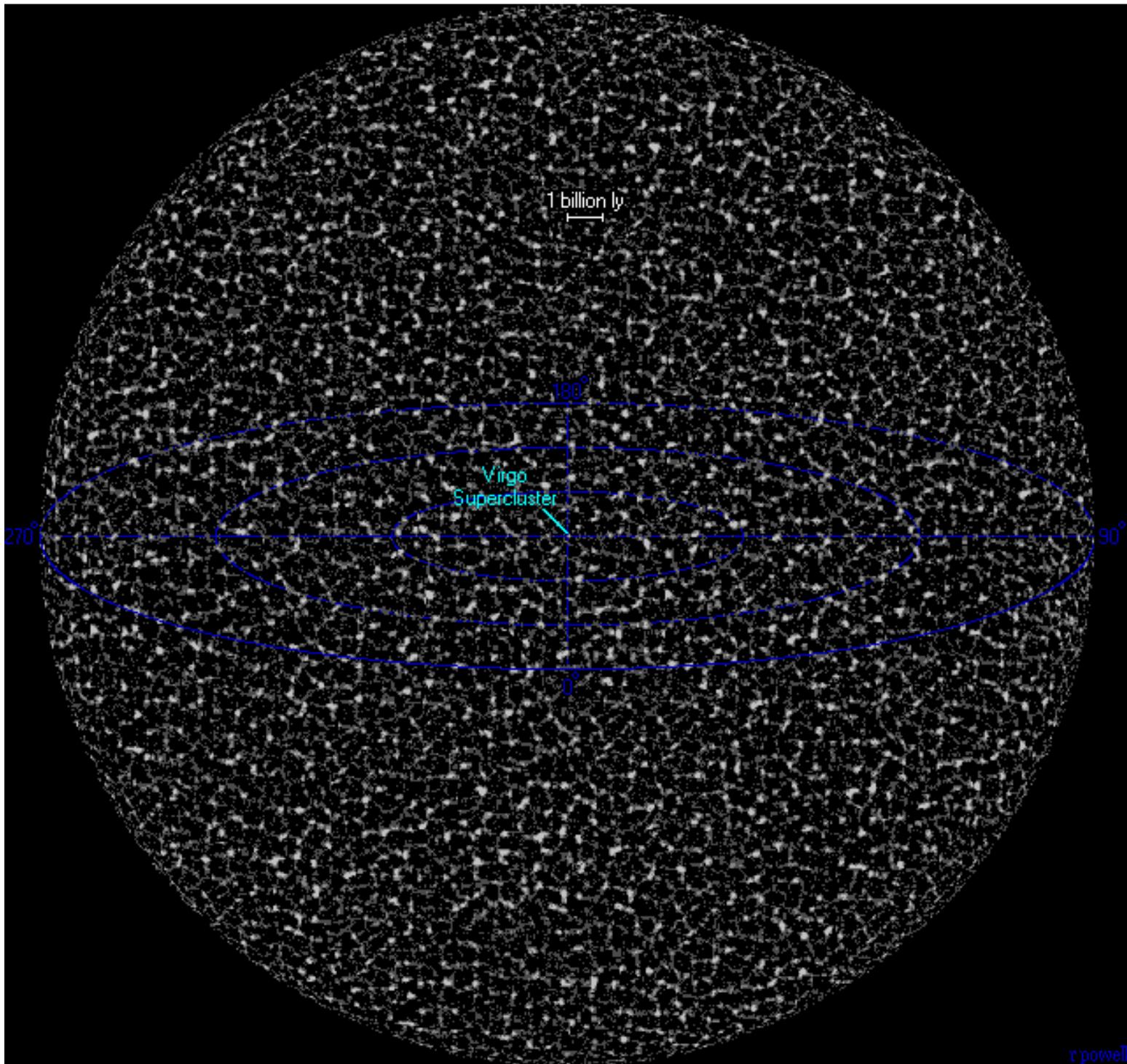
100 Mlyr



1 Gyr



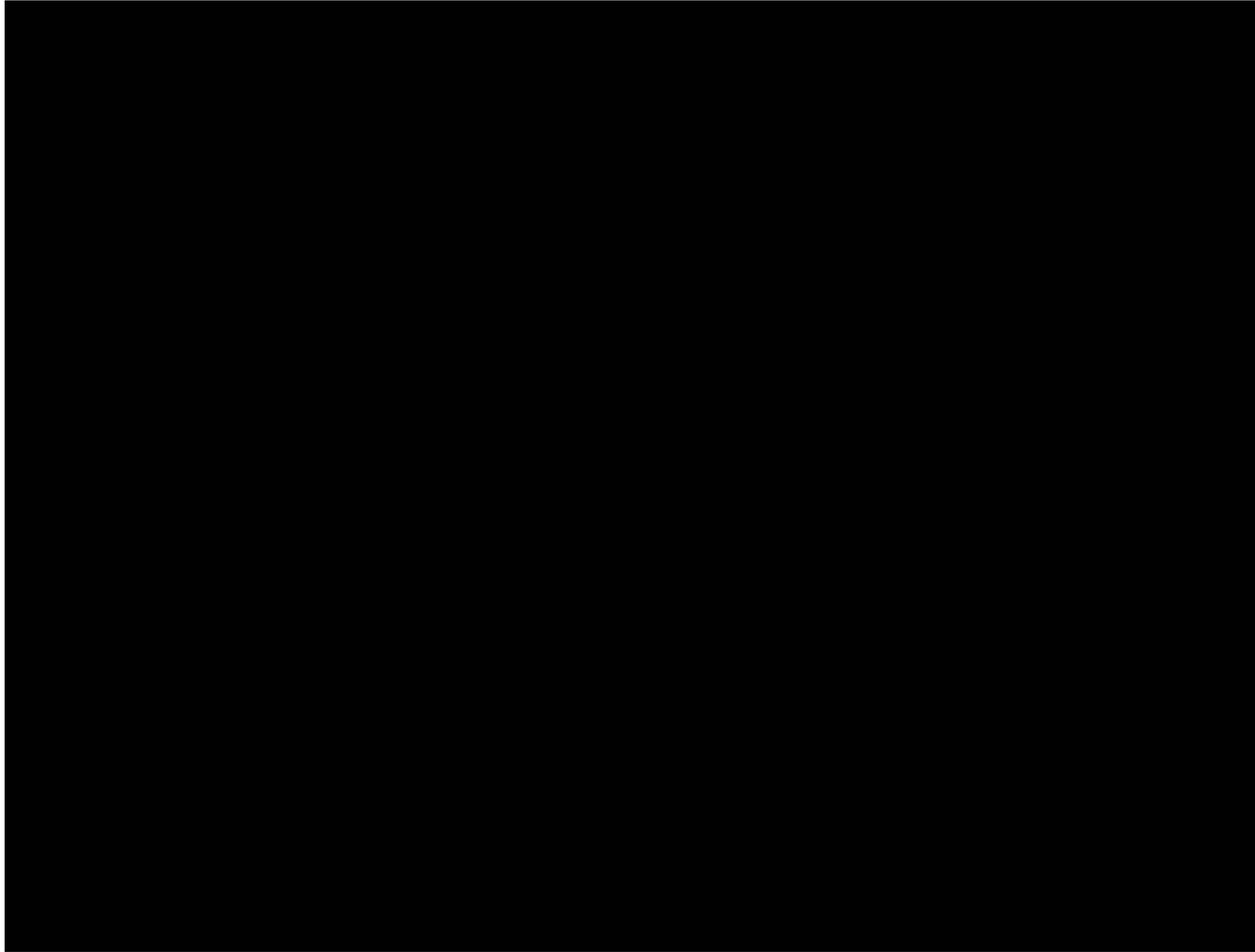




14 Gyr

- število nadjat v vidnem vesolju = 10 milijonov
- število skupin galaksij v vidnem vesolju = 25 milijard
- število velikih galaksij v vidnem vesolju = 350 milijard
- število pritlikavih galaksij v vidnem vesolju = 7 bilijonov
- število zvezd v vidnem vesolju =  $3 \times 10^{22}$

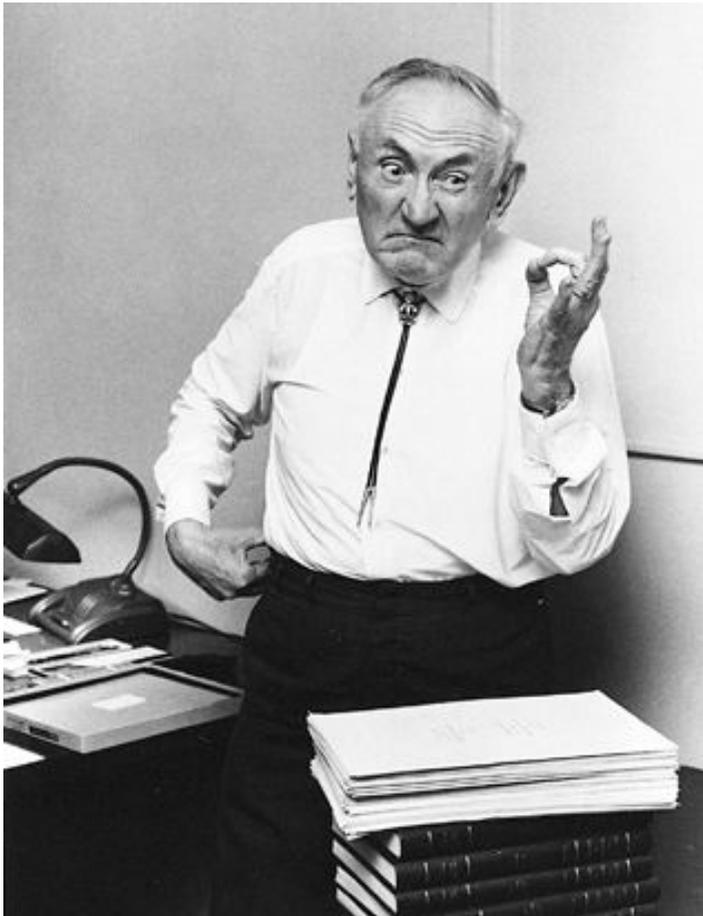
# Razdalje v vesolju



# mase jat galaksij

virializirane jate / nevirializirane

disperzija hitrosti, virialni teorem:  $M \approx R_A \langle \Delta v^2 \rangle / G$



Coma cluster:

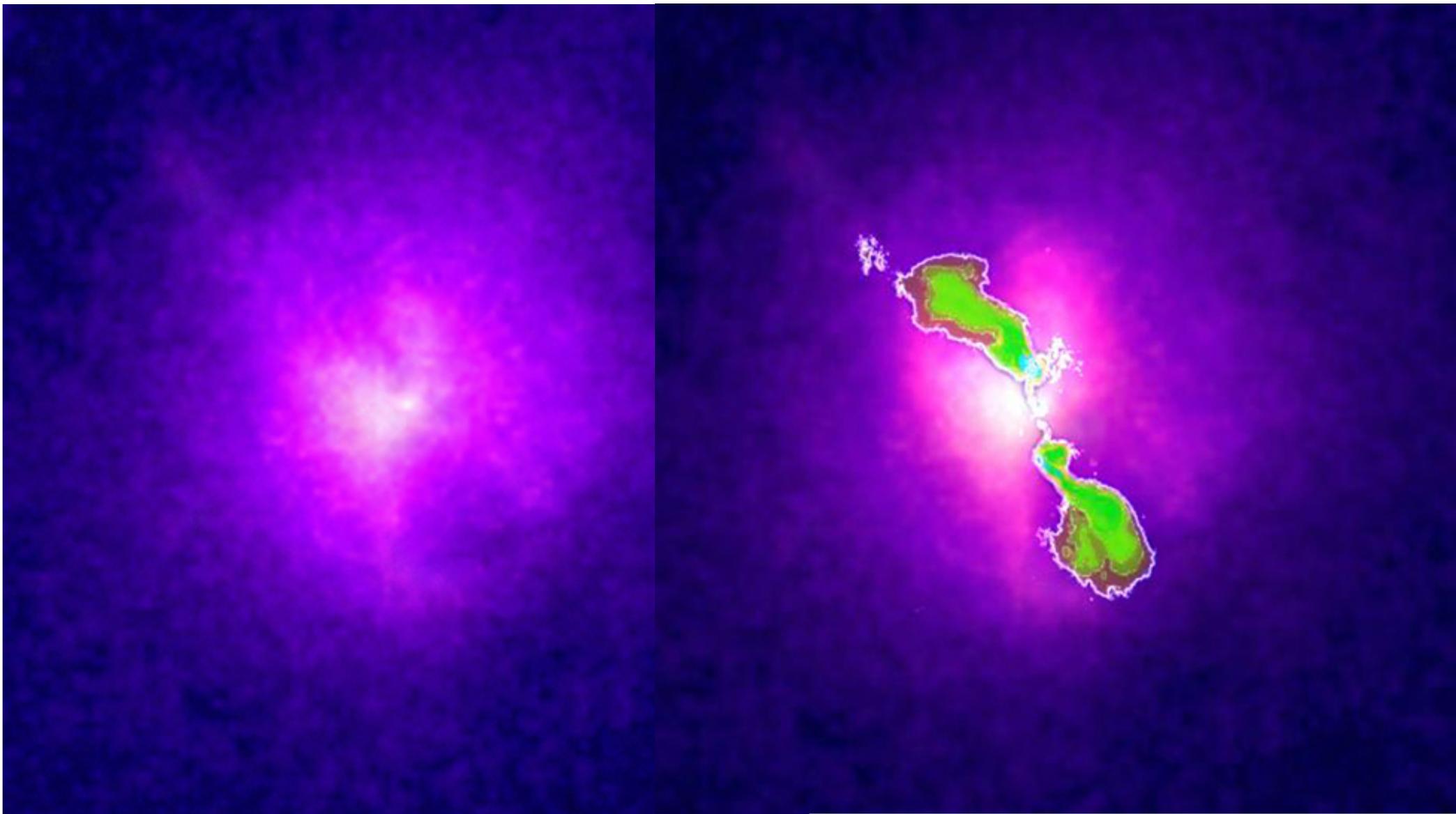
skupna masa  $\gg$  mase galaksij

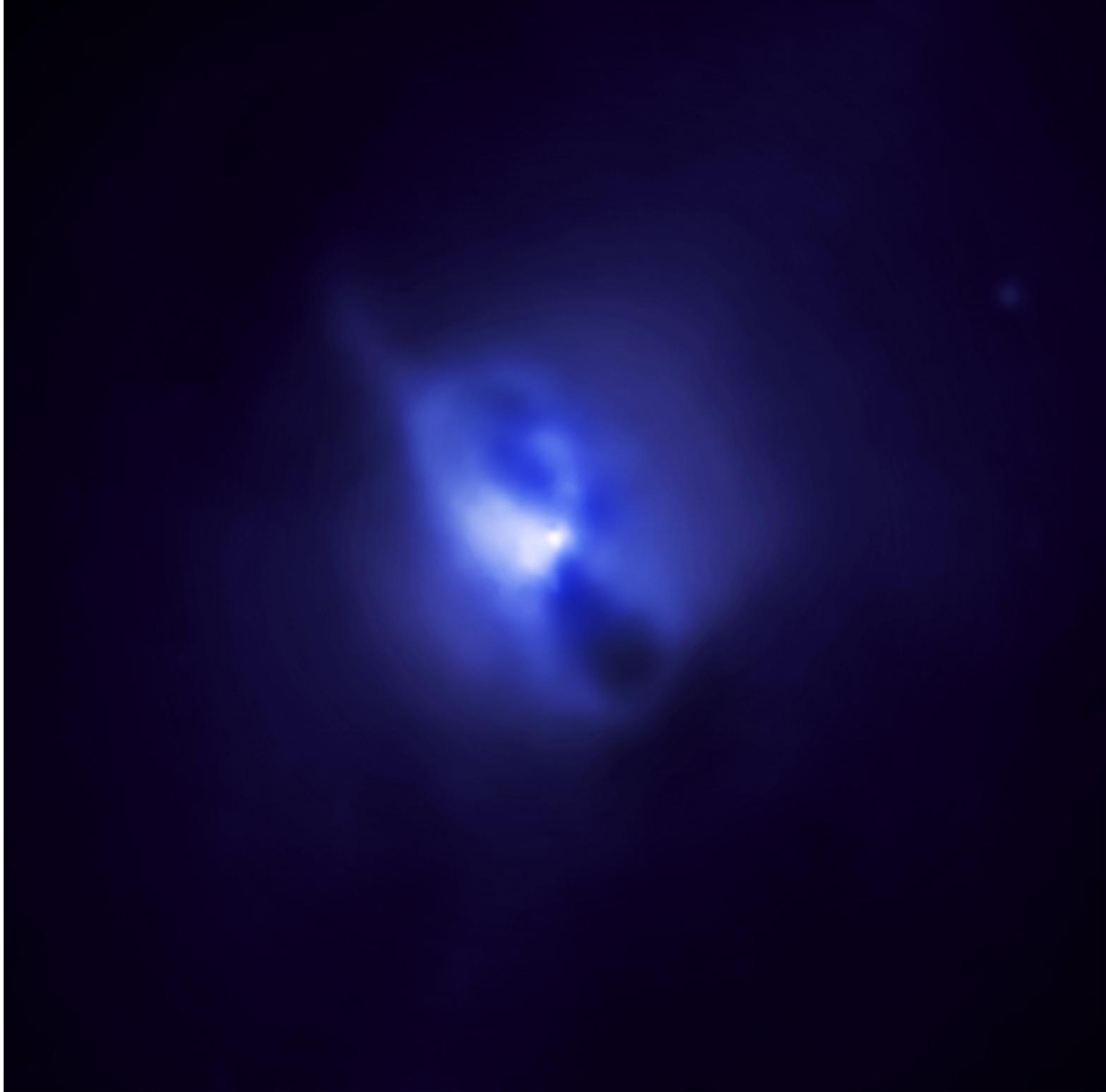
eden prvih dokazov o temni snovi!

$\Delta v \approx 550 \text{ km/s} \rightarrow M \approx 10^{14} M_{\odot}$

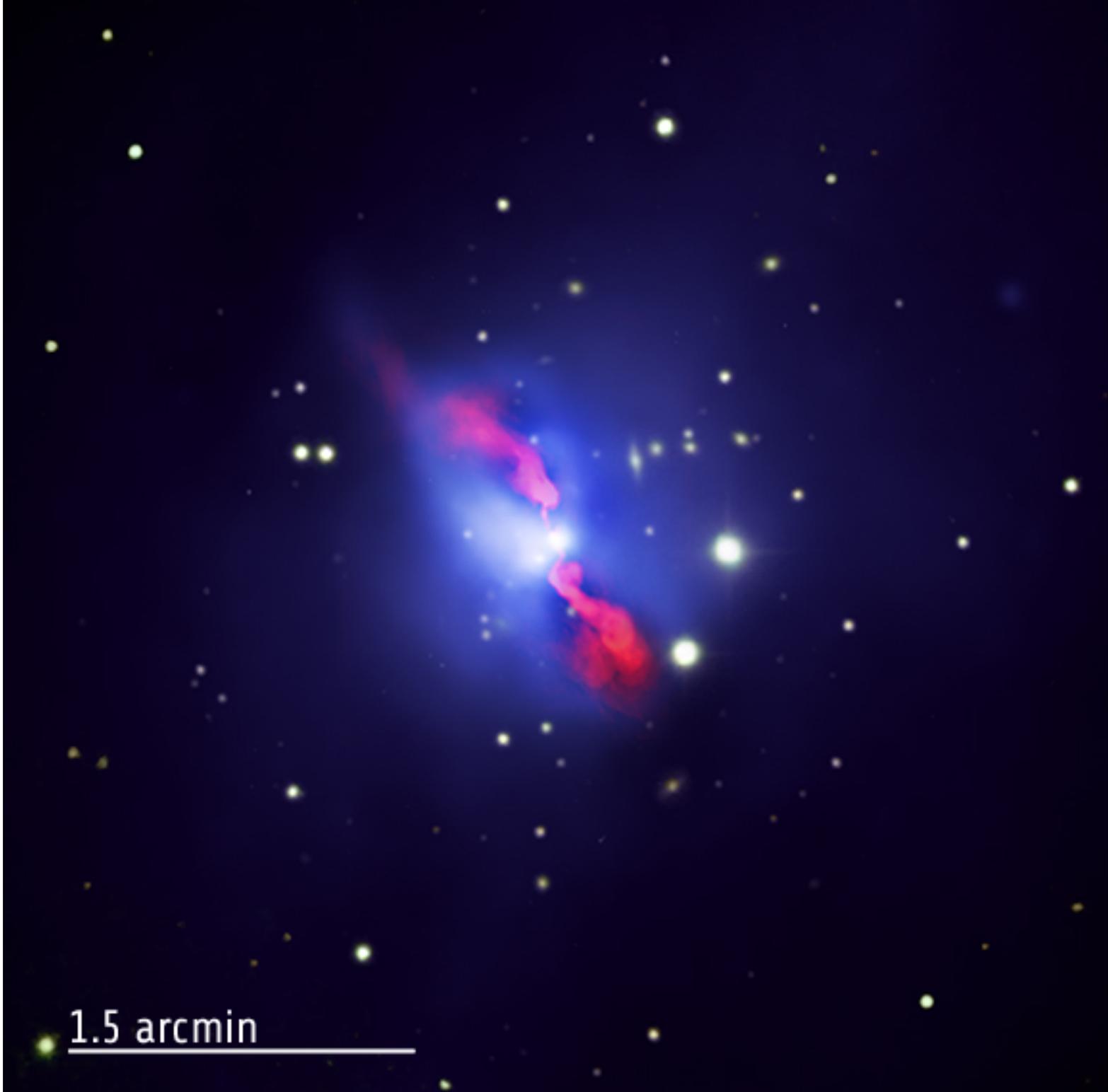
Fritz Zwicky (1898 – 1974)

# Hydra A





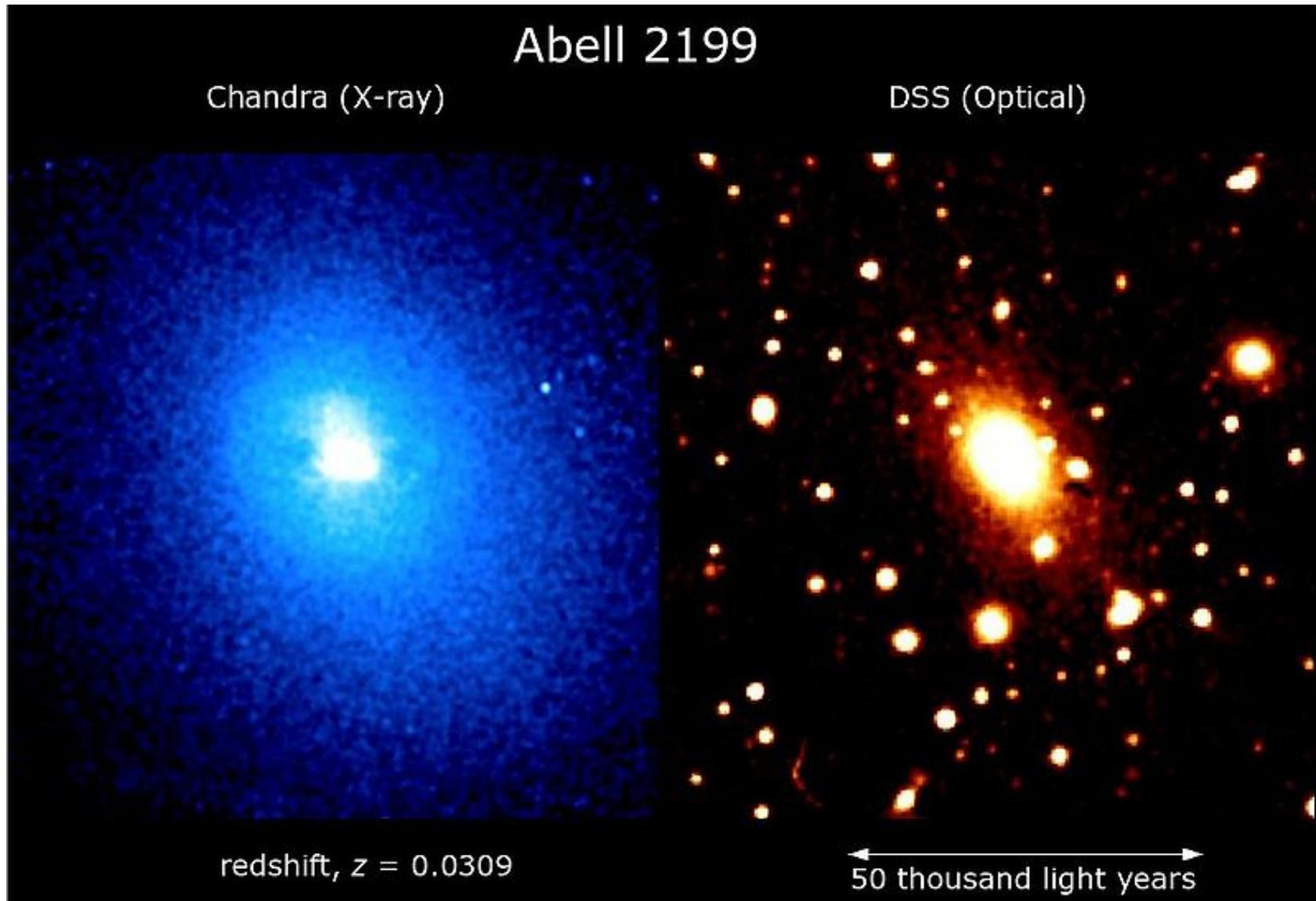




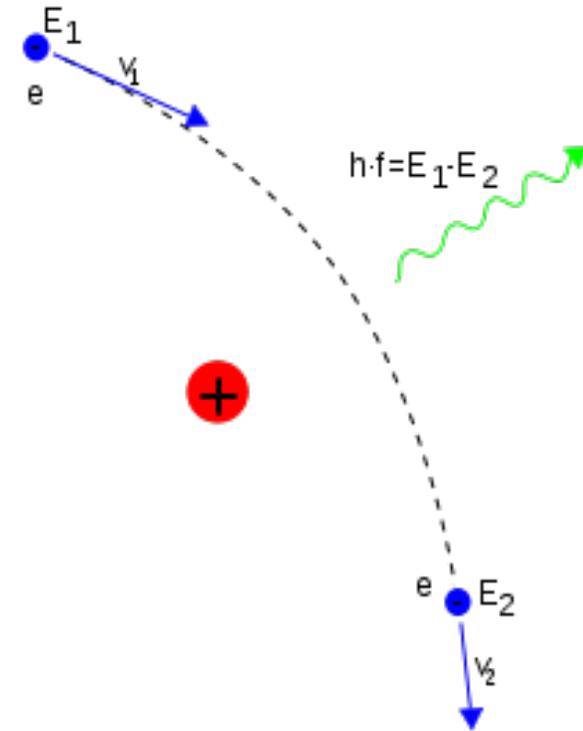
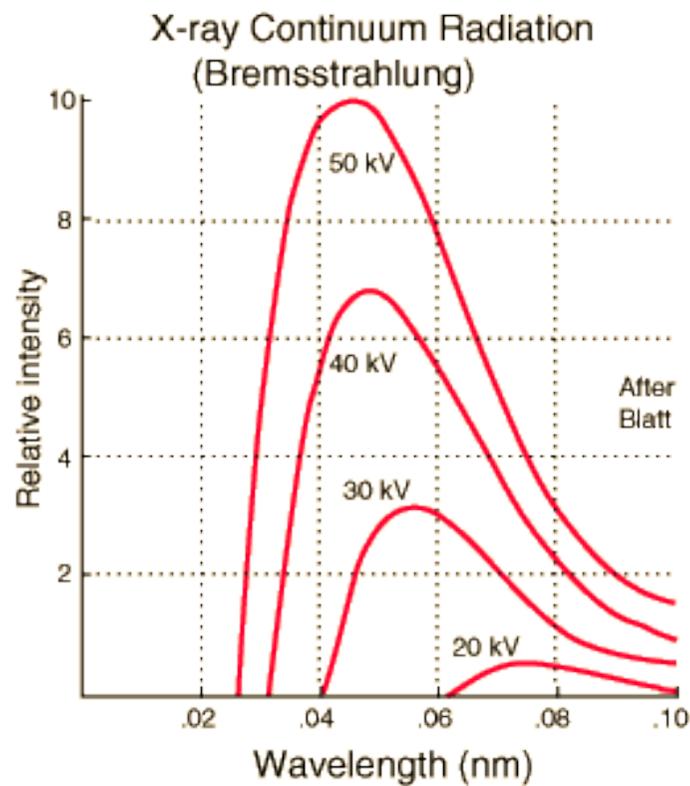
1.5 arcmin



# jate vidne v rentgenski svetlobi



# zavorno sevanje

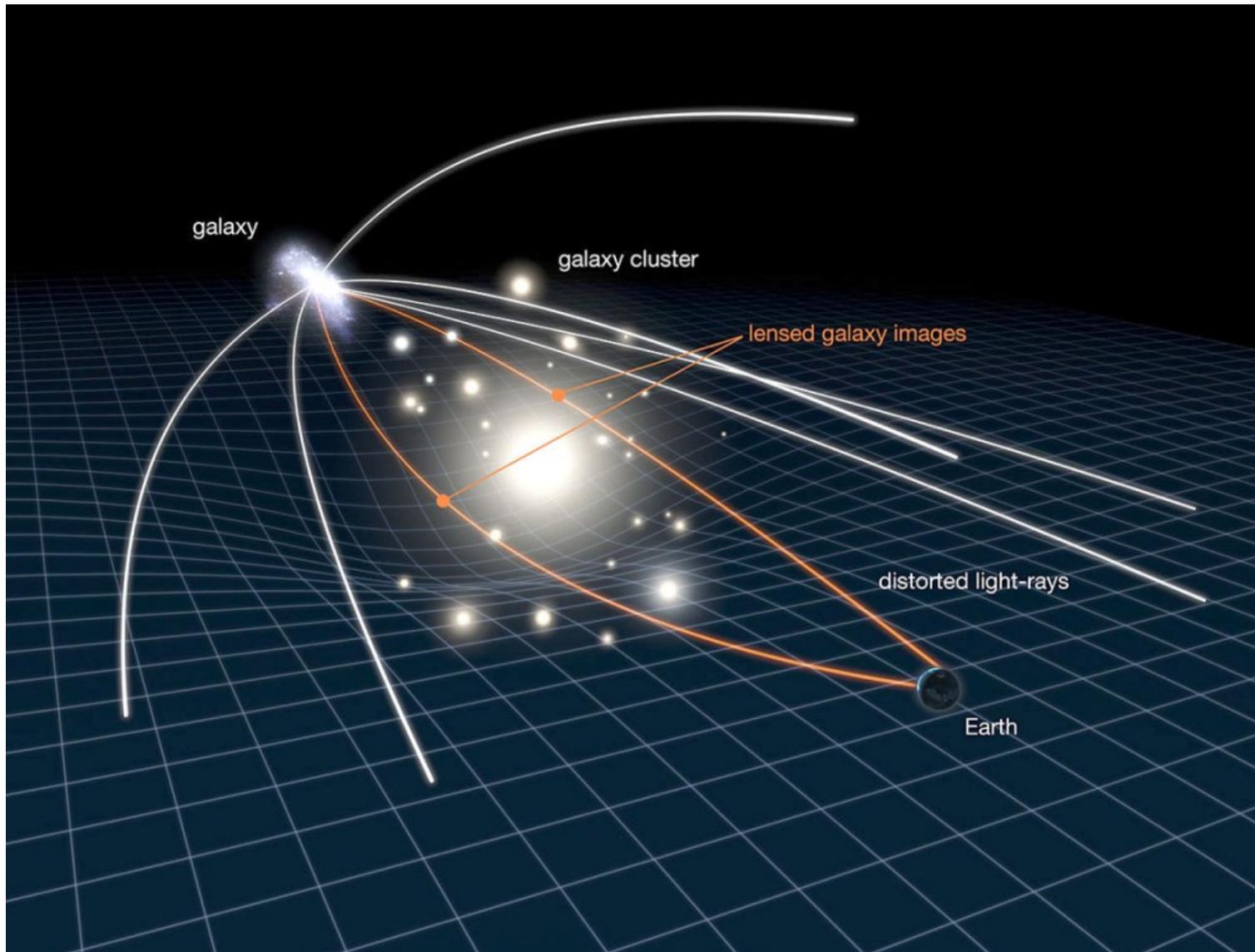


$$E_\gamma \approx kT$$

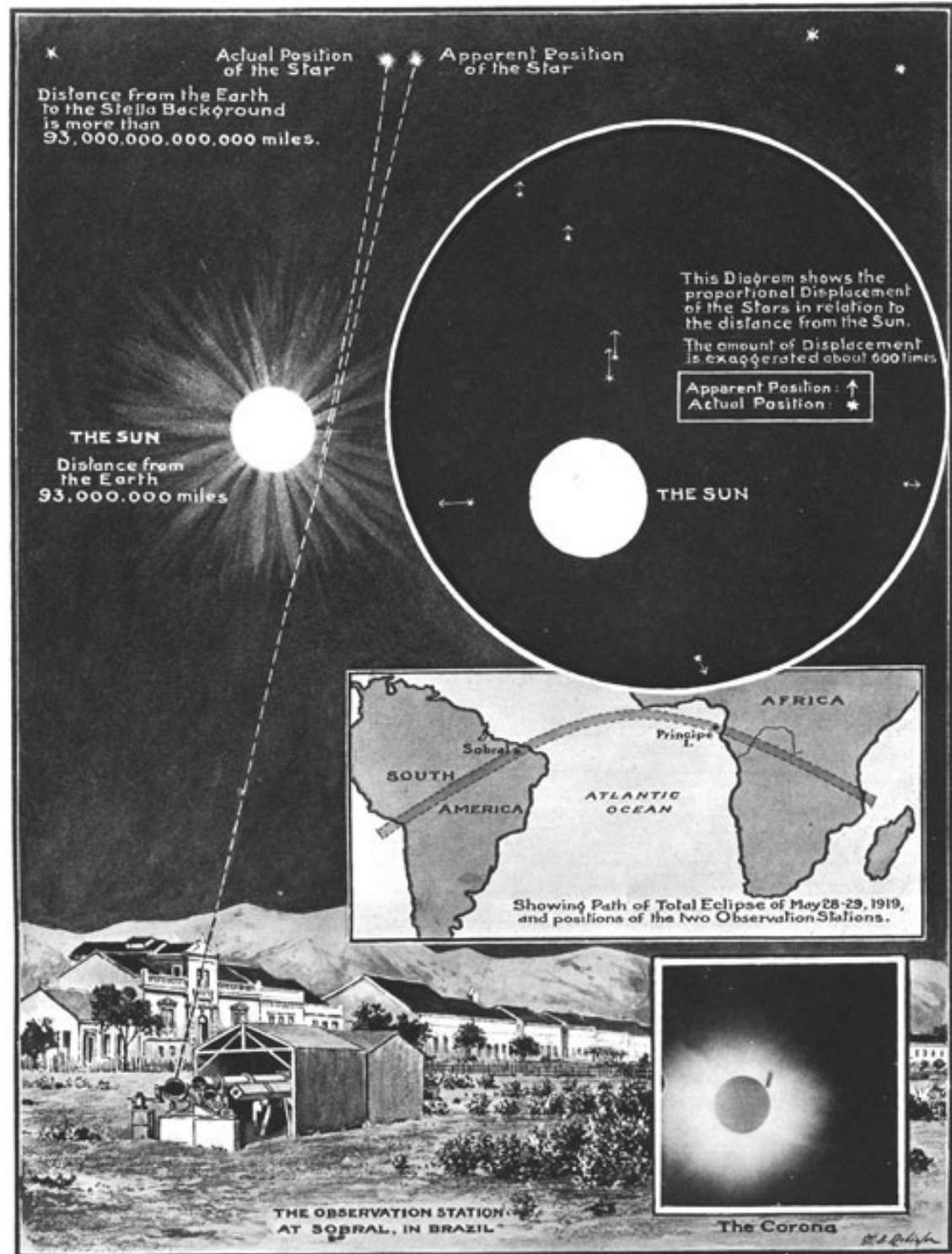
$$E_\gamma \approx 1-10 \text{ keV} : T \approx 10^7 - 10^8 \text{ K}$$

- zakaj je plin tako vroč, da seva v rentgenski svetlobi? – virialni teorem
- zakaj se ne sesede? – hidrostatično ravnovesje
- kaj nam pove o masi jate galaksij? –
- $10^{14} - 10^{15} M_{\odot}$   
≈10% galaksije  
≈10-30% Inter Cluster Medium (ICM)  
ostalo: temna snov

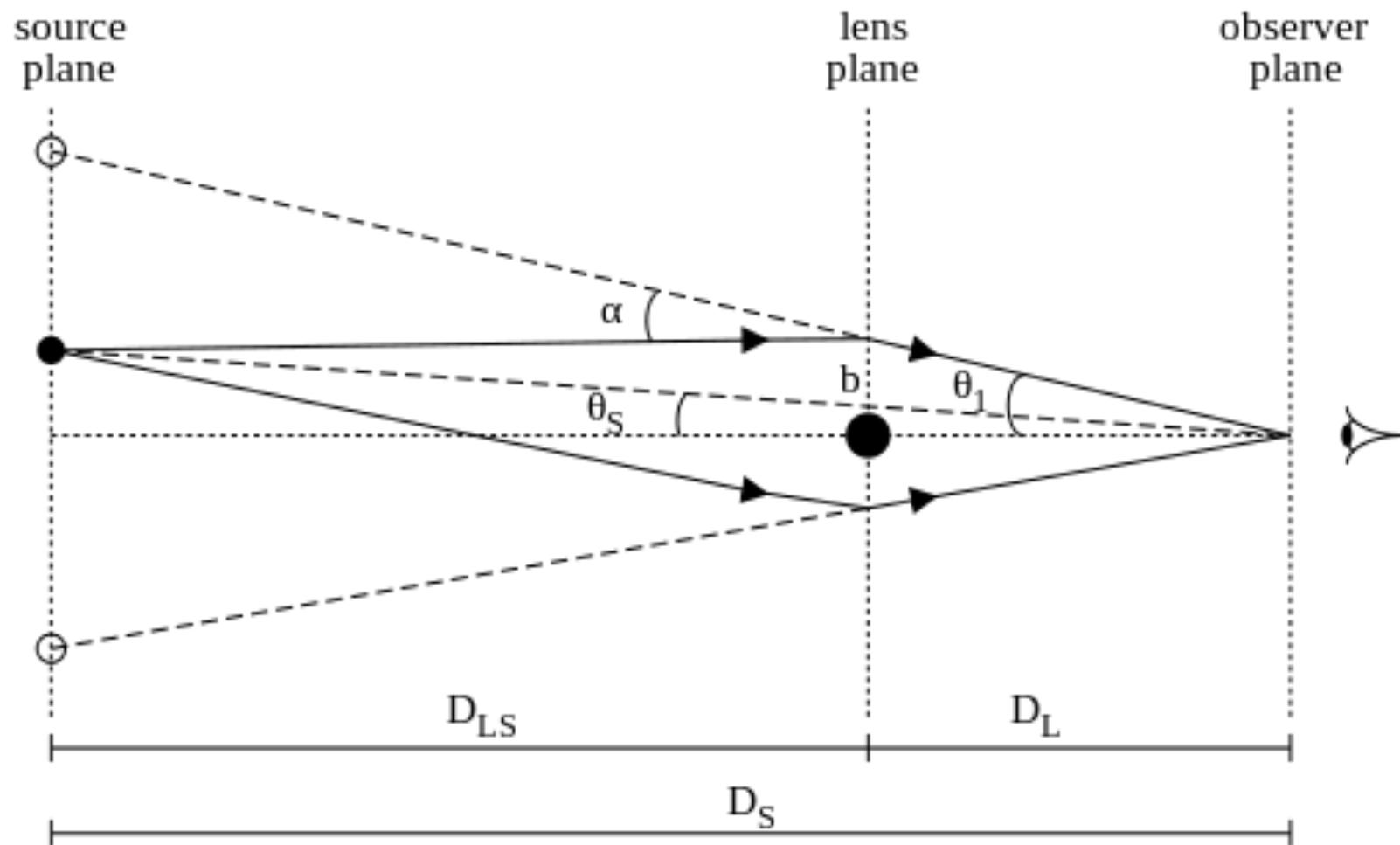
# gravitacijsko lečenje



- Einstein
- 1919: Eddington

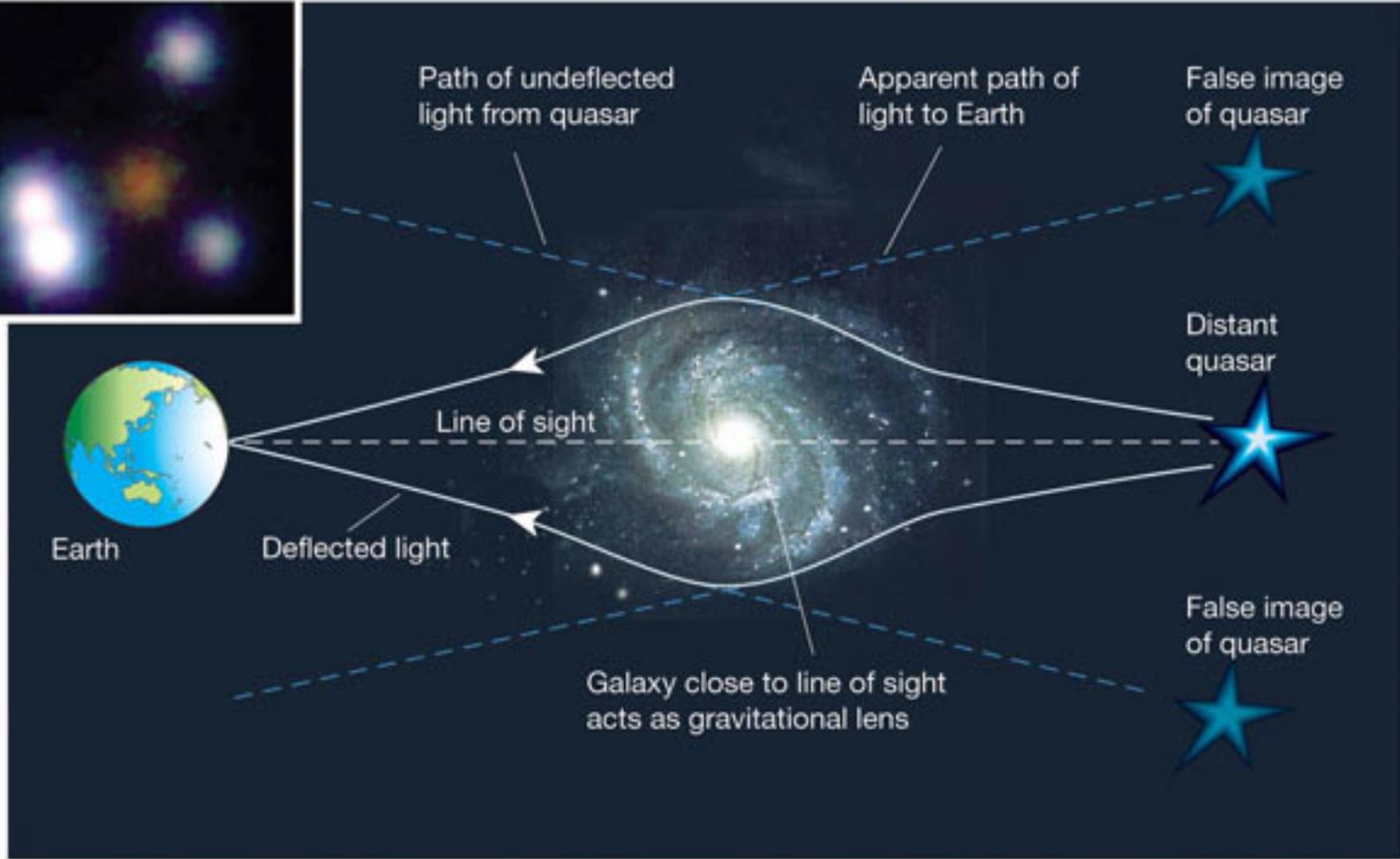


- Newtonov pristop
- splošno relativističen:
- $\alpha = 4GM/bc^2$
- enačba šibkega lečenja:



$$\theta_E = \left( \frac{4GM}{c^2} \frac{d_{LS}}{d_L d_S} \right)^{1/2}$$

$$\theta_1 = \theta_S + \frac{\theta_E^2}{\theta_1}$$





**EINSTEIN RING  
IMAGE**

*An Einstein Ring is formed when  
the earth, lens and object are  
perfectly aligned*

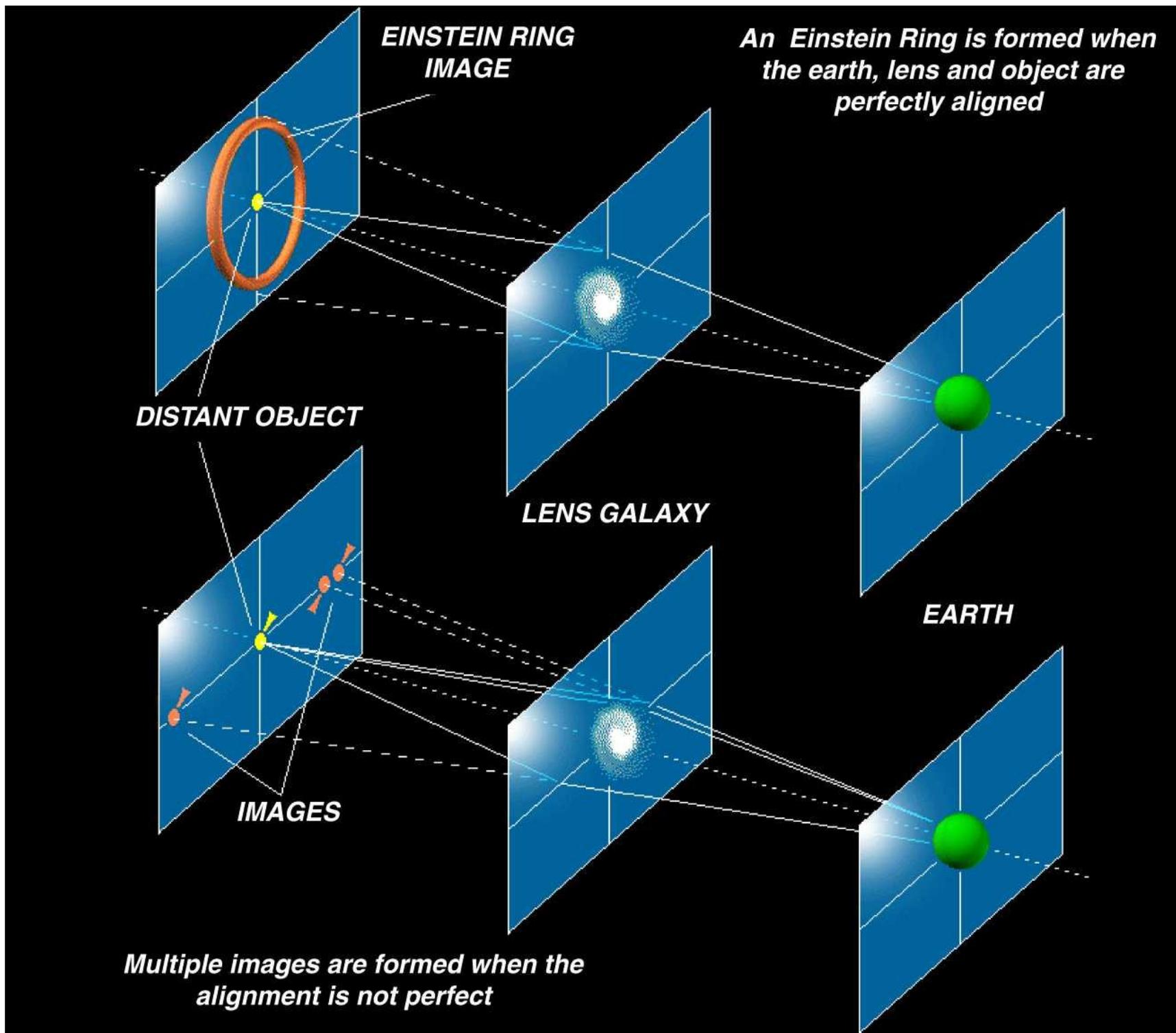
**DISTANT OBJECT**

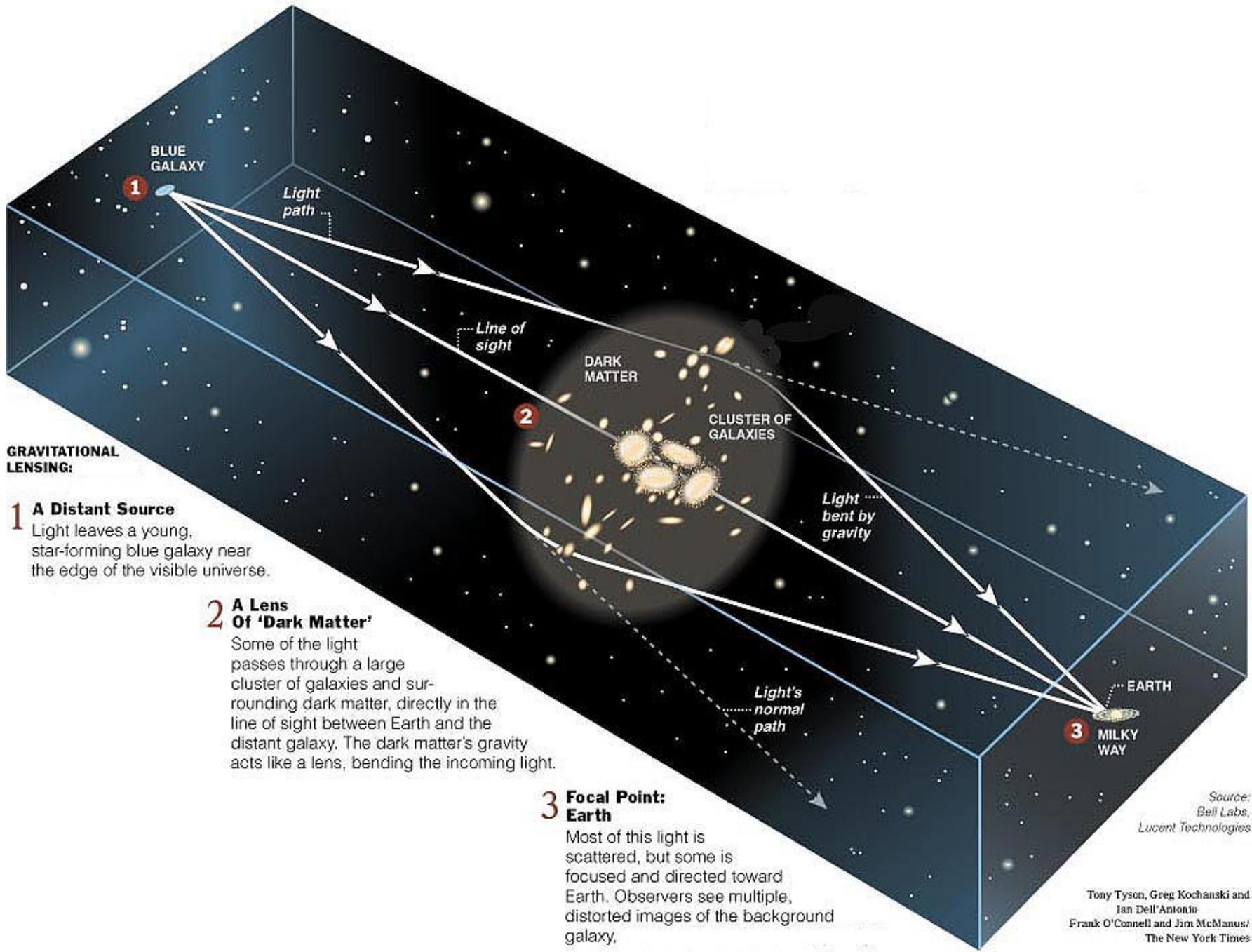
**LENS GALAXY**

**EARTH**

**IMAGES**

*Multiple images are formed when the  
alignment is not perfect*





**GRAVITATIONAL LENSING:**

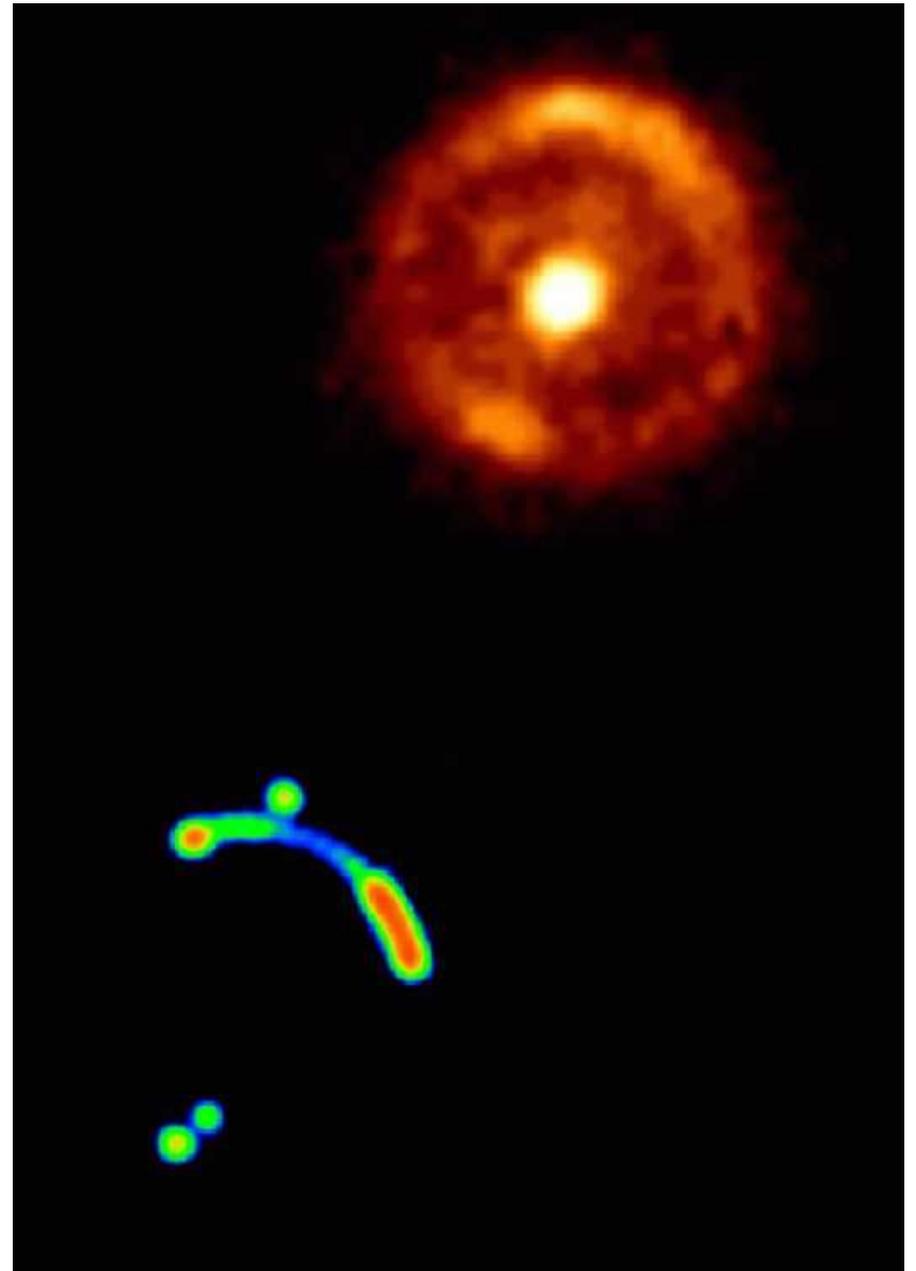
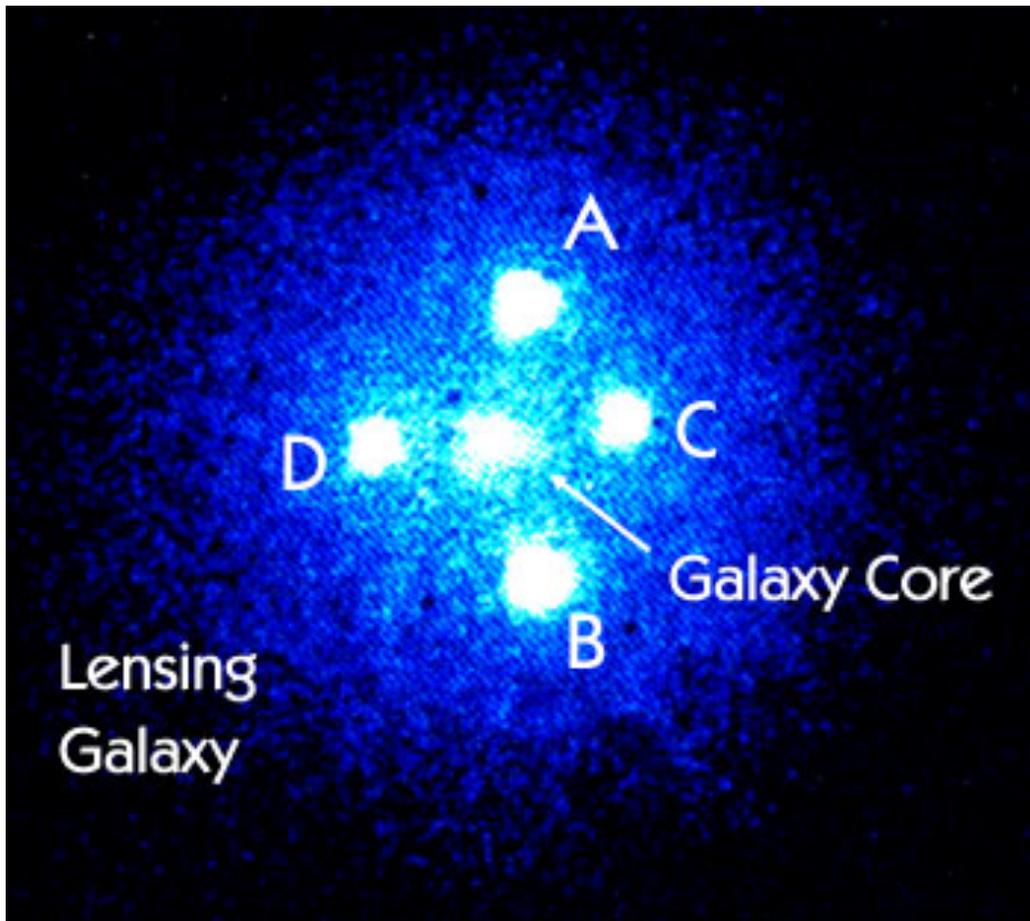
**1 A Distant Source**  
 Light leaves a young, star-forming blue galaxy near the edge of the visible universe.

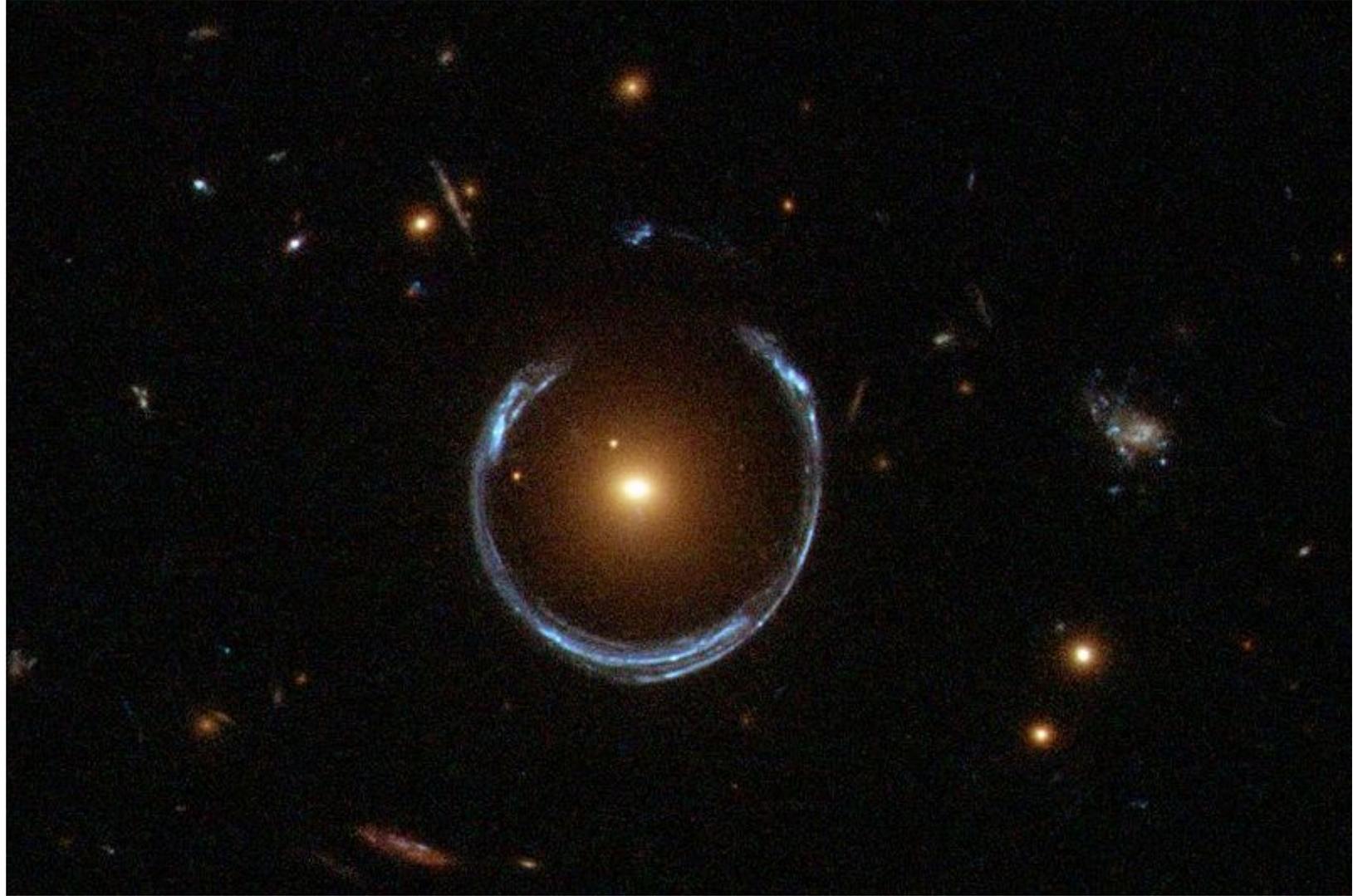
**2 A Lens Of 'Dark Matter'**  
 Some of the light passes through a large cluster of galaxies and surrounding dark matter, directly in the line of sight between Earth and the distant galaxy. The dark matter's gravity acts like a lens, bending the incoming light.

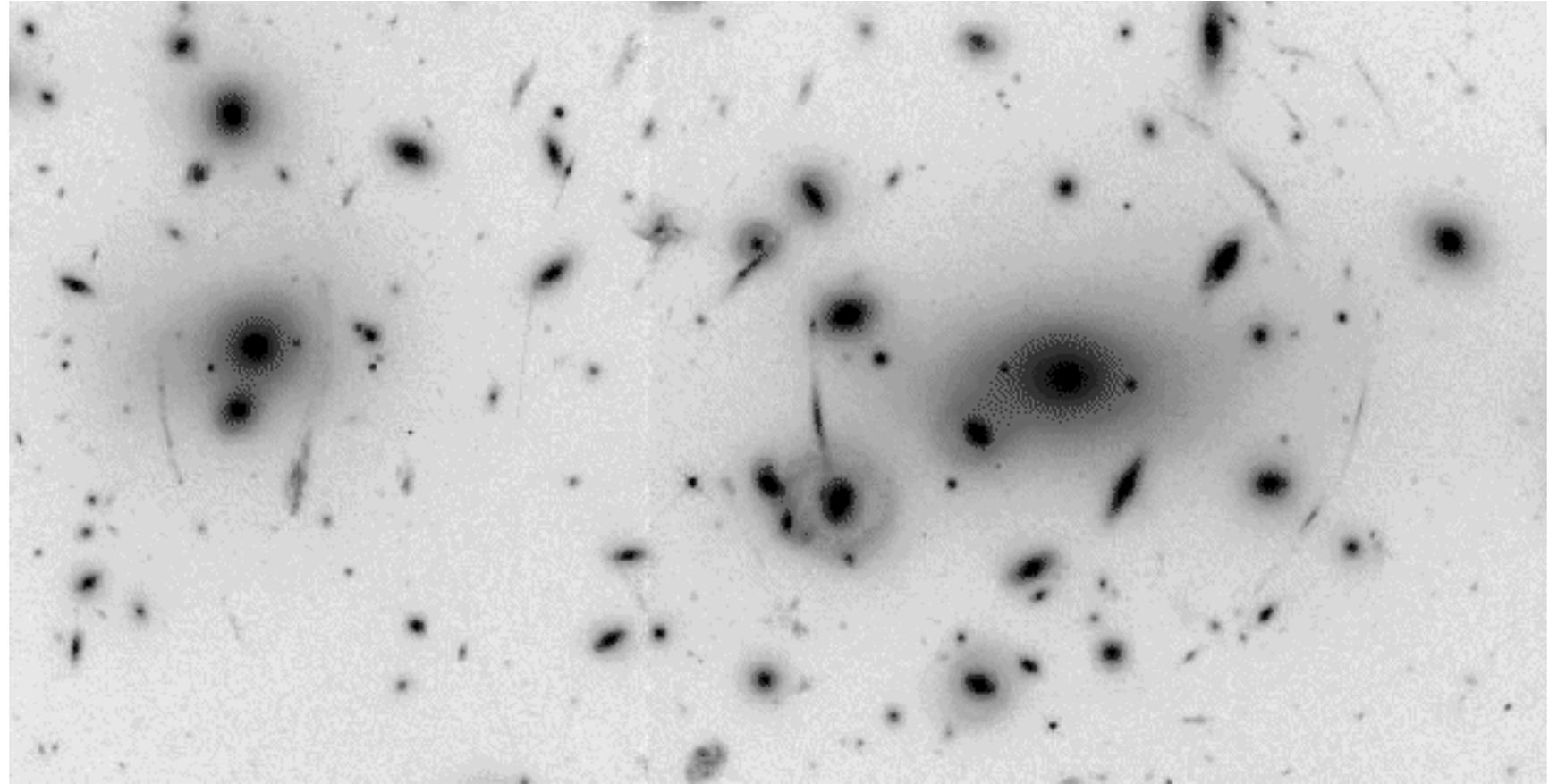
**3 Focal Point: Earth**  
 Most of this light is scattered, but some is focused and directed toward Earth. Observers see multiple, distorted images of the background galaxy.

Source:  
 Bell Labs,  
 Lucent Technologies

Tony Tyson, Greg Kochanski and  
 Jan Dell'Antonio  
 Frank O'Connell and Jim McManus/  
 The New York Times









# sestava jat

- 3 metode, konsistentni rezultati
- $10^{14}$ - $10^{15} M_{\odot}$
- galaksije: <10% mase
- plin: 10-25%
- temna snov: 70-90%

# Nastanek in razvoj jat

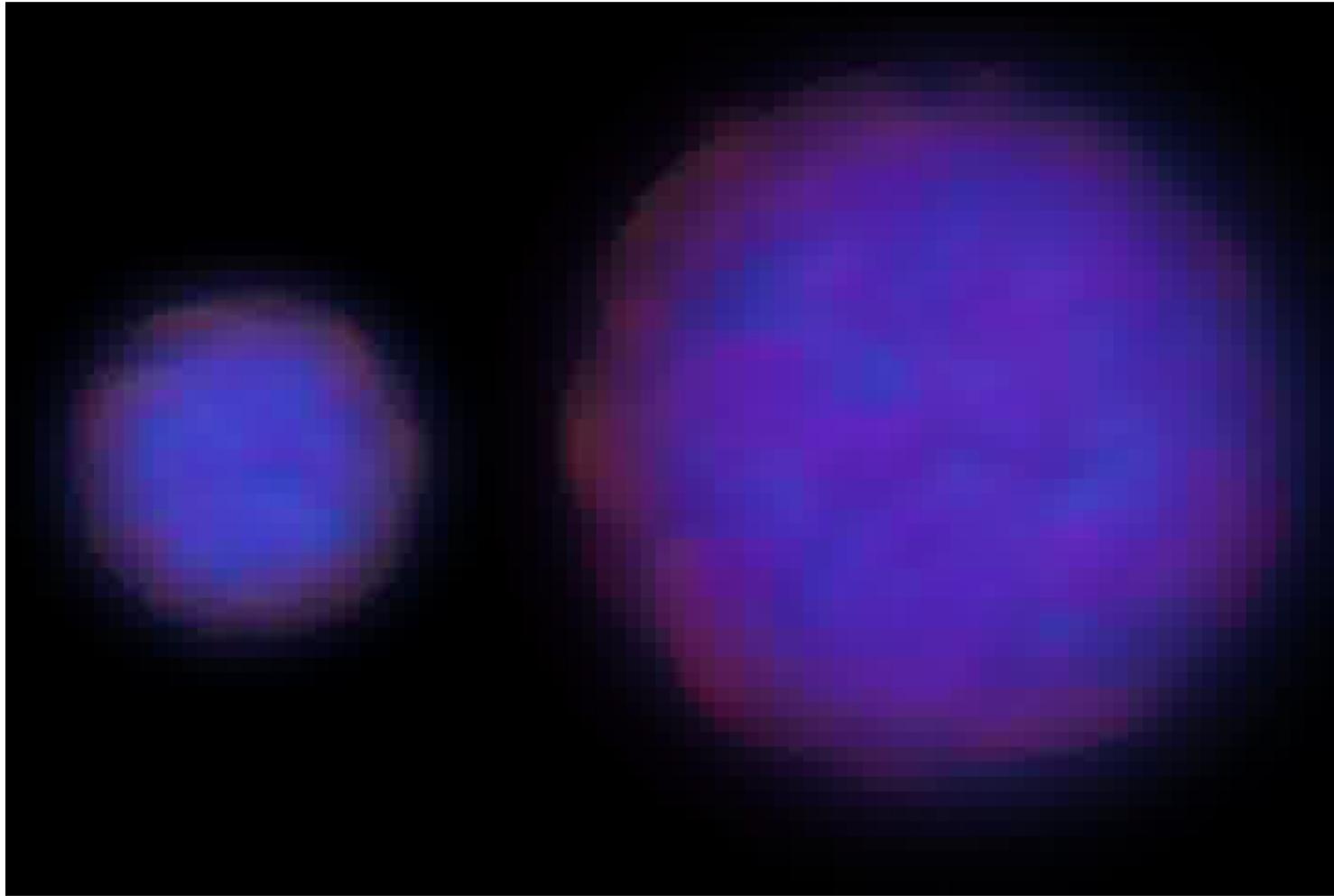
- hierarhični model
- trki jat:

jata Izstrelek  
(Bullet cluster)

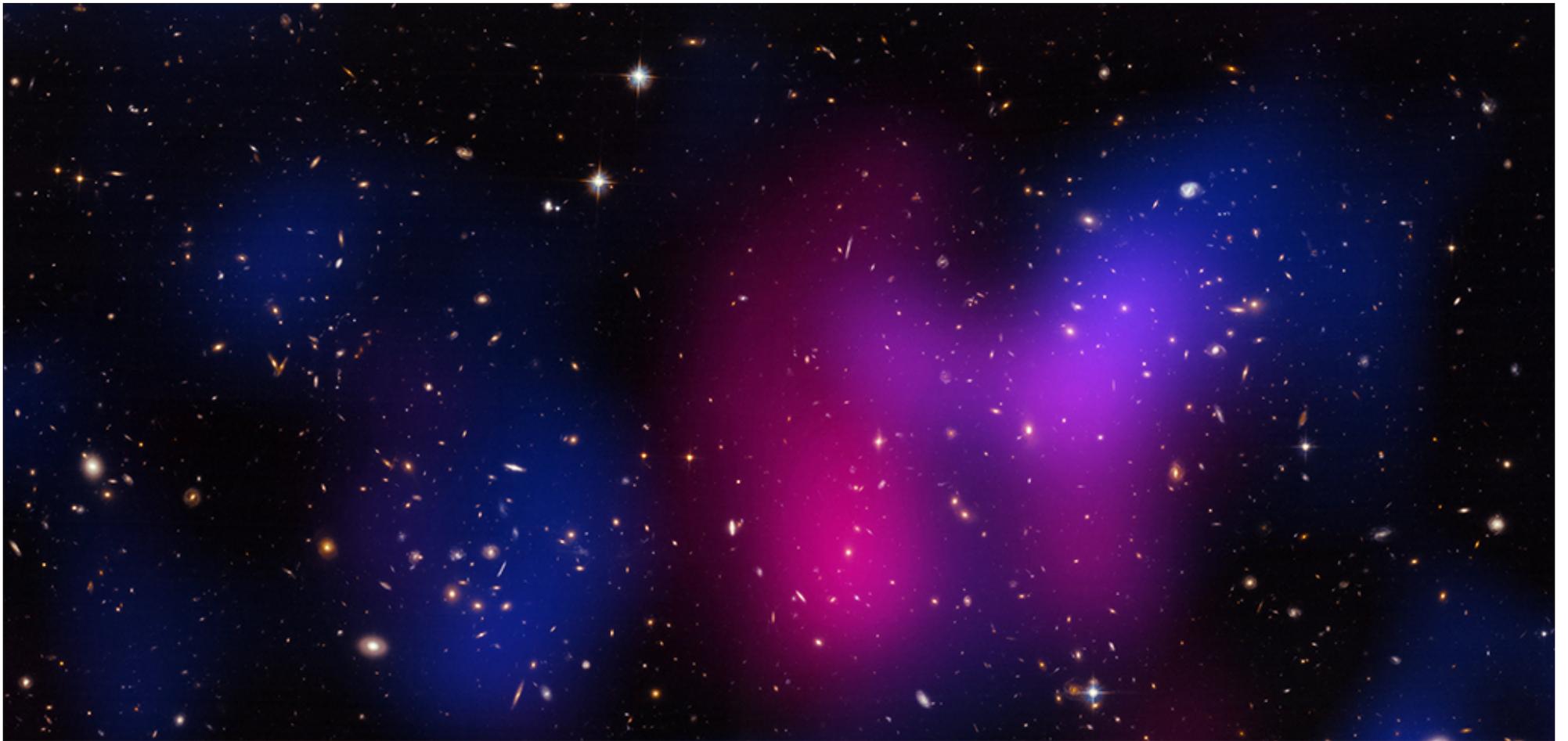




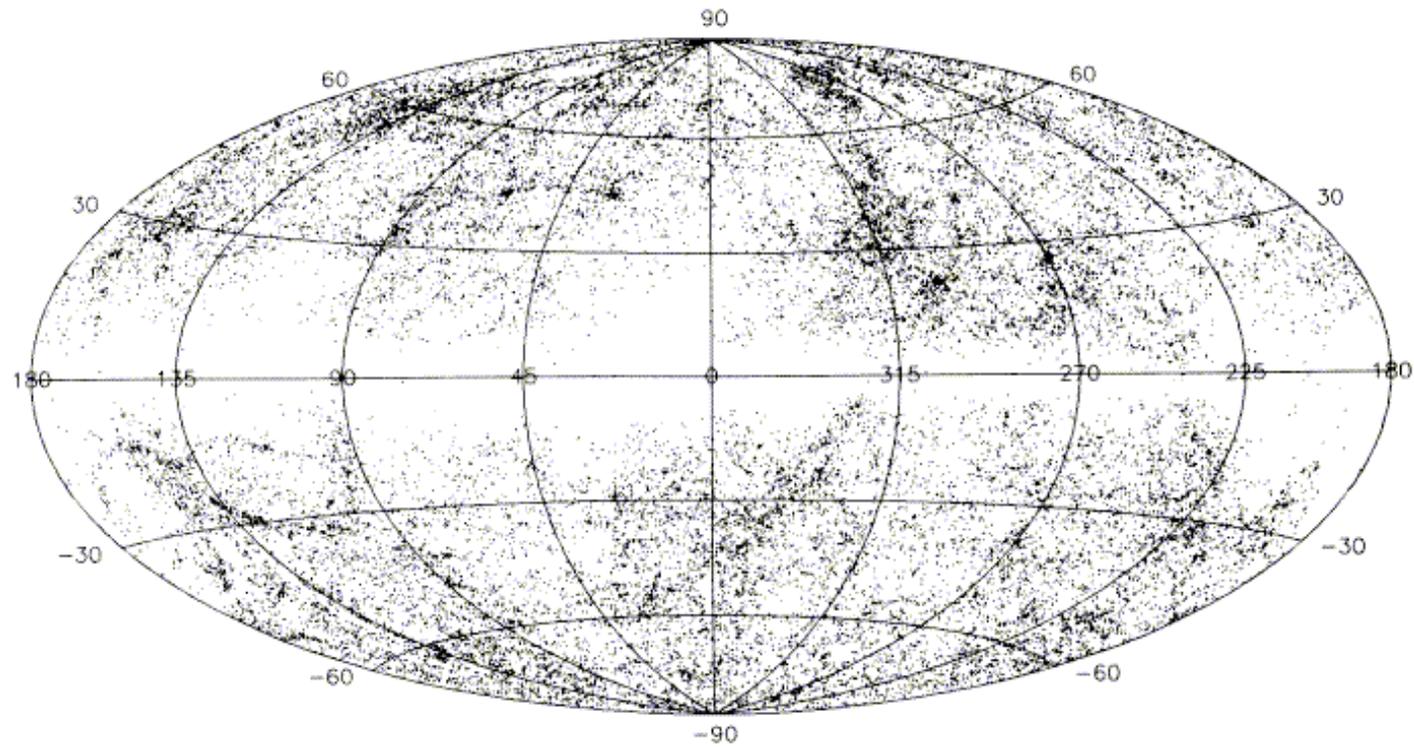




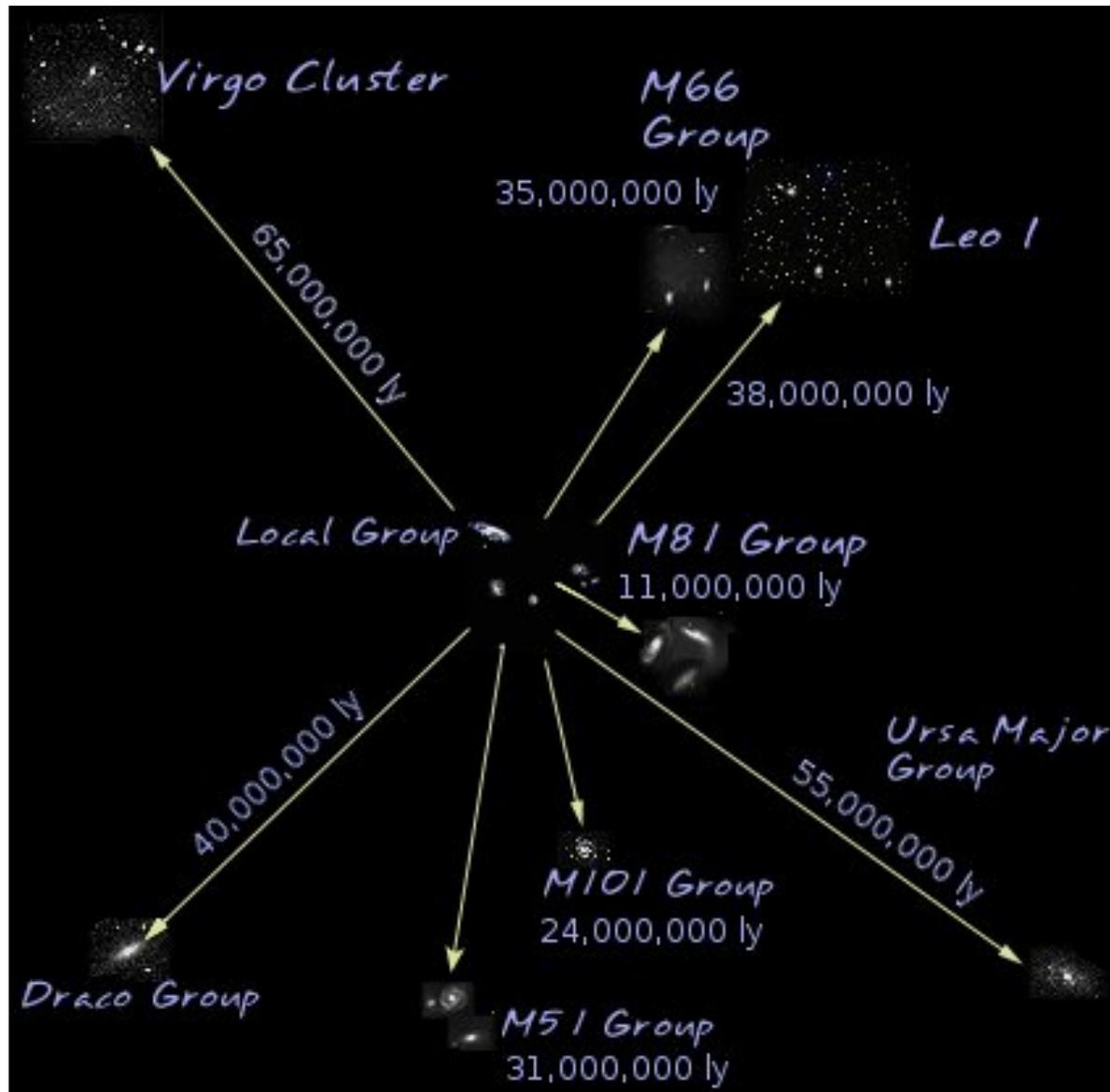
jata Mušketna krogla (Musket Ball cluster)



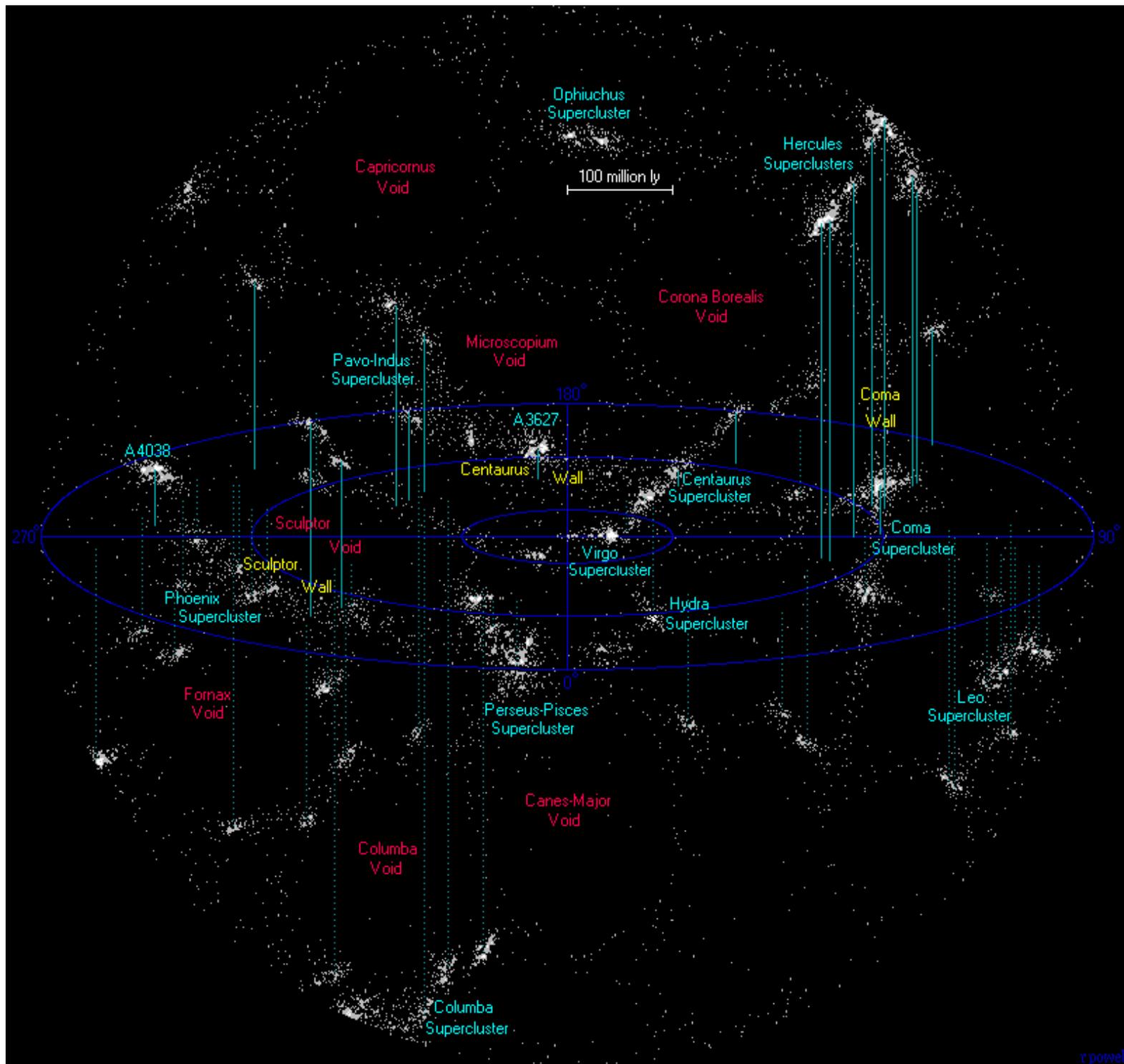
# na večjih skalah



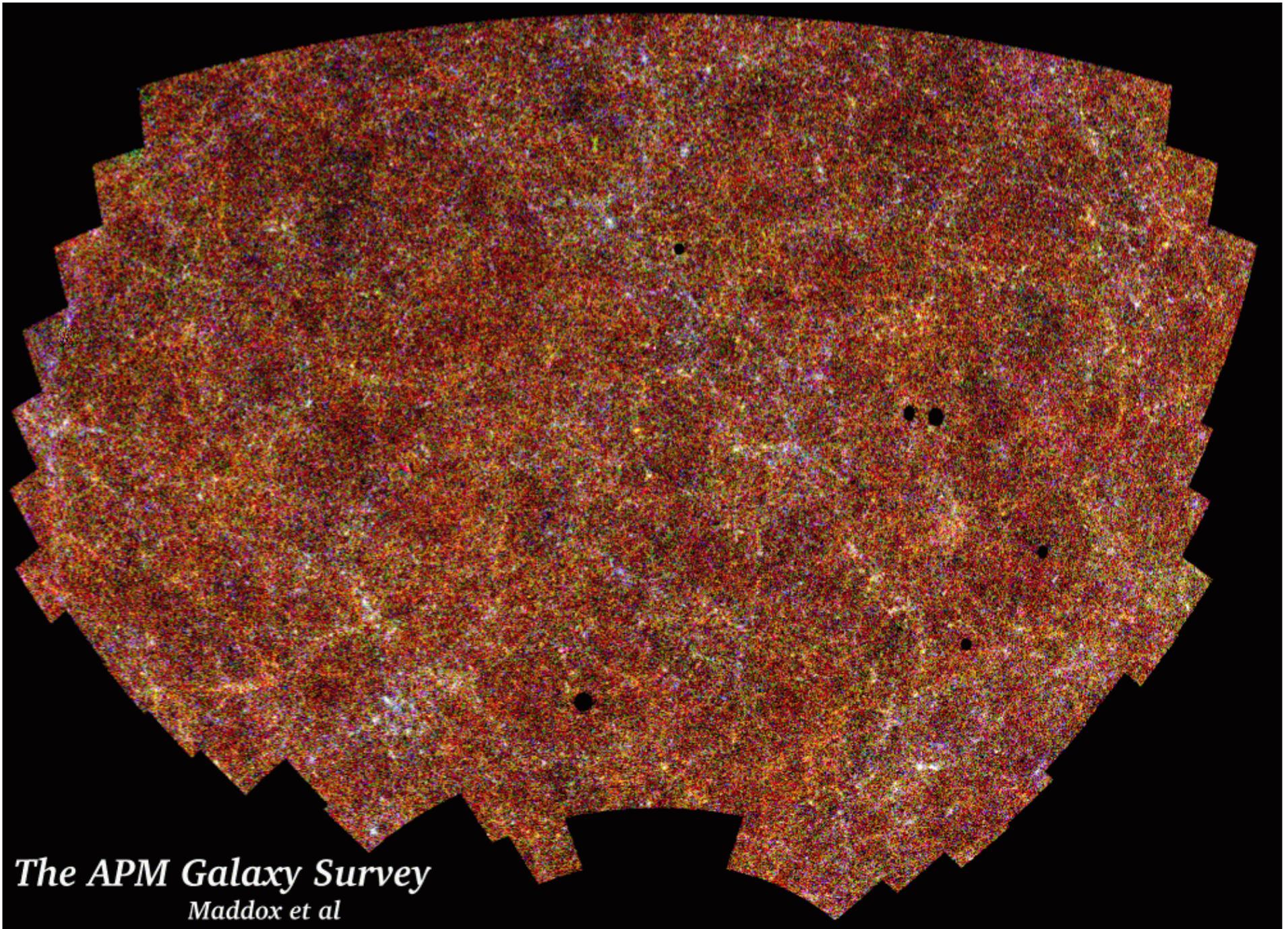
# lokalna nadjata







1 Gyr

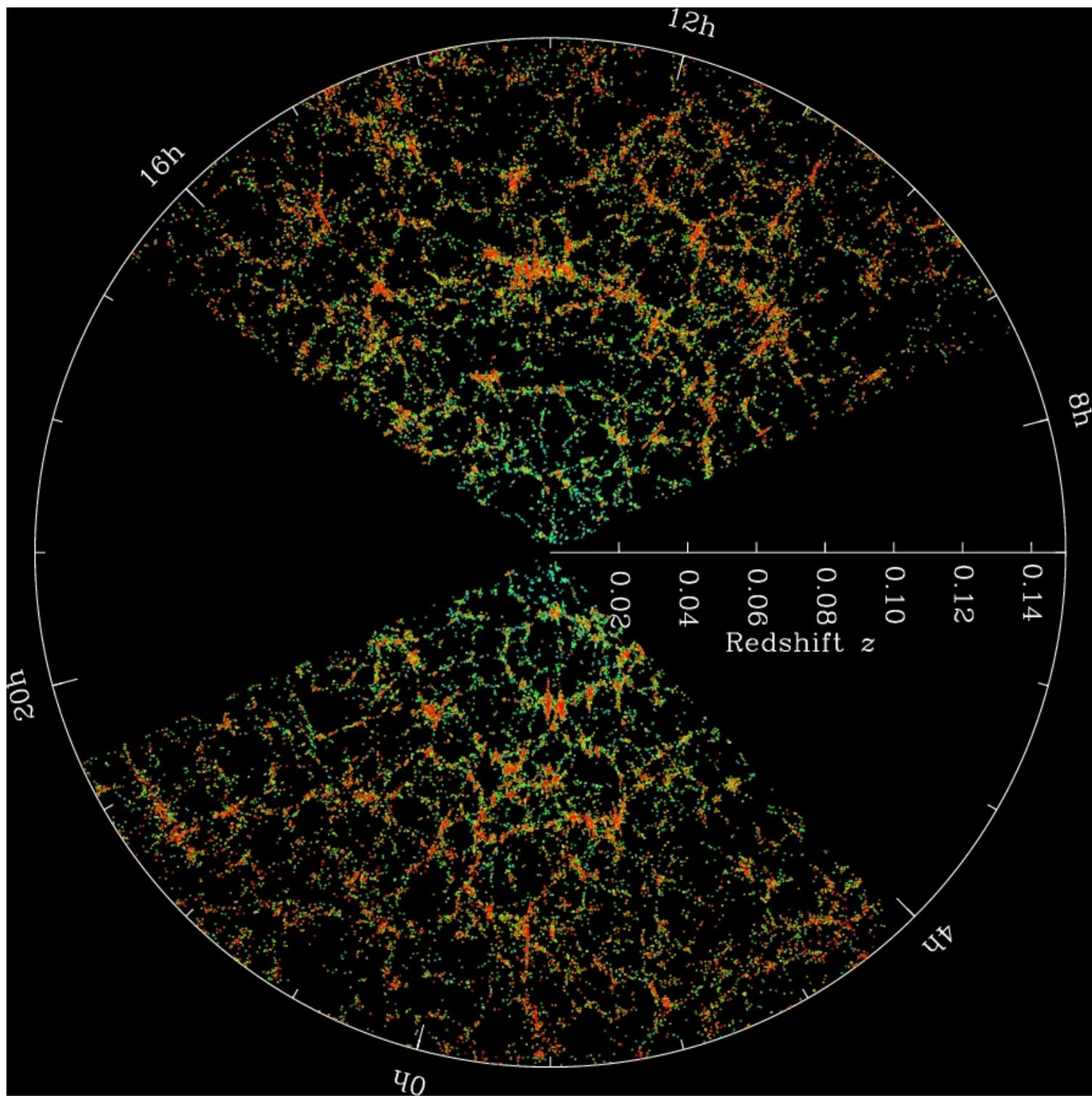


*The APM Galaxy Survey*  
*Maddox et al*

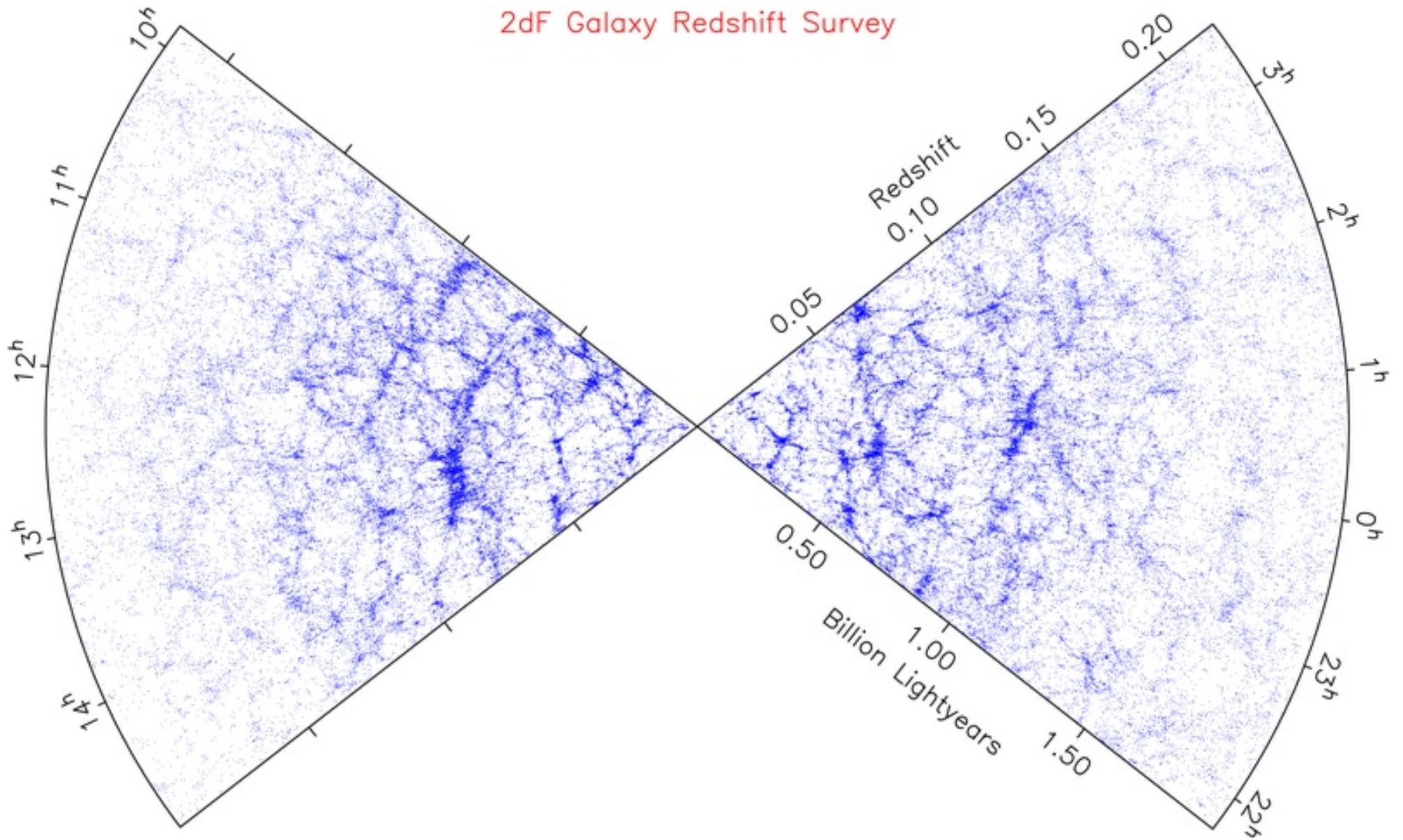


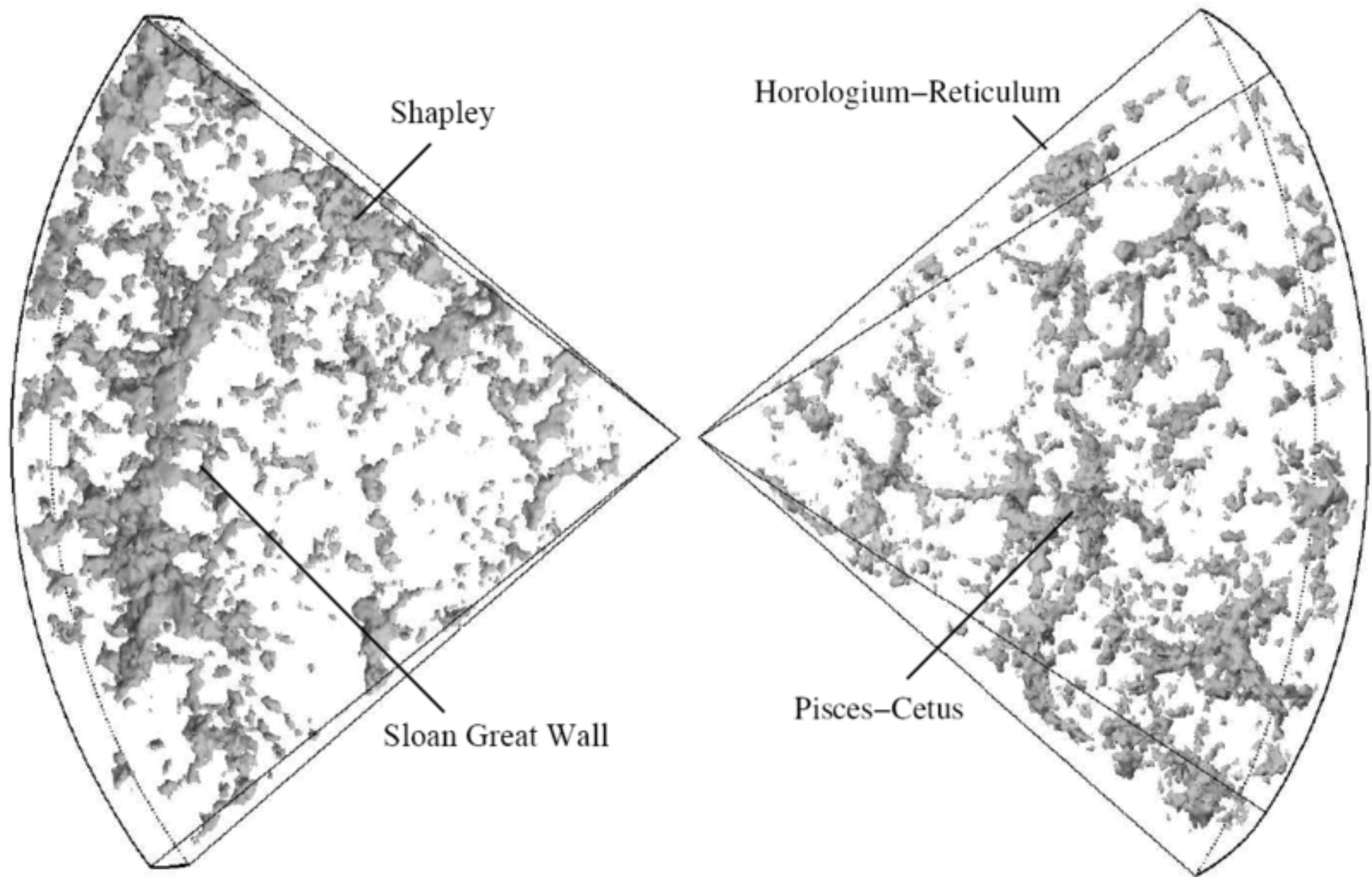
3D

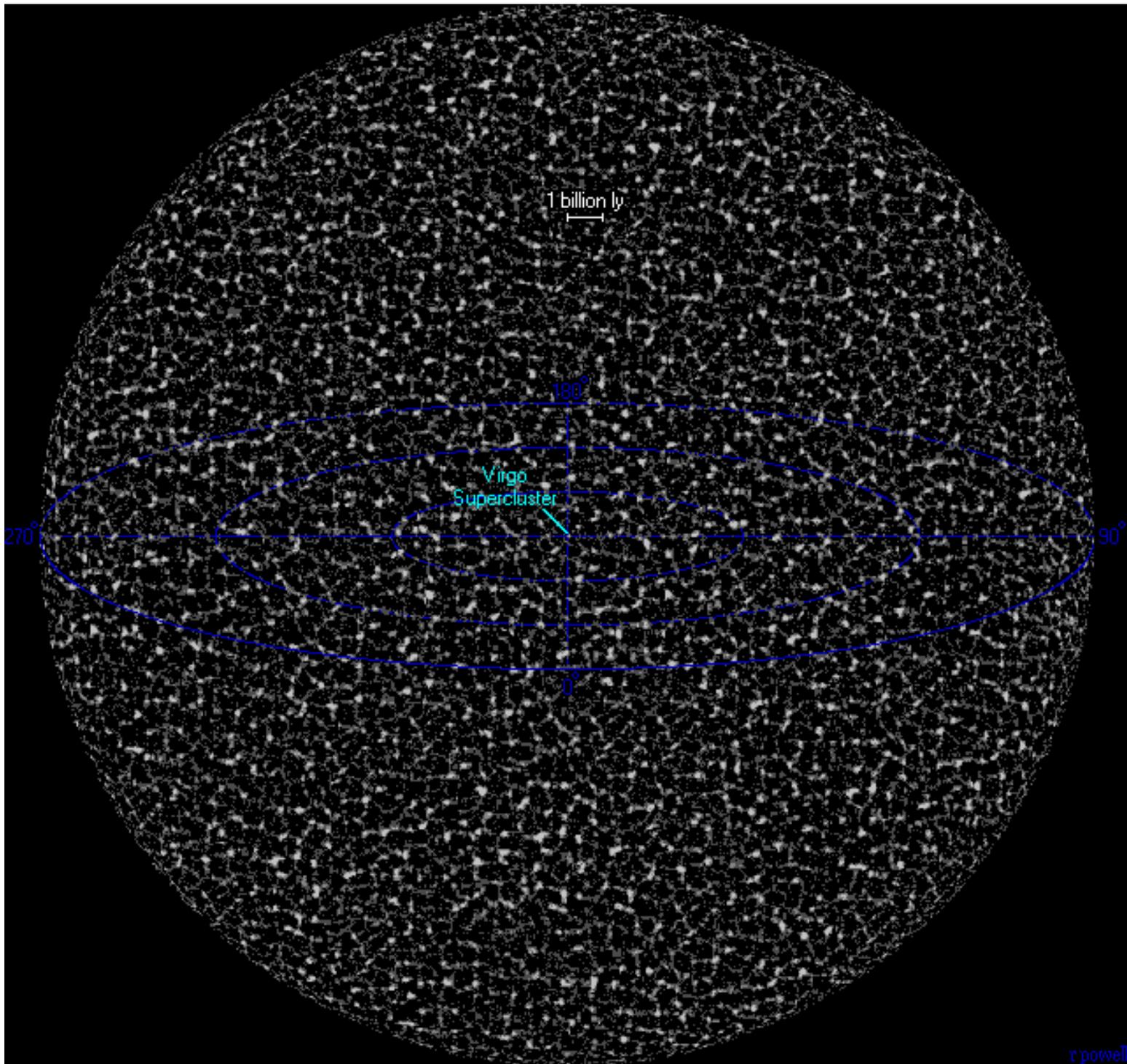
SDSS



# 2dF Galaxy Redshift Survey





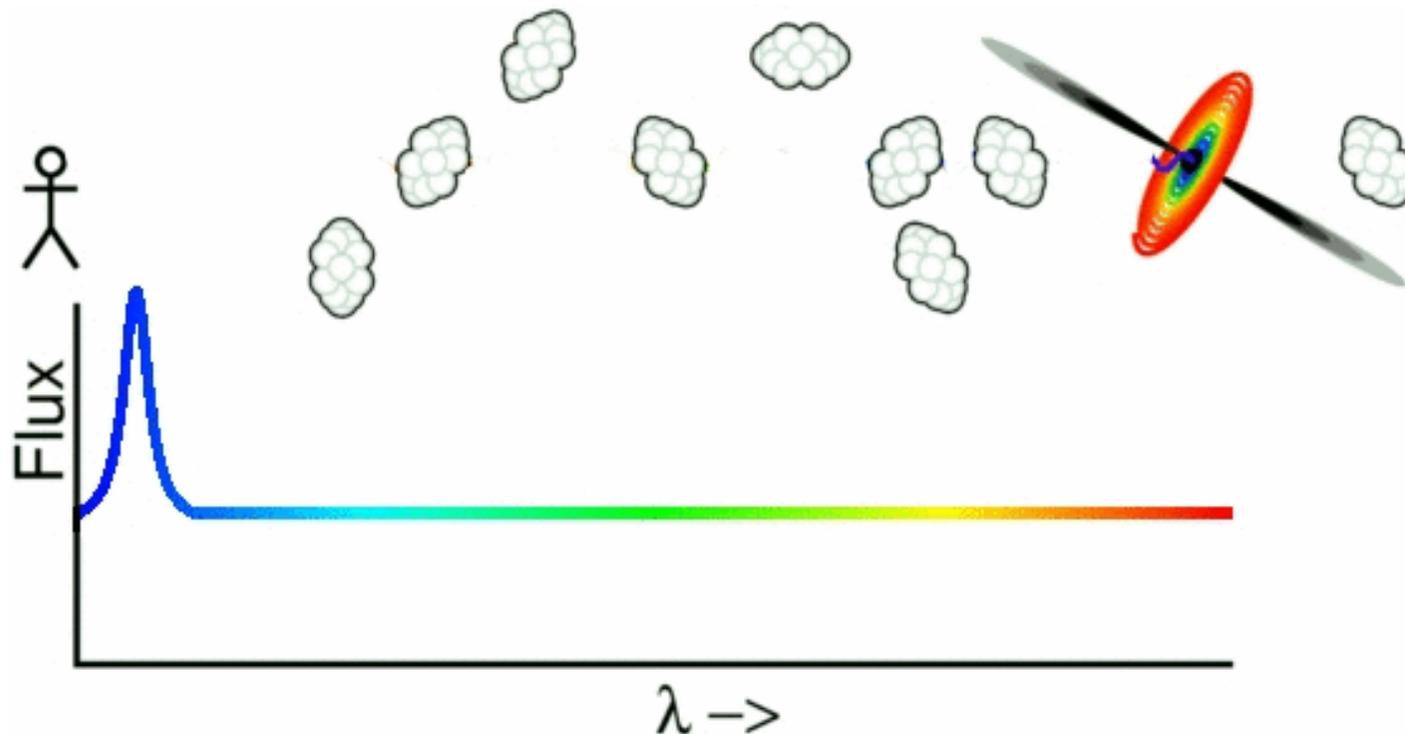


200 Mpc

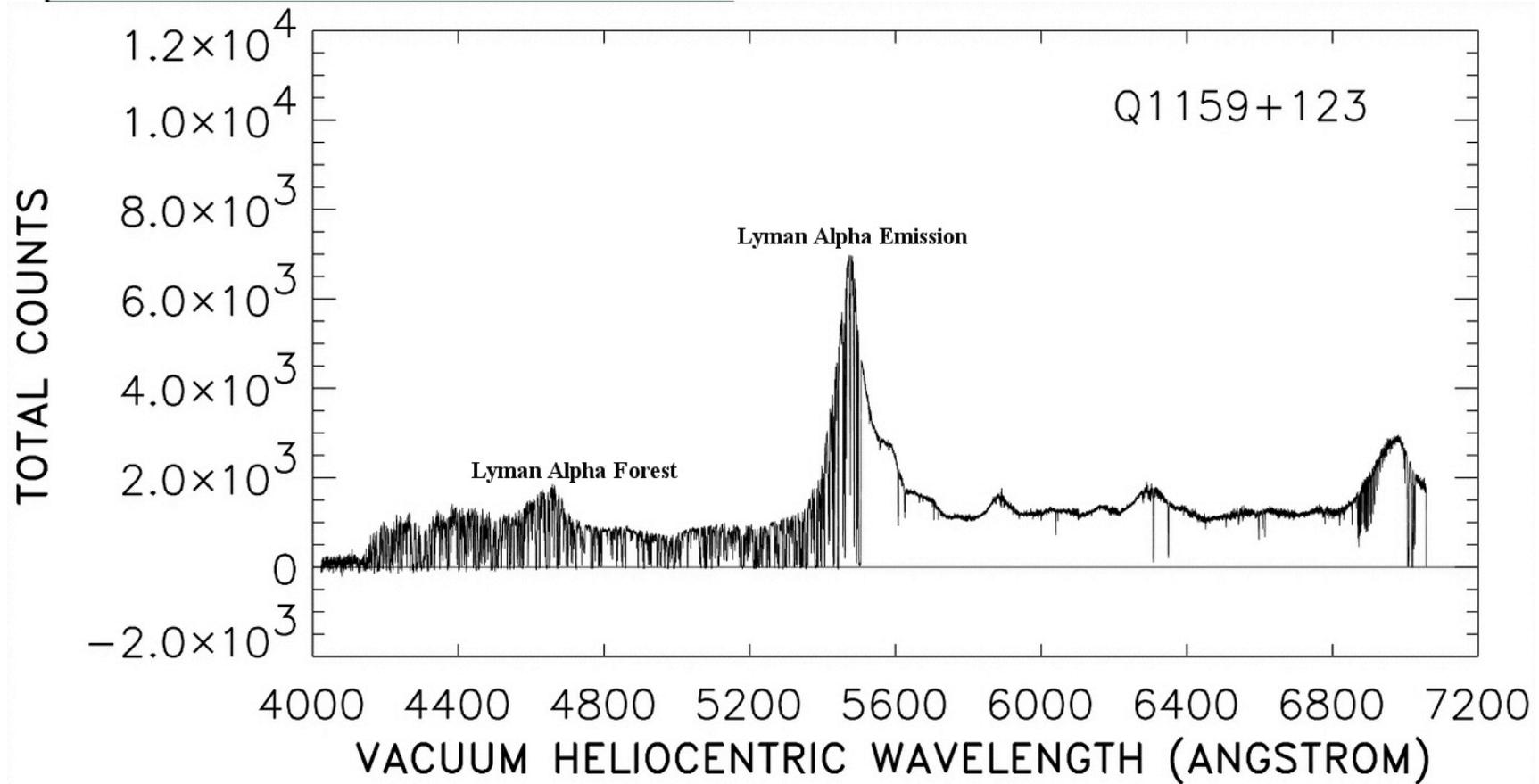
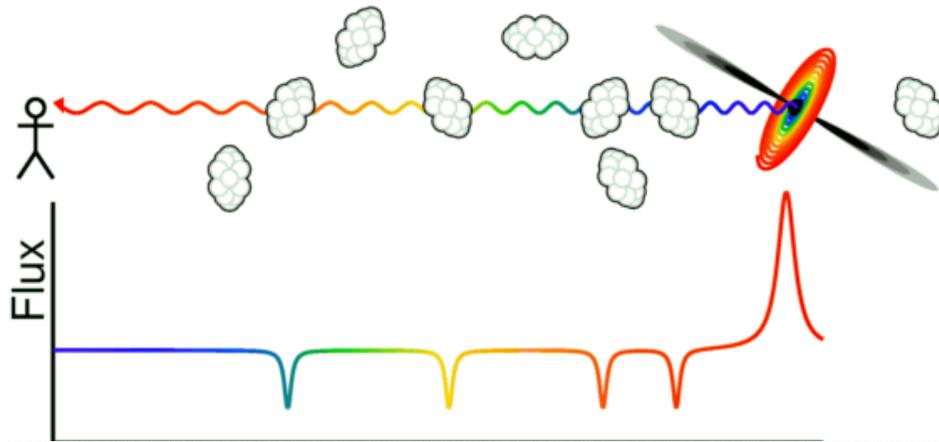
14 Gyr

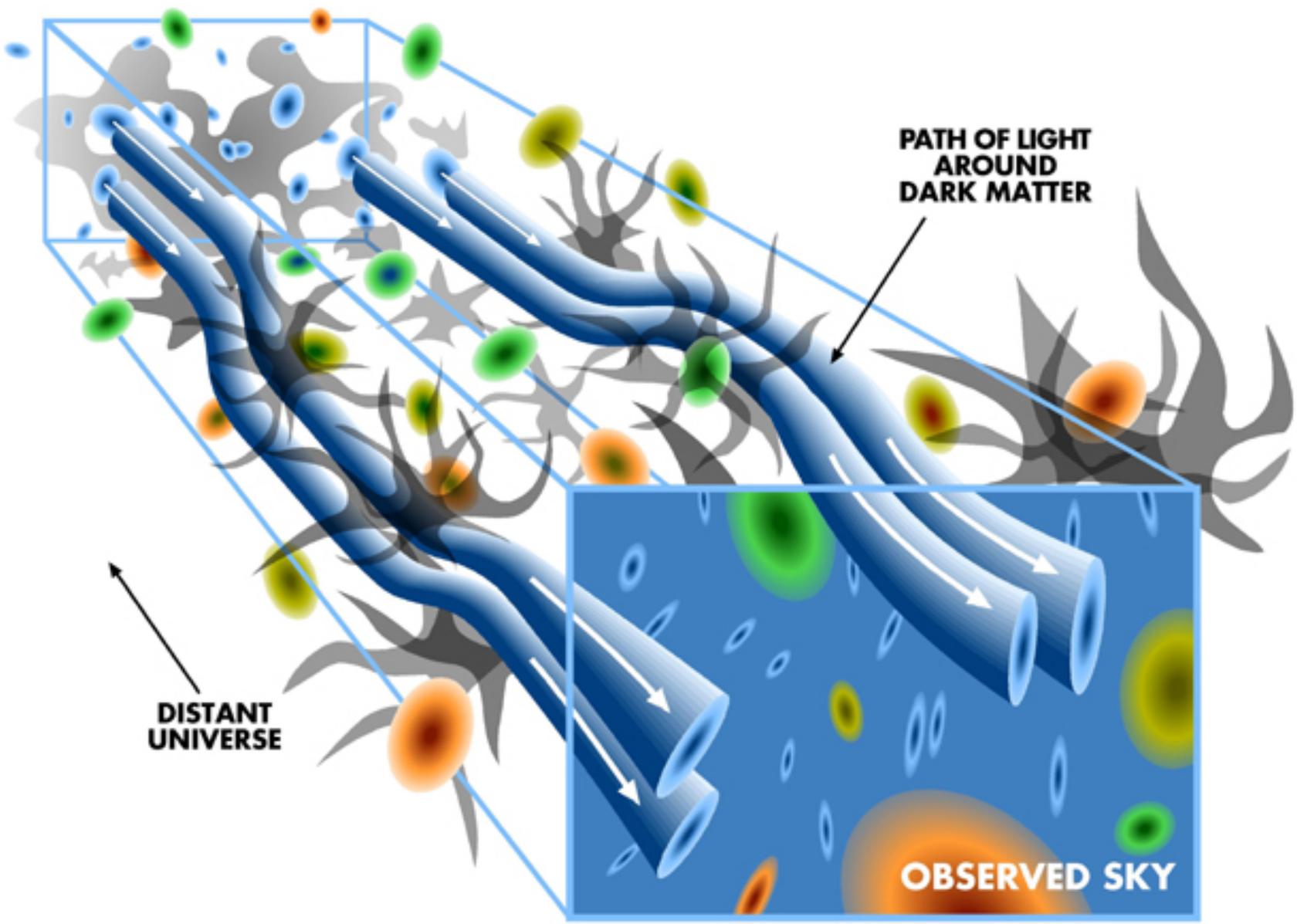
# Lyman $\alpha$ gozd, zlom

- Lyman  $\alpha$ : prehod med  $n=1$  in  $n=2$ ,  $\lambda=121.6$  nm
- kozmološki rdeči premik:  $\frac{\lambda_{obs}}{\lambda_{em}} = 1 + z$



# Lyman $\alpha$ gozd









Coma cluster

