

# Navadne galaksije

Nastanek in razvoj galaksij

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Komplementarna pristopa:

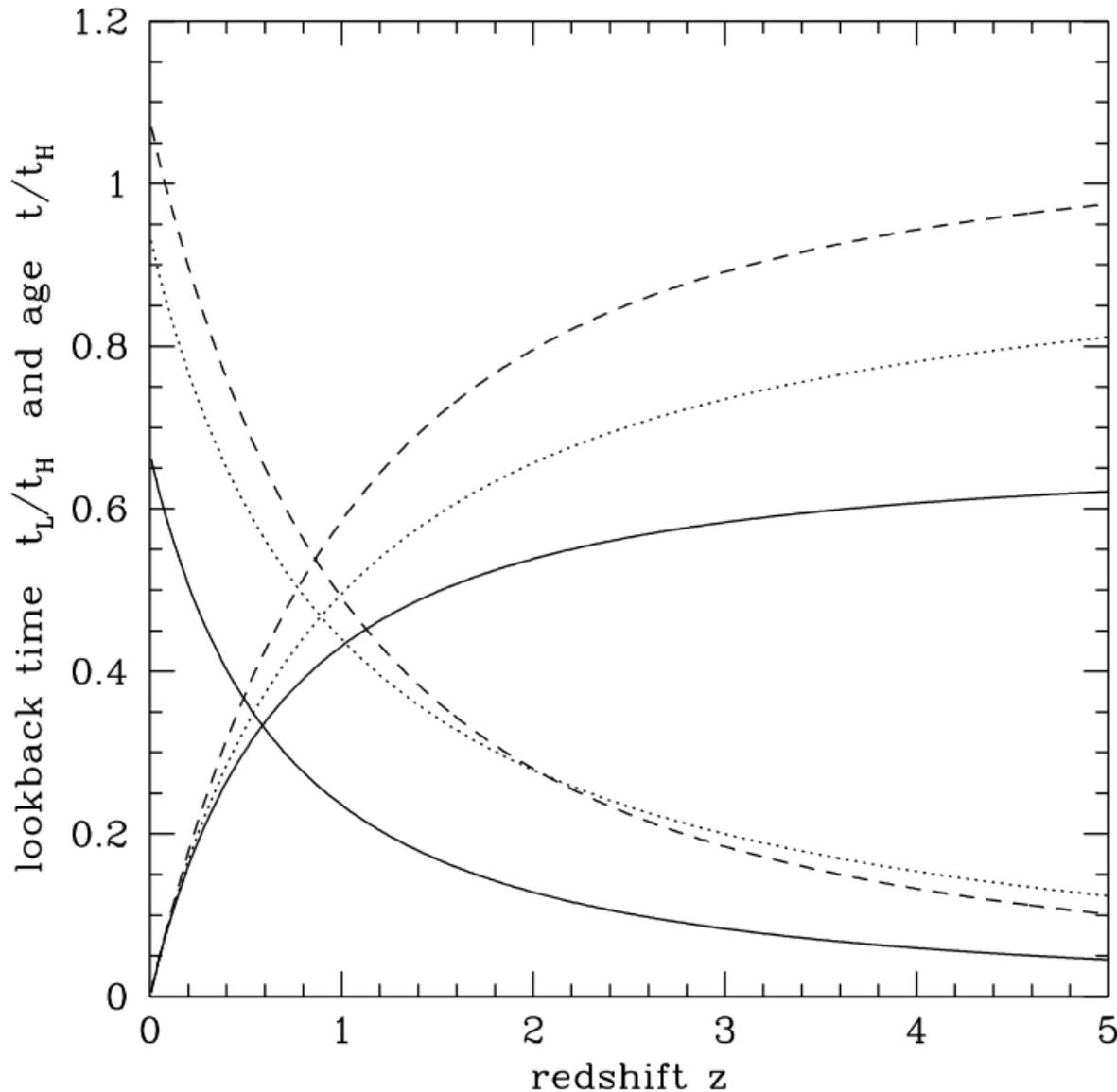
- opazovanja galaksij na različnih z
  - *pogled v preteklost*
- teorija (modeli)
  - *iz začetnih pogojev*

# Nastanek in razvoj galaksij

## Kratek opis zgodnjega vesolja:

- vesolje je nastalo pred okrog 14 milijardami let
- širjenje vesolja (Hubblev zakon), hitrost širjenja je bila različna ( $H(z)$ ); pospešeno širjenje vesolja
- v zgodnjem vesolju izjemno visoka  $T$ ,  $\rho$ 
  - $T$  in  $\rho$  snovi zelo enakomerni v vsakem trenutku
- vesolje širi, ohlaja; kvarki  $\rightarrow$  p,n (p v enakem številu kot e-)
- v nekaj min nastala He jedra  $\rightarrow$  24% He, 76% H, sled Li, D
- tudi ne-barionski delci  $\rightarrow$  ne-barionska temna snov
- vedno deluje gravitacijska sila
- prisotne majhne fluktuacije v  $\rho$

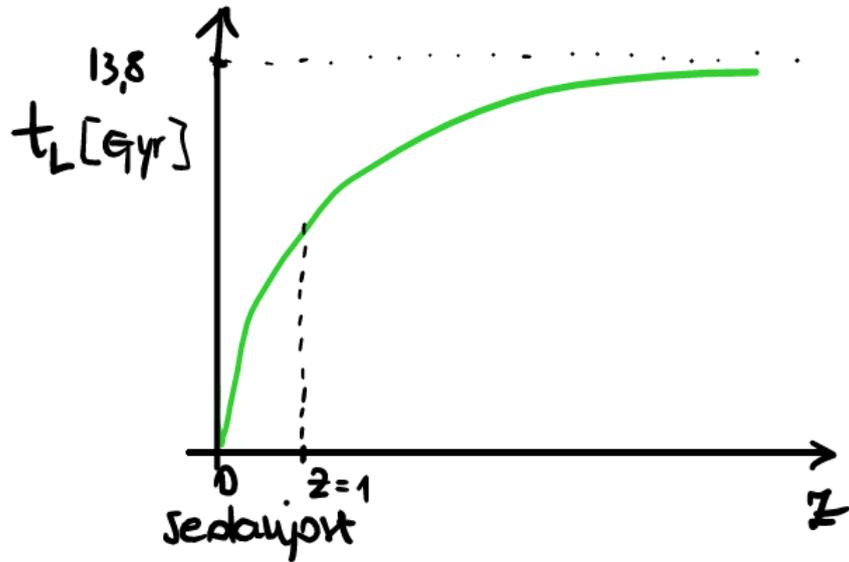
# Lookback time - rdeči premik



*lookback time ( $t_L$ )*

čas, ki je potekel od nastanka (npr. emisije fotona) do opazovanja danes

$(\Omega_M, \Omega_\Lambda) = (1, 0)$ , solid;  $(0.05, 0)$ , dotted; and  $(0.2, 0.8)$ , dashed.



$t_L = \text{lookback time}$

$$z = 1 \quad t_L \sim 8 \cdot 10^9 \text{ let}$$

$$z = 10 \quad t_L \sim 13,5 \cdot 10^9 \text{ let}$$

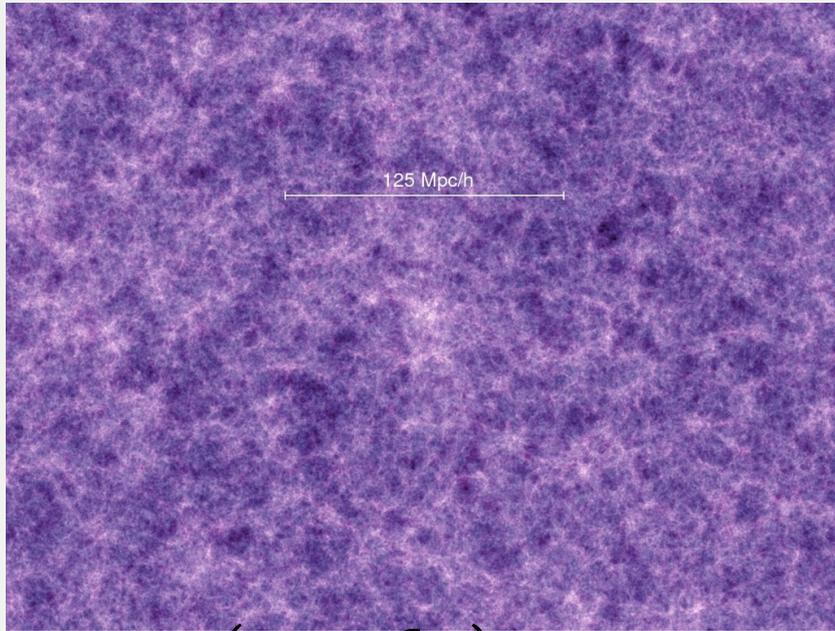
$$t_H \text{ (starost vesolja)} \sim 13,8 \cdot 10^9 \text{ let}$$

Starost vesolja pri  $z=1$ ?

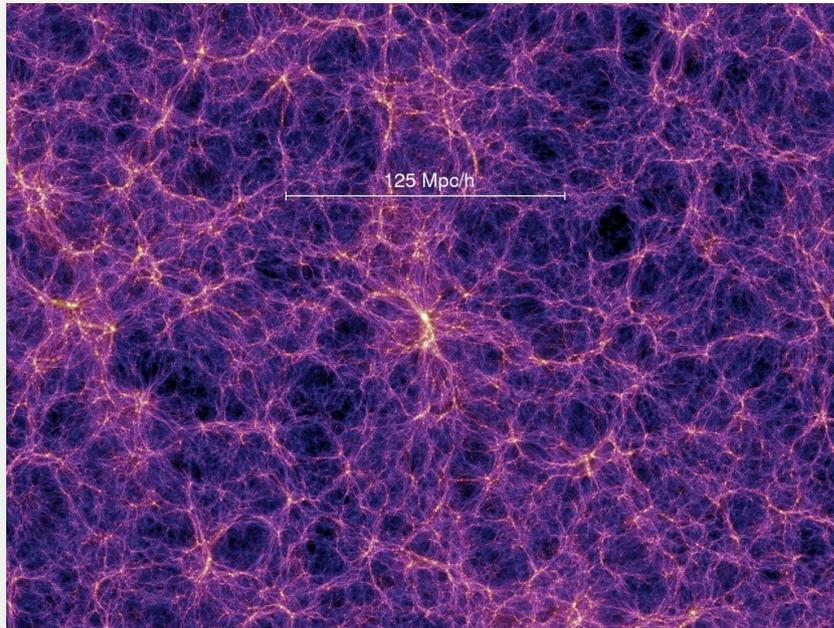
$$(13,8 - 8) \cdot 10^9 \text{ let} \approx 5,8 \text{ Gyr}$$

$$\text{Pri } z=1 \quad \frac{5,8}{13,8} \approx 0,42 \quad 42\%$$

$z=18.3$  ( $t = 0.21$  Gyr)

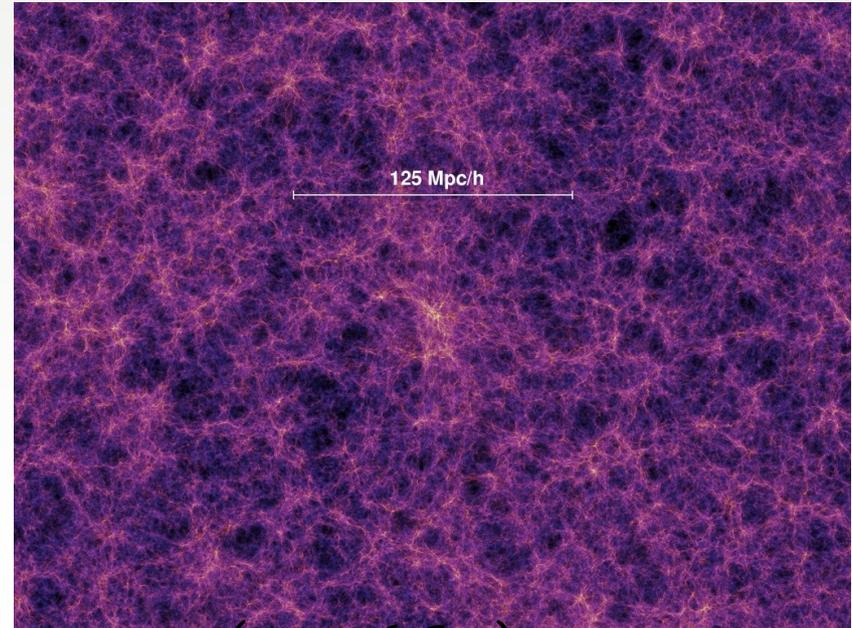


$z=1.4$  ( $t = 4.7$  Gyr)

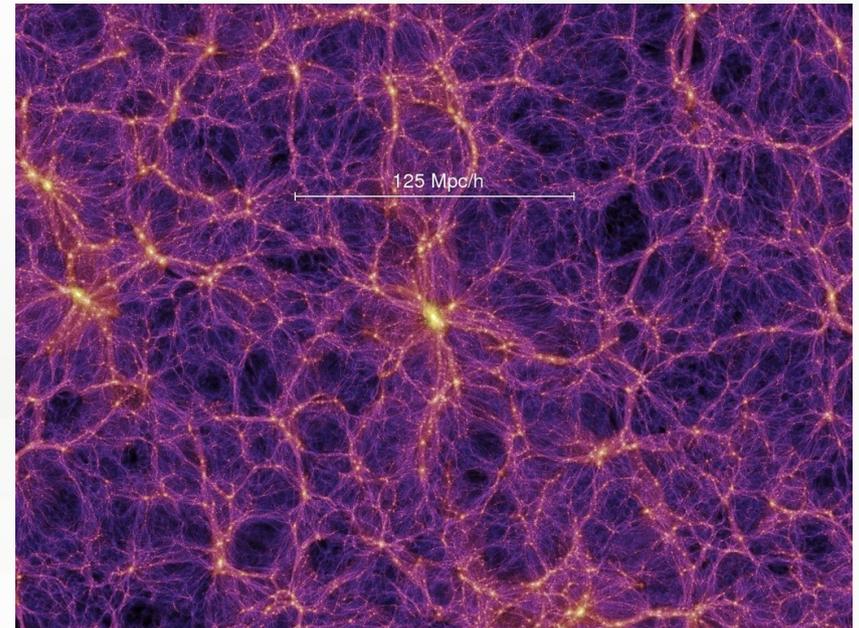


# Fluktuacije v gostoti

$z=5.7$  ( $t = 1.0$  Gyr)

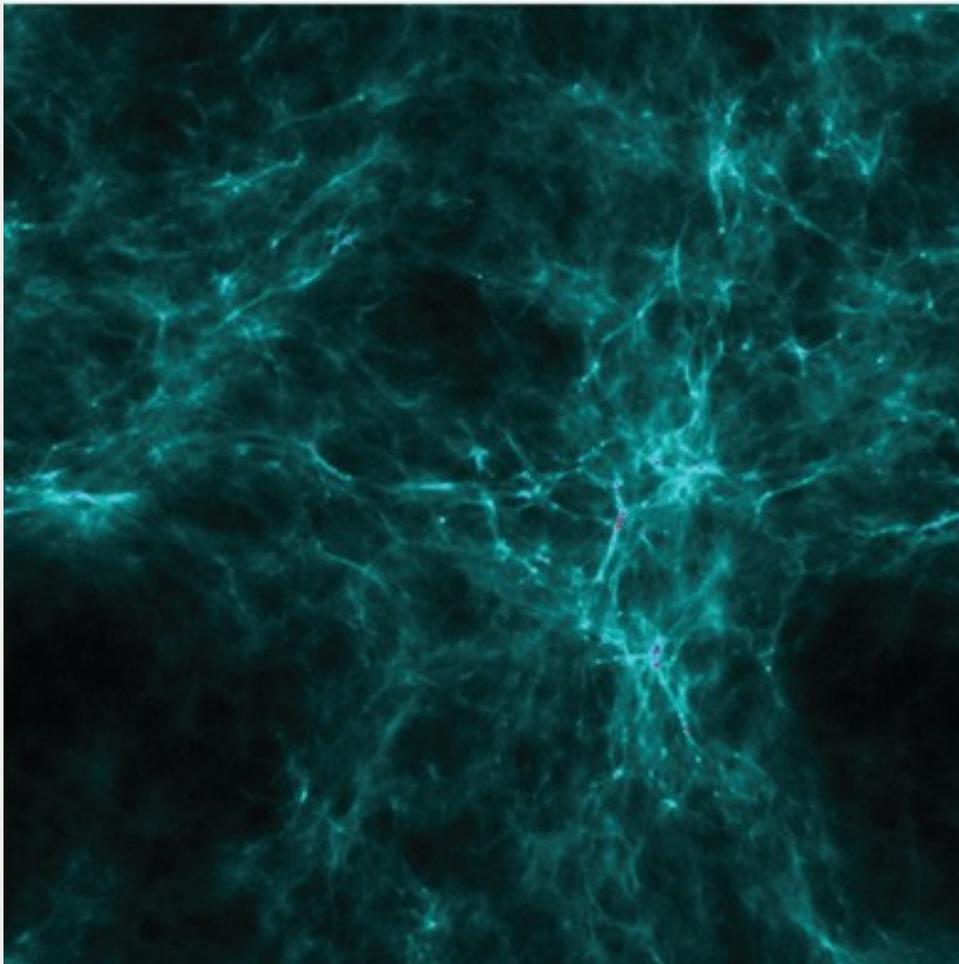


$z=0$  ( $t = 13.6$  Gyr)



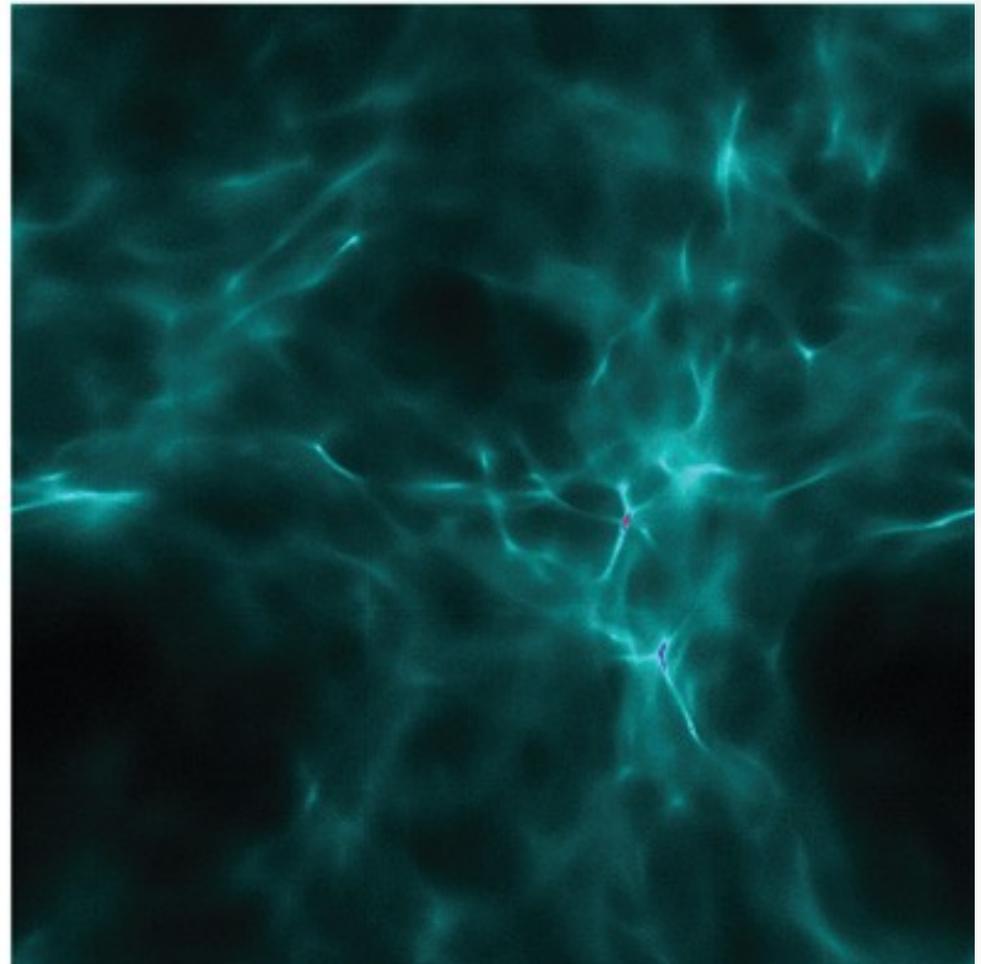
# Temna snov (hladna in vroča)

**a**

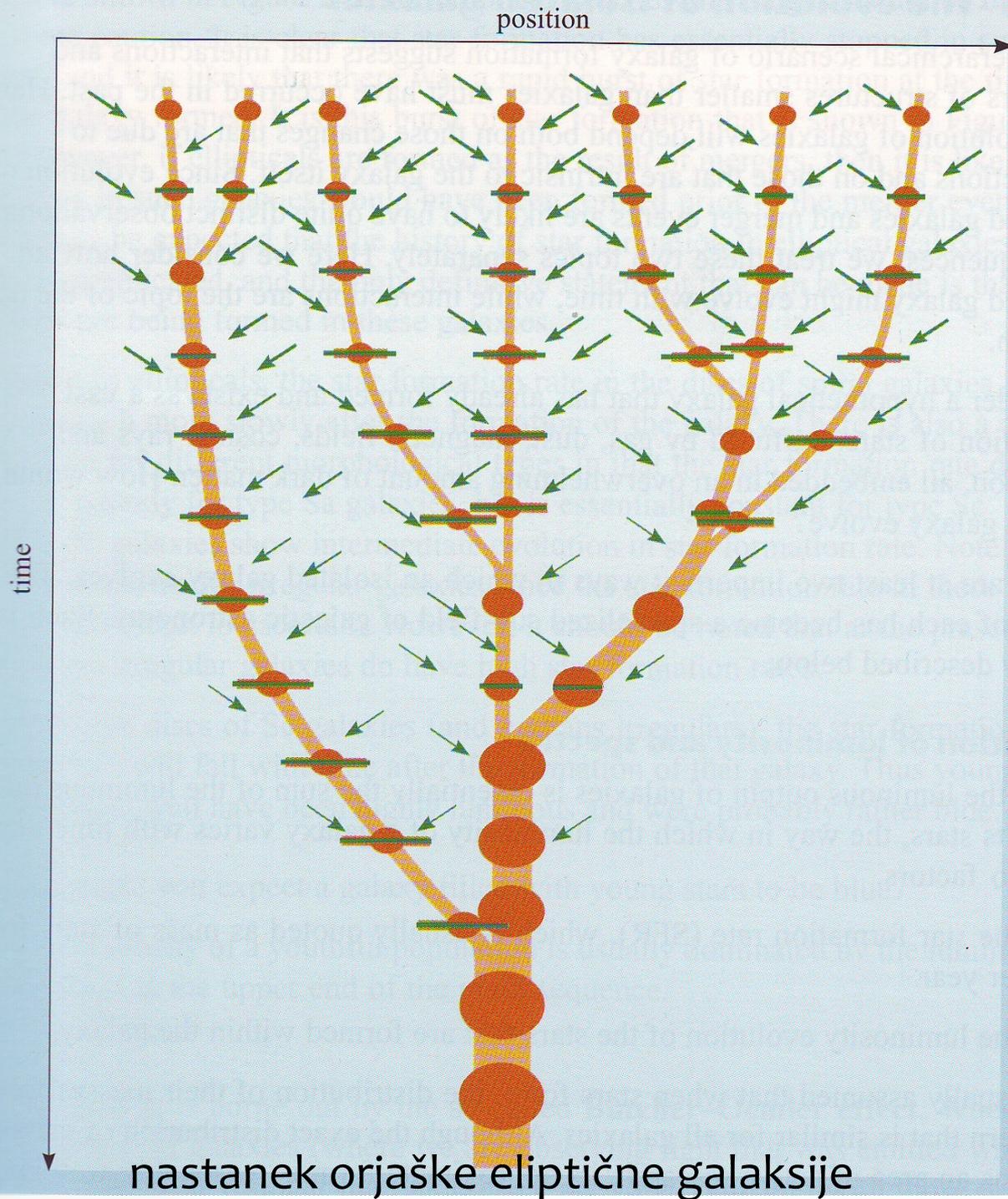


CDM (cold dark matter)  
hierarhični scenarij (bottom-up)  
→ združevanje

**b**



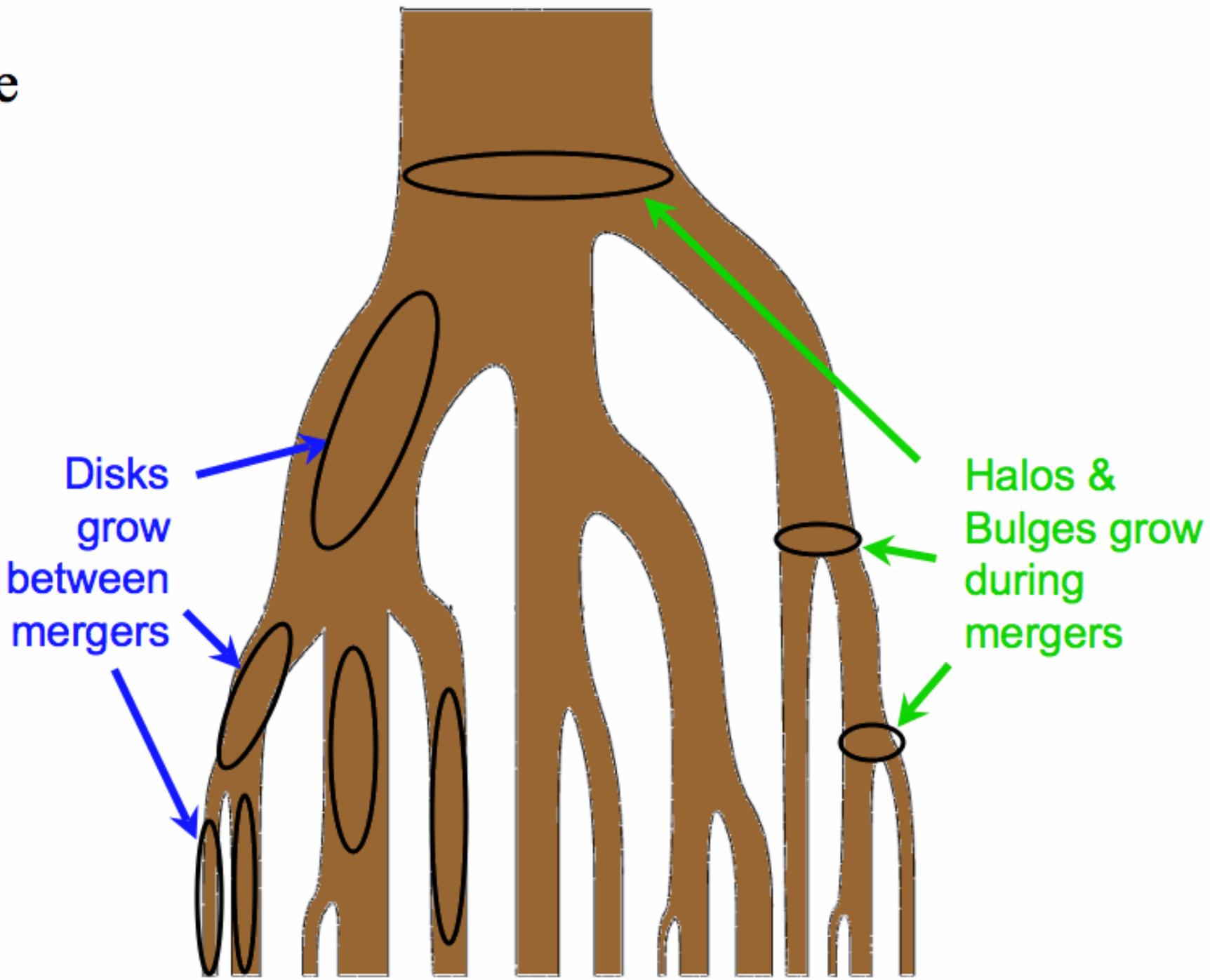
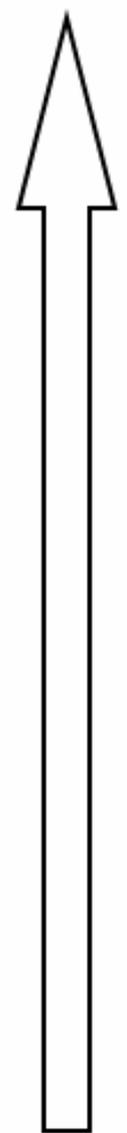
HDM (hot dark matter)  
monolitni scenarij (top-down)  
→ fragmentacija



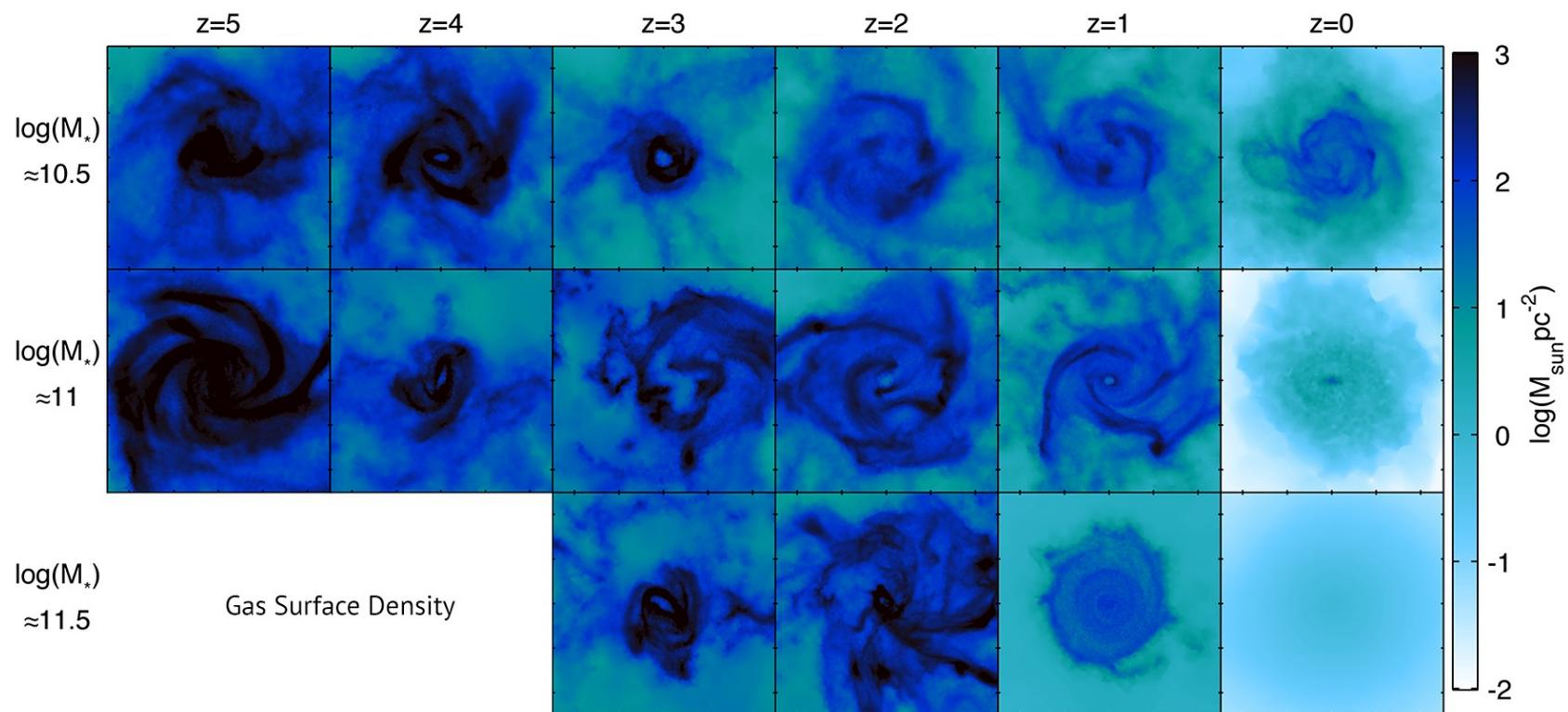
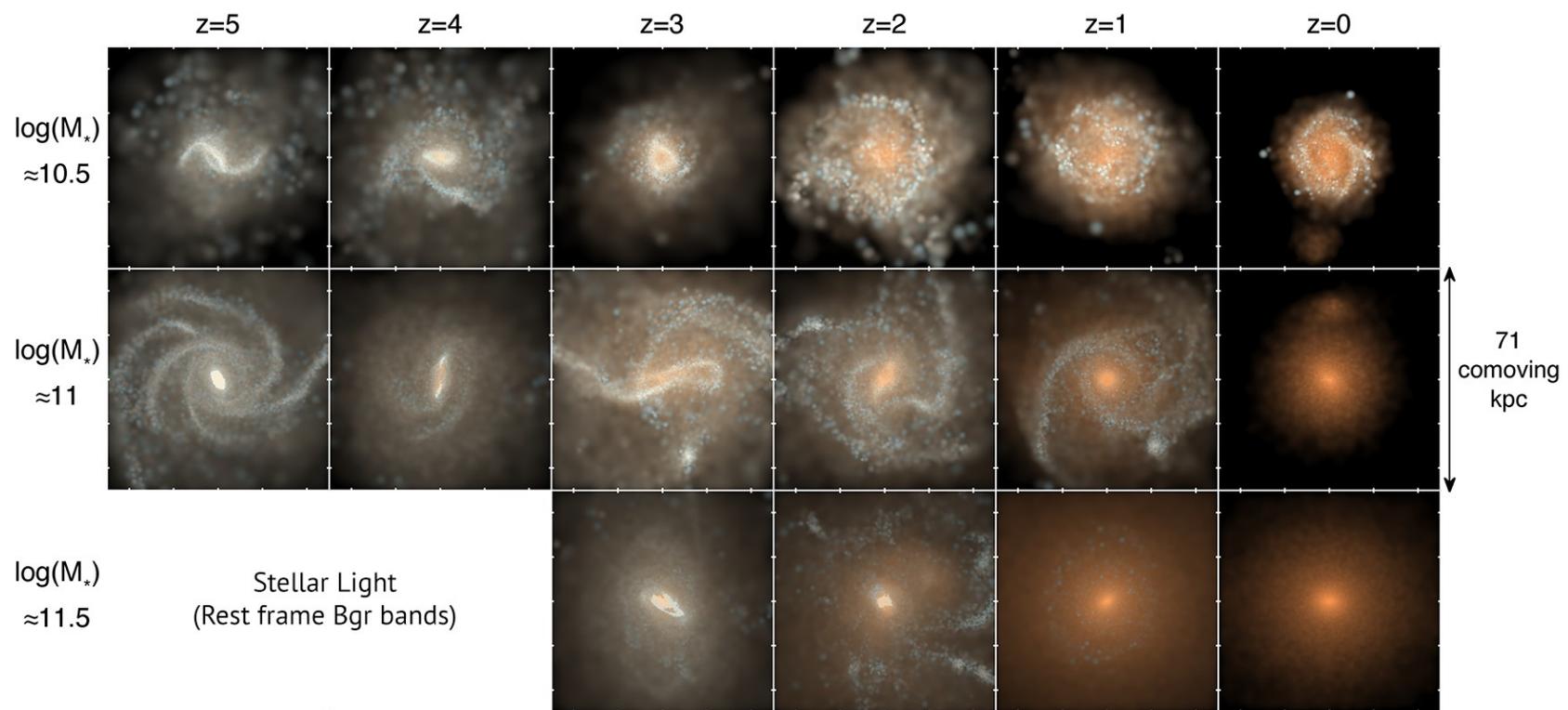
nastanek orjaške eliptične galaksije

# Merger Tree

Time

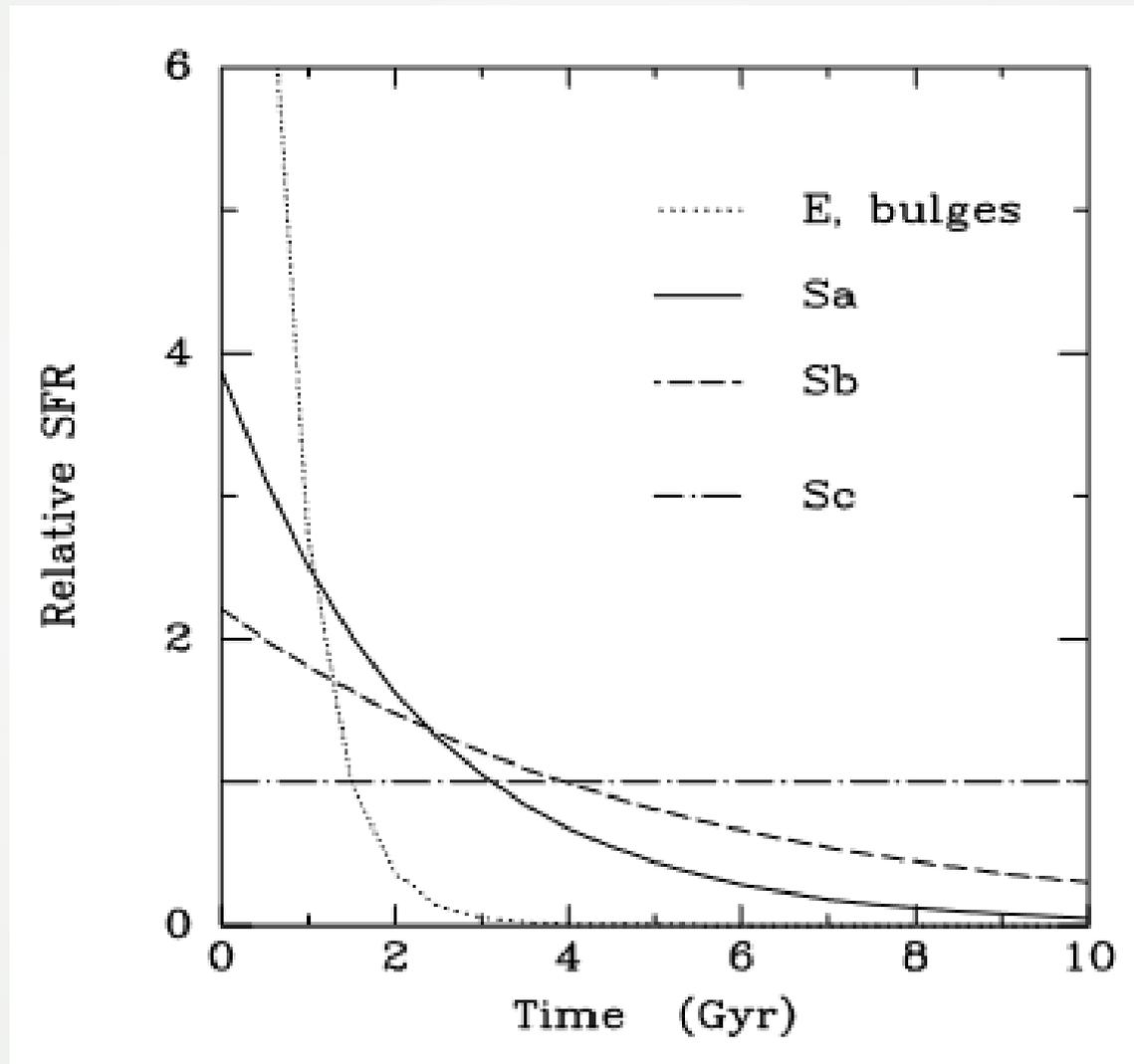


[https://www.illustris-project.org/movies/illustris\\_movie\\_cube\\_sub\\_frame.mp4](https://www.illustris-project.org/movies/illustris_movie_cube_sub_frame.mp4)



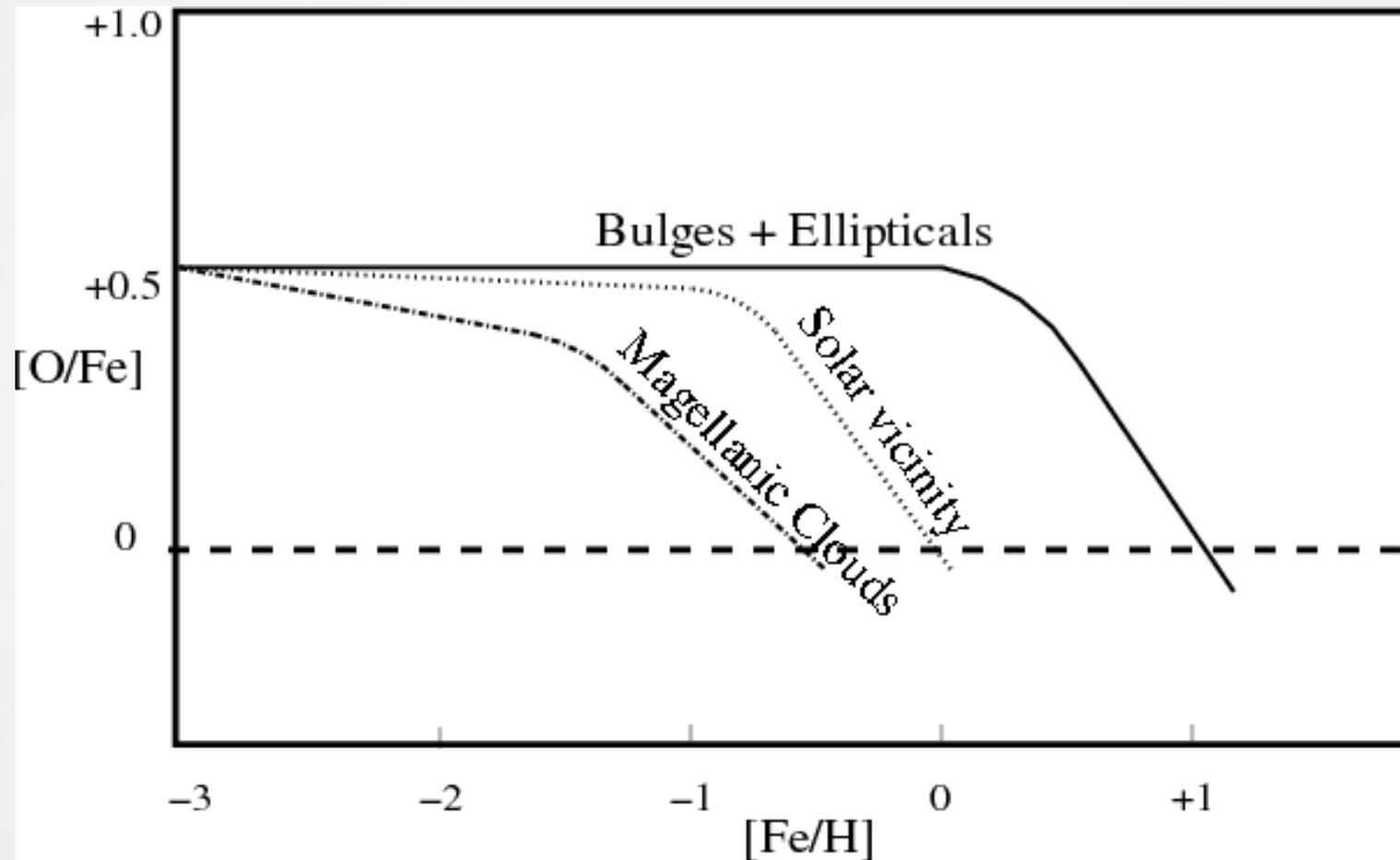
# Evolucija izolirane galaksije

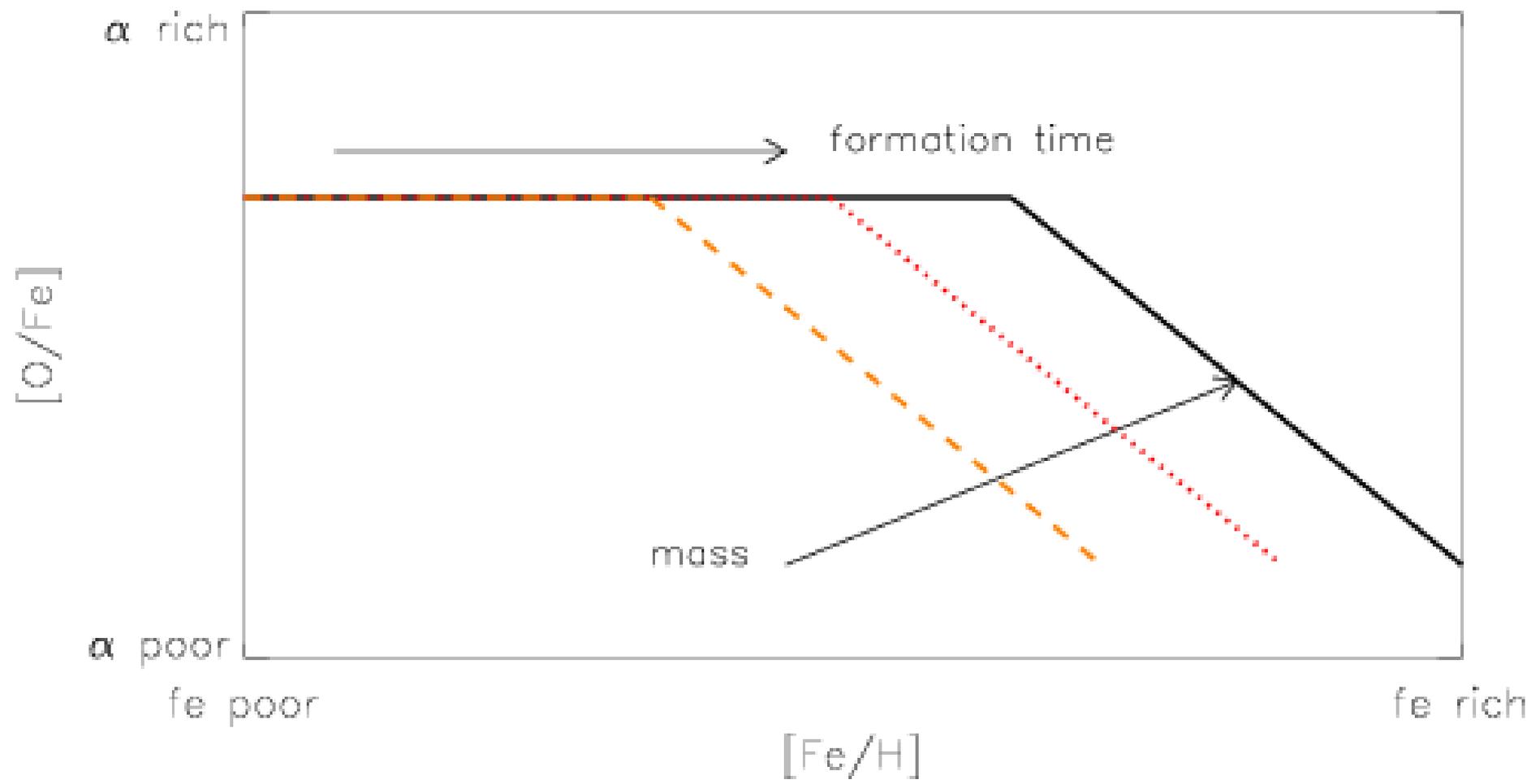
R.C. Kennicutt, Annu. Rev. Astron. Astrophys. 1998. 36: 189-231



Star formation rate (SFR)  
hitrost nastanka novih zvezd ( $M_{\text{sun}}/\text{yr}$ )

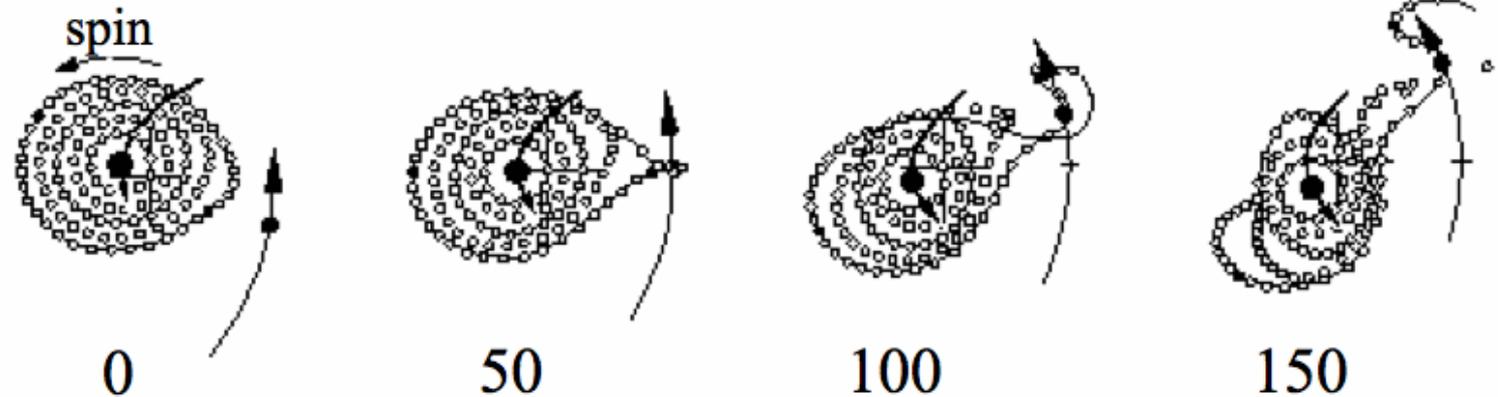
# Kemična evolucija galaksij



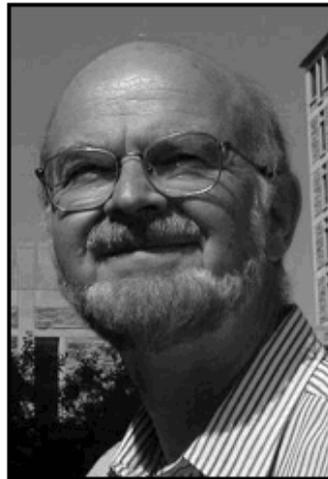


# Razvoj galaksij v združevanju/trčenju

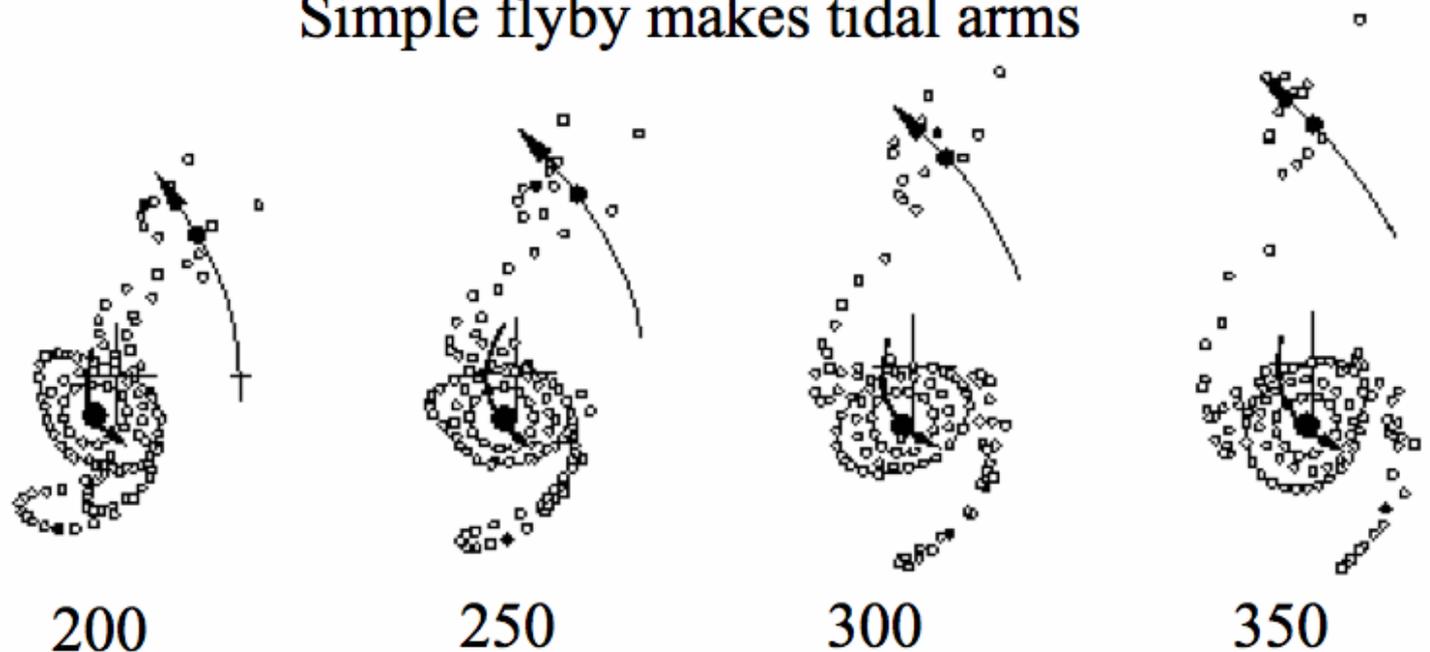
The Toomre's 1972 calculation of galaxy flyby



Simple flyby makes tidal arms



Alar & Juri  
Toomre



# Pomen interakcij med galaksijami

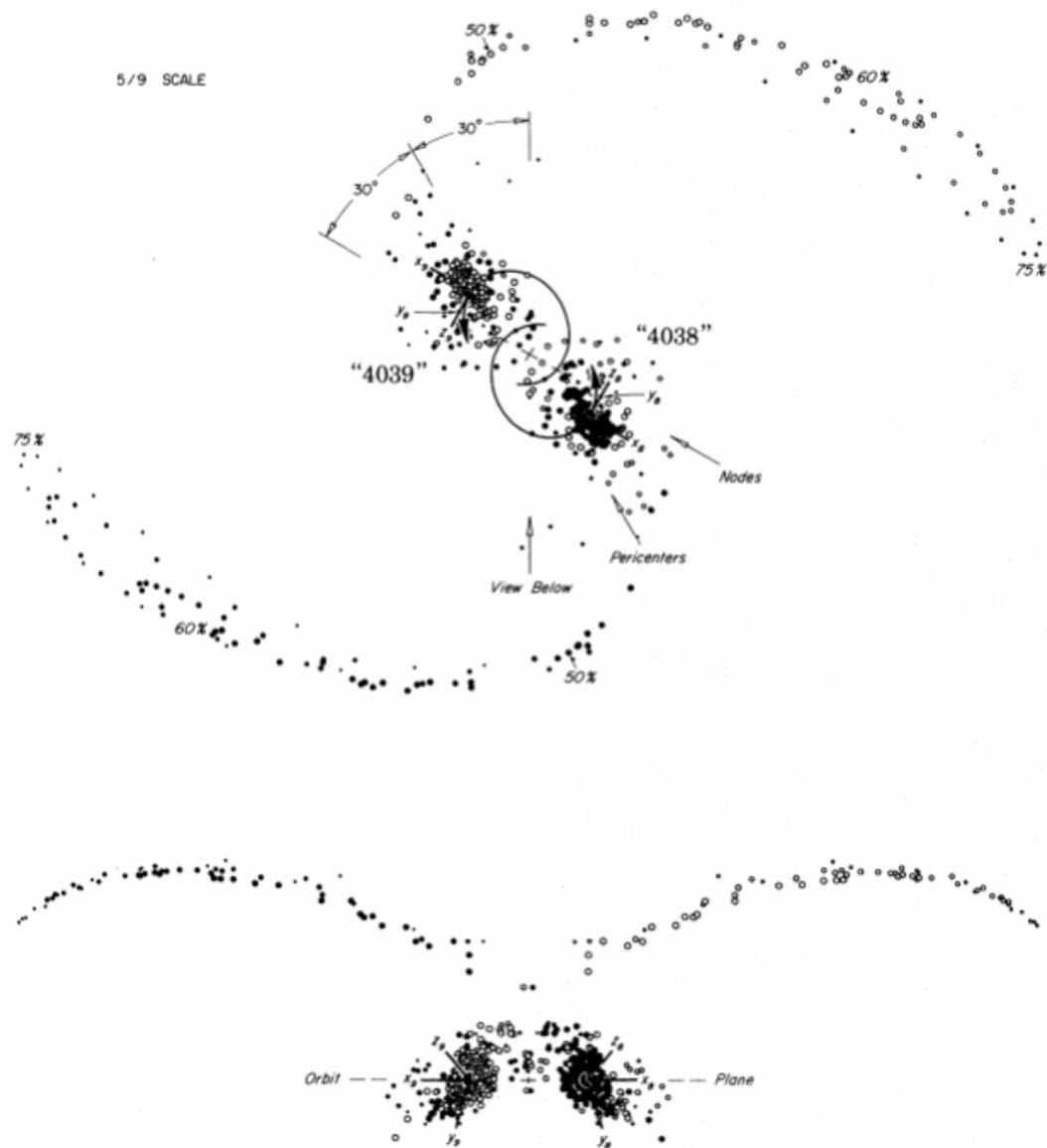
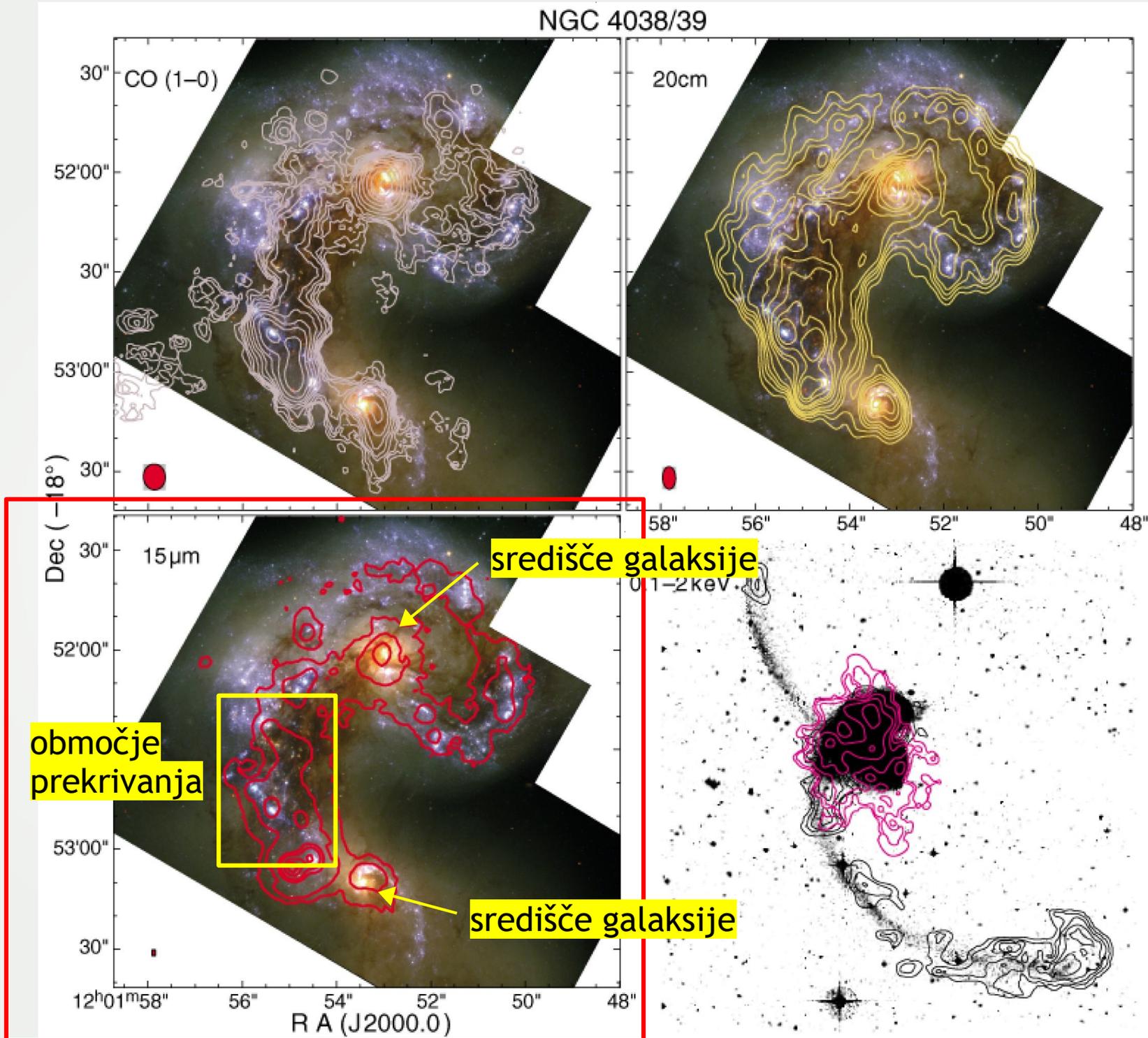
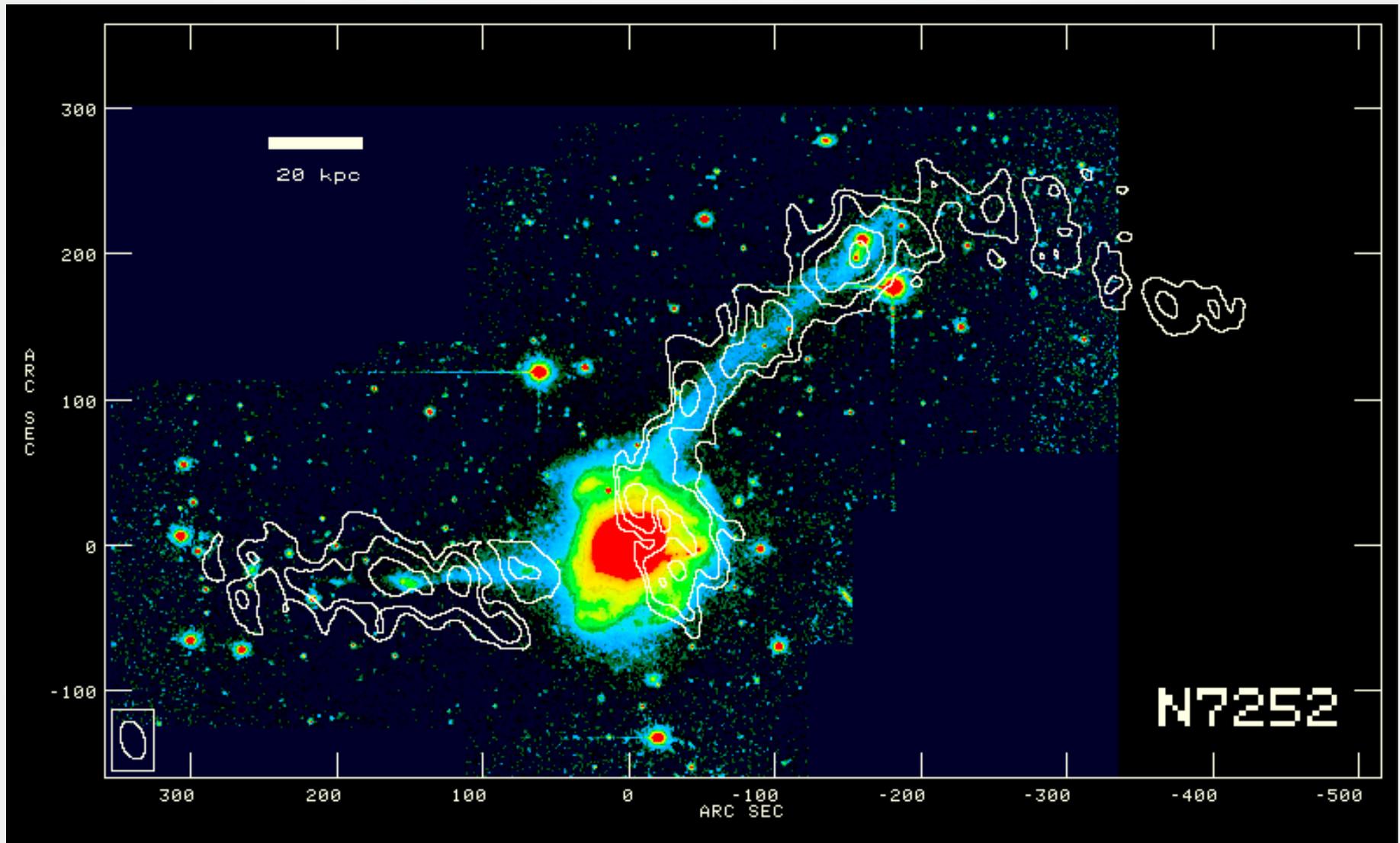


FIG. 23.—Symmetric model of NGC 4038/9. Here two identical disks of radius  $0.75R_{\min}$  suffered an  $e \approx 0.5$  encounter with orbit angles  $i_8 = i_9 = 60^\circ$  and  $\omega_8 = \omega_9 = -30^\circ$  that appeared the same to both. The above all-inclusive views of the debris and remnants of these disks have been drawn exactly normal and edge-on to the orbit plane; the latter viewing direction is itself  $30^\circ$  from the line connecting the two pericenters. The viewing time is  $t = 15$ , or slightly past apocenter. The filled and open symbols again disclose the original loyalties of the various test particles.

# Središče galaksij Anteni



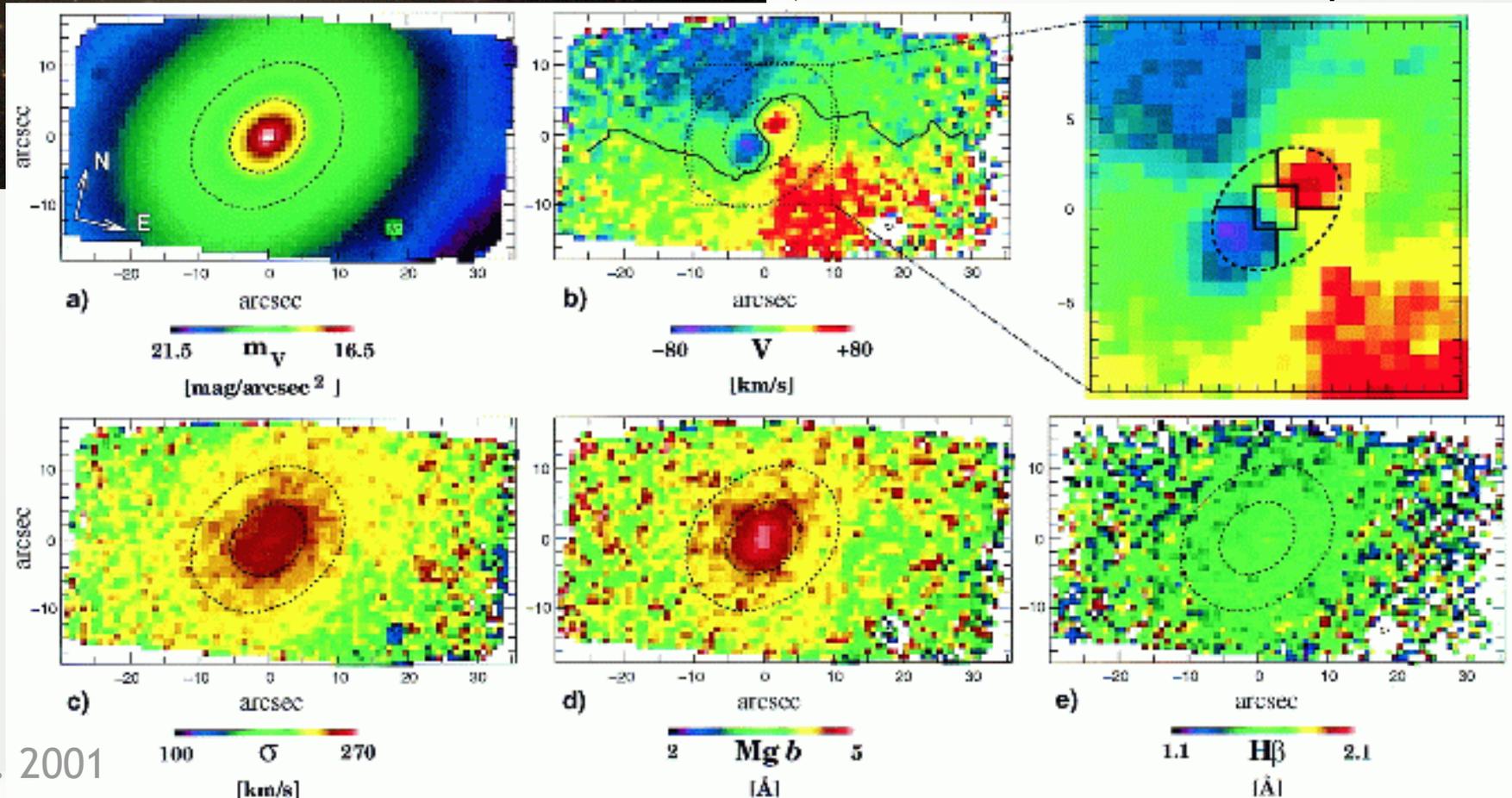
# Ali lahko po trku dveh spiralnih galaksij nastane eliptična galaksija?



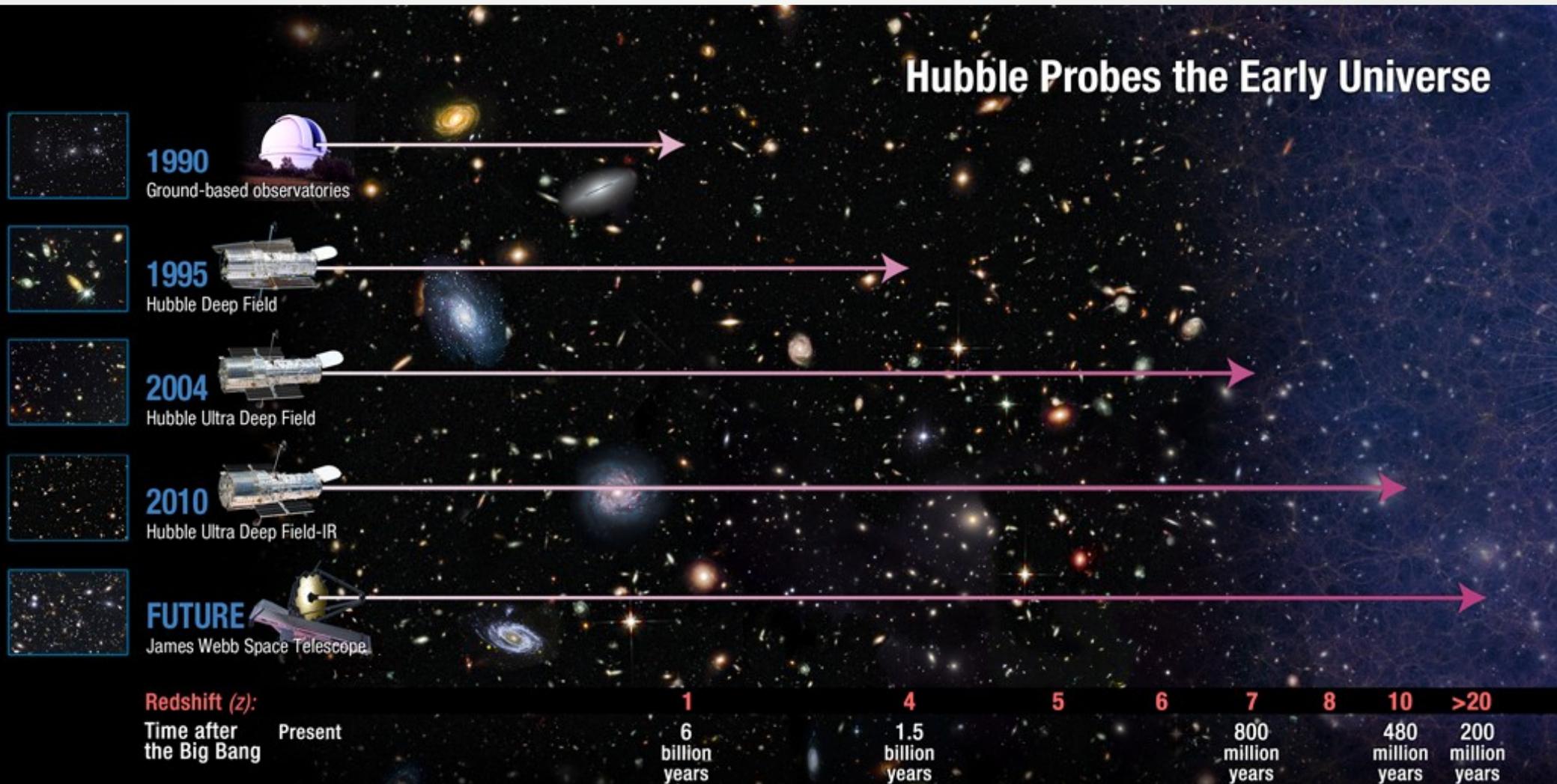
Galaksija NGC7252: bele konture prikazujejo HI (atomarni vodik), v ozadju pa slika v vidnem območju (umetne barve). Iz trka dveh spiralnih galaksij naj bi nastala v tem primeru večja galaksija podobna eliptični. Avtorstvo: *Hibbard et al. (1994)*

# od morfologije do kinematskih lastnosti

NGC 4365 zglada normalna galaksija, eliptična (E3). Sled trka dveh galaksij v hitrostih zvezd v eliptični galaksiji (ob trku sta bili vrtilni osi pravokotni)



# Globoka polja



Hubble Deep Fields (na spletni strani vesoljskega teleskopa Hubble):  
[https://www.spacetelescope.org/science/deep\\_fields/](https://www.spacetelescope.org/science/deep_fields/)

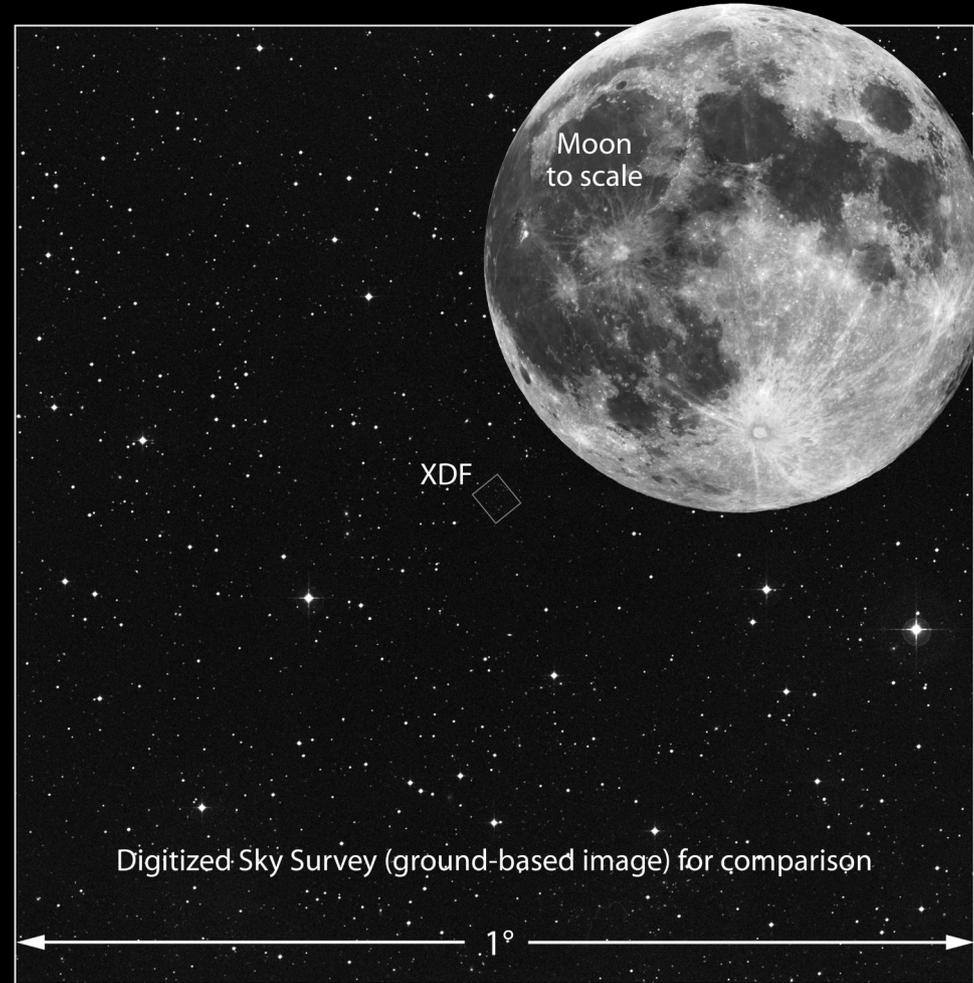
# Hubblovo ekstremno globoko polje

The image shows a dense field of galaxies, each with a different color and shape. Some are bright yellow or orange, while others are blue or red. The galaxies vary in size and orientation, some appearing as distinct spirals or ellipticals, while others are more diffuse or irregular. The background is a deep black, making the individual points of light stand out sharply.

Credit: NASA; ESA; G. Illingworth, D. Magee, and P. Oesch, University of California, Santa Cruz; R. Bouwens, Leiden University; and the HUDF09 Team



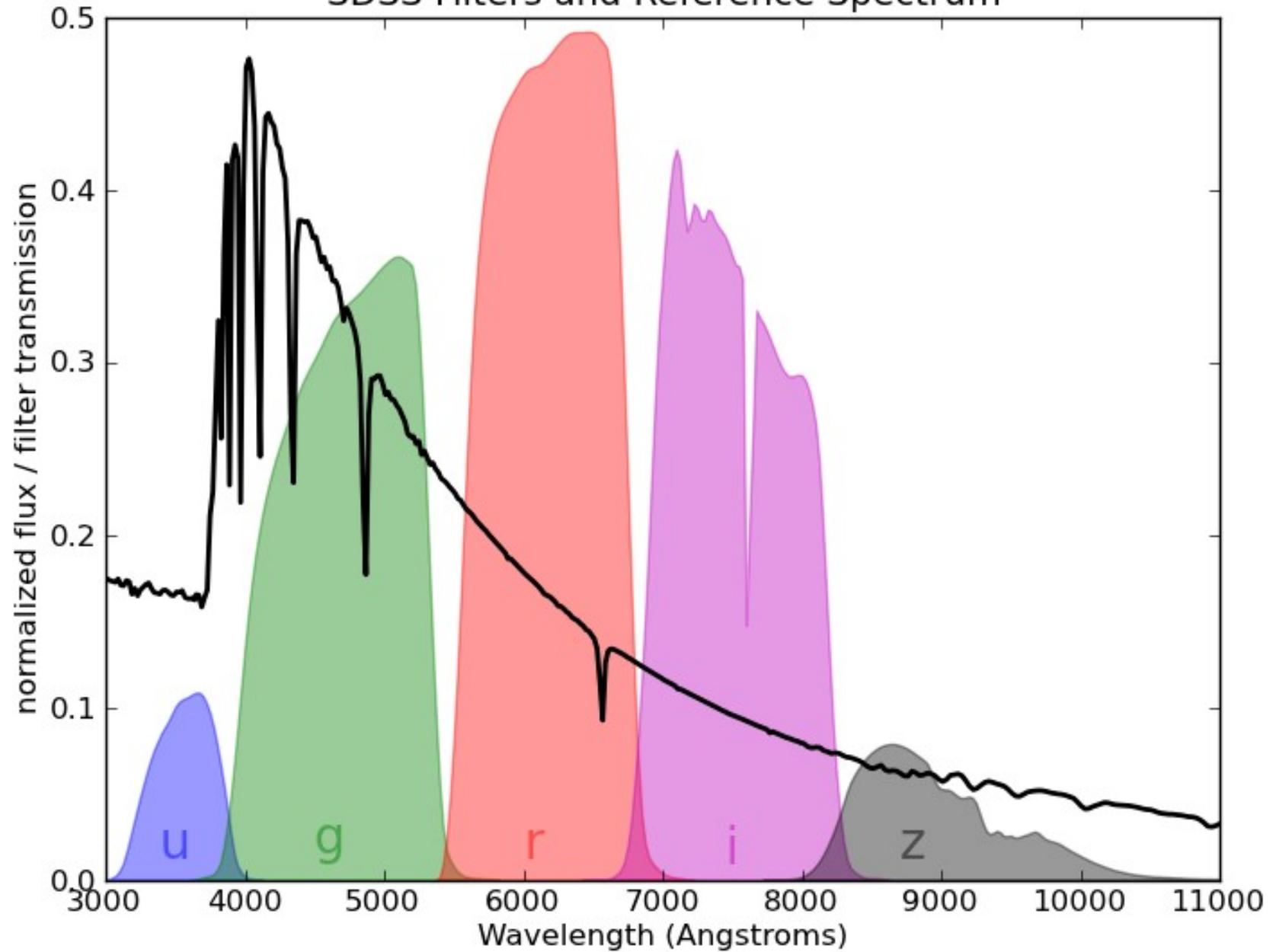
### Size of Hubble eXtreme Deep Field on the Sky



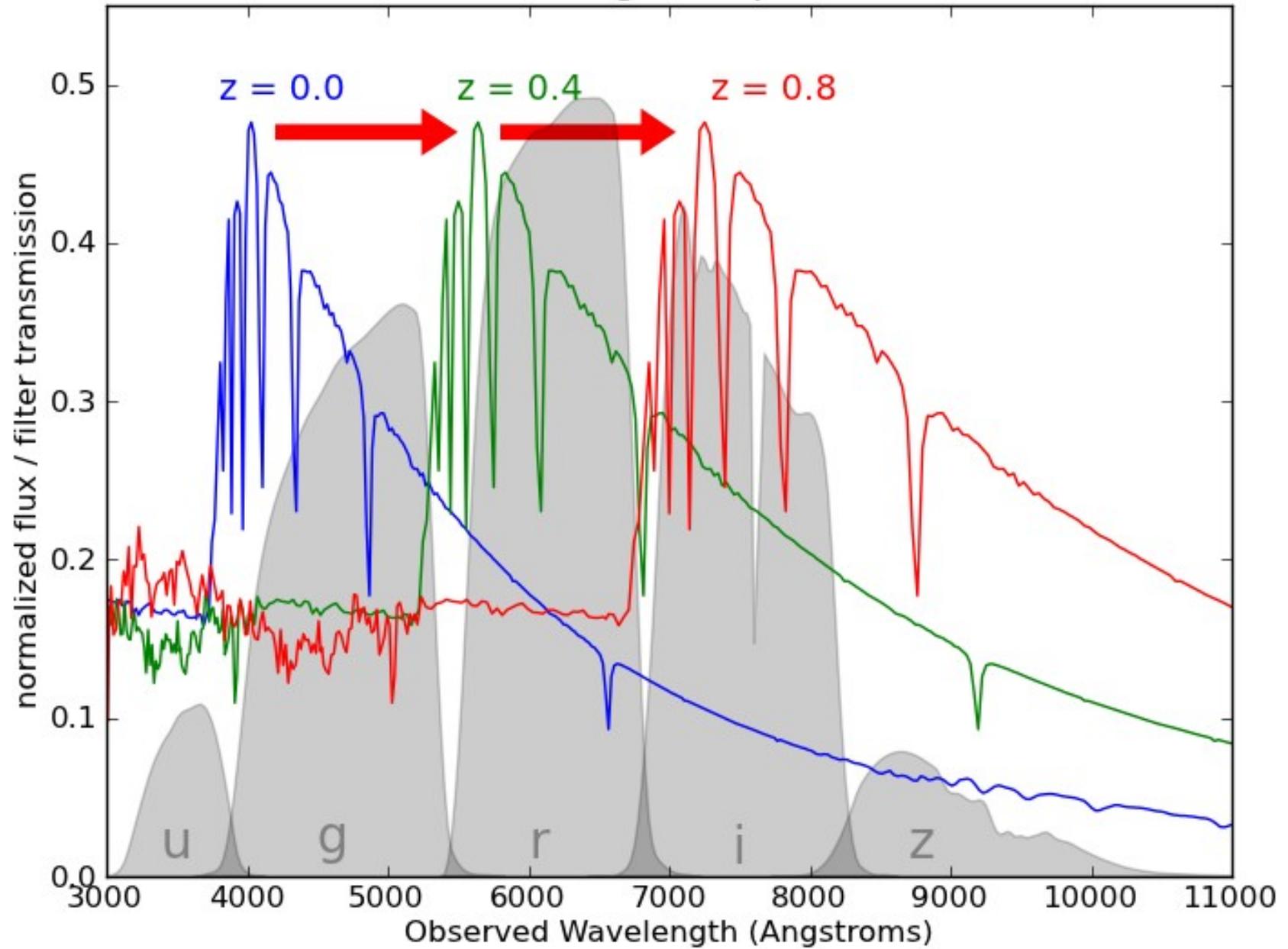
Credit: NASA; ESA; G. Illingworth, D. Magee, and P. Oesch, University of California, Santa Cruz; R. Bouwens, Leiden University; and the HUDF09 Team

Illustration Credit: NASA; ESA; and Z. Levay, STScI; Moon Image Credit: T. Rector; I. Dell'Antonio/NOAO/AURA/NSF

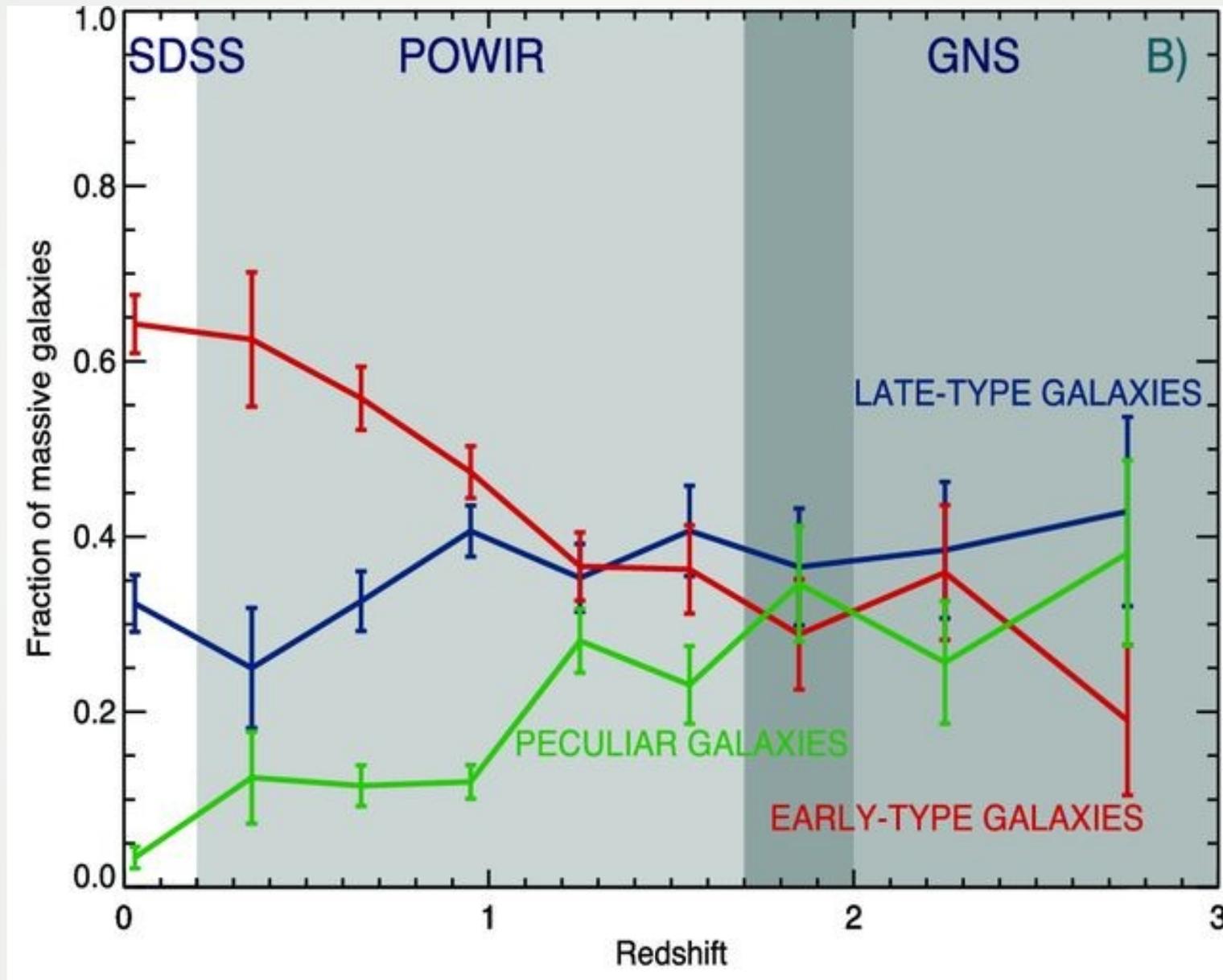
### SDSS Filters and Reference Spectrum



## Redshifting of a Spectrum

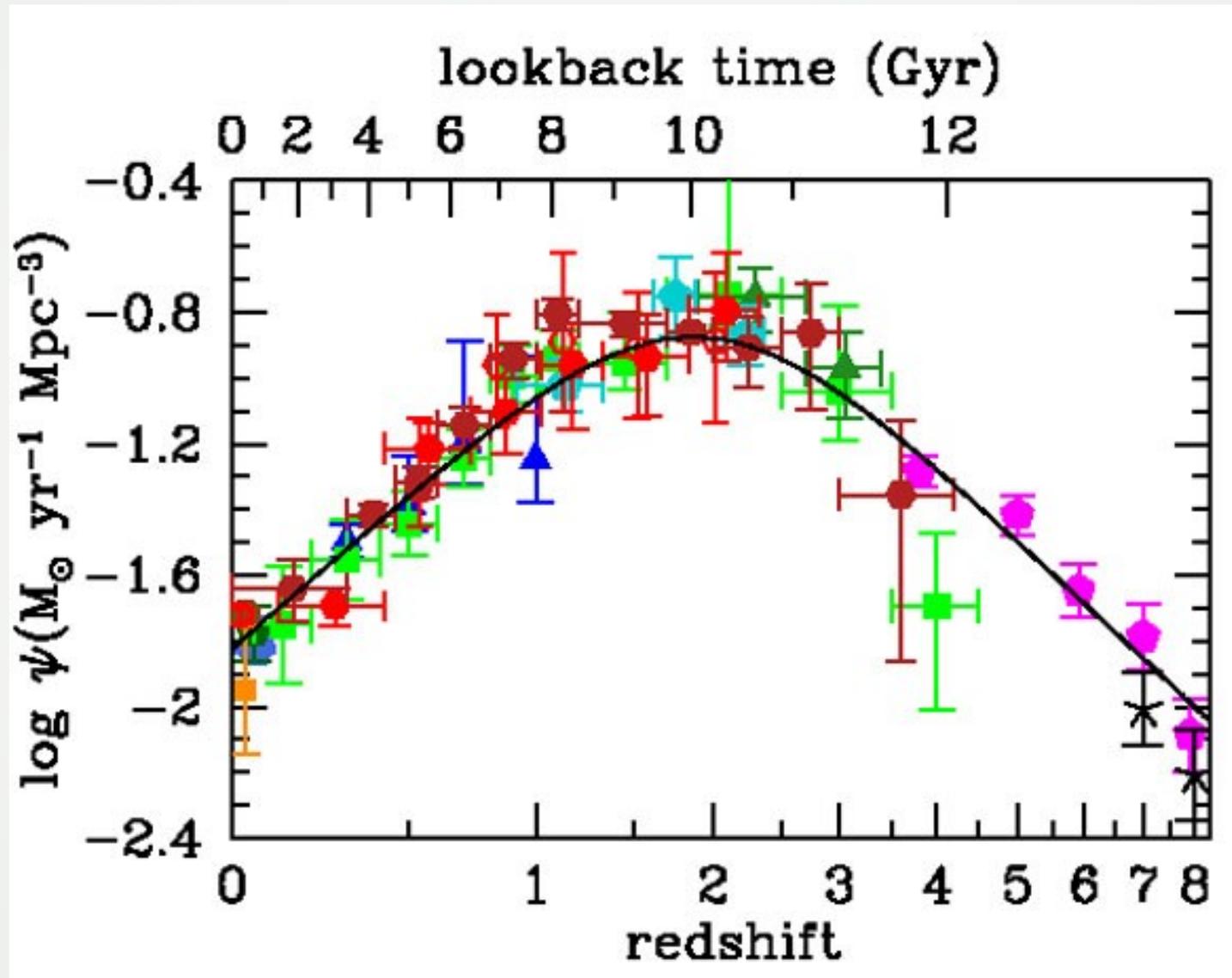


# Morfološka sprememba z rdečim premikom



delež masivnih galaksij ( $M > 10^{11} M_{\text{sun}}$ ) glede na rdeči premik (Buitrago et al. 2013)

# Zgodovina nastajanja zvezd v vesolju



Hitrost nastanka zvezd (*SFR* - *star formation rate*) v odvisnosti od rdečega premika. Simboli se nanašajo na rezultate različnih pregledov neba (IR in UV) (*Madau & Dickinson 2014*)