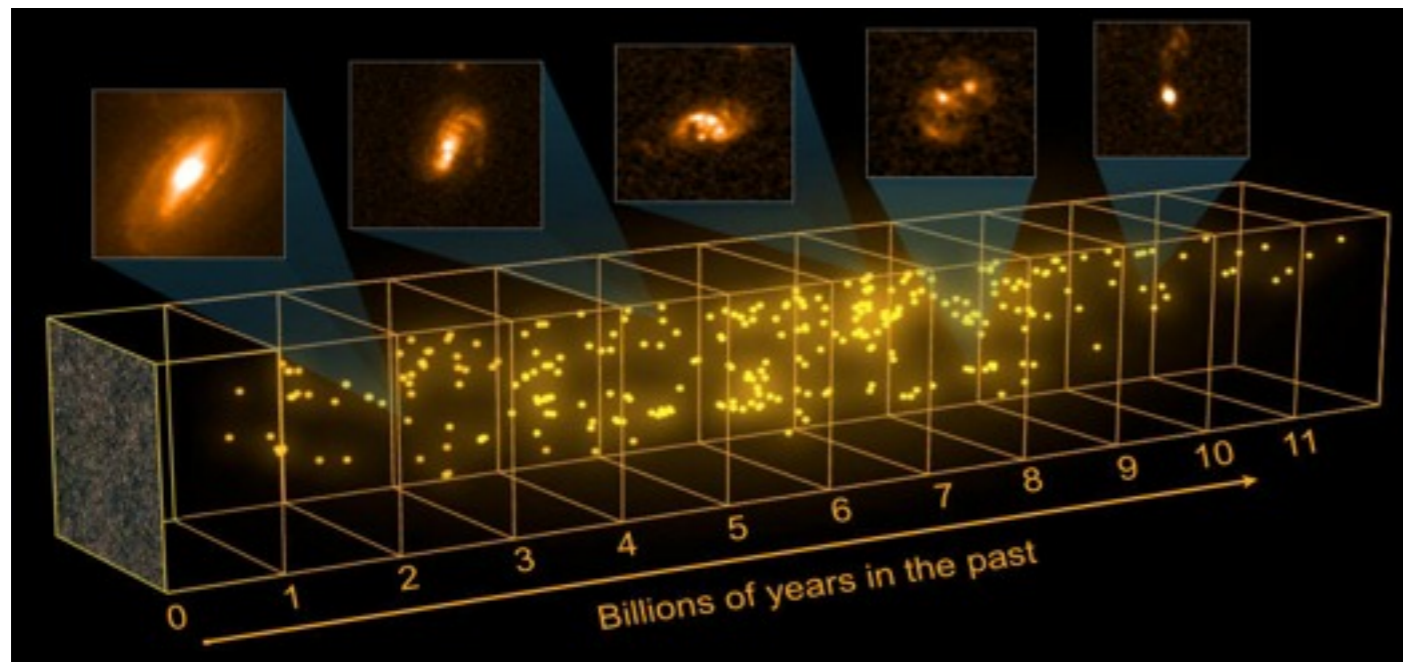




Evolucija ranih galaksija

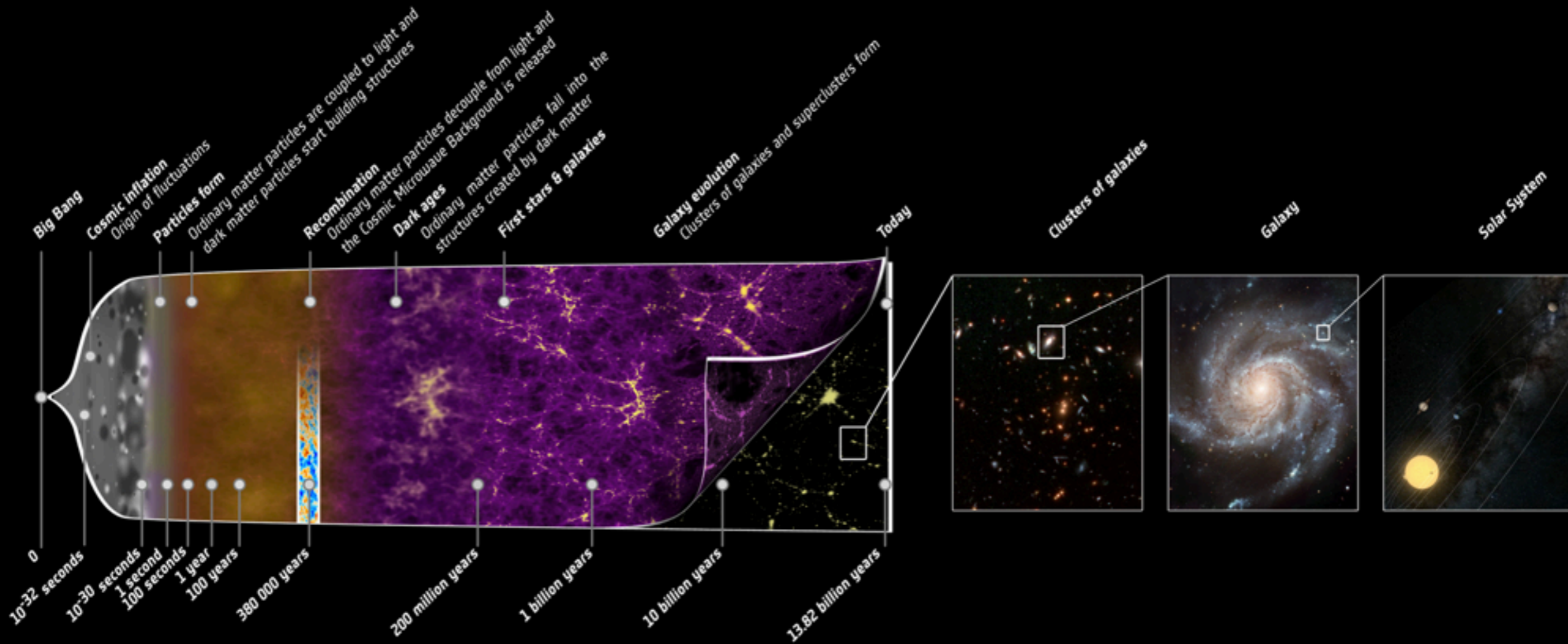


Darko Donevski
Leiden Observatory
ASTRON Institute
University of Leiden

Sadržaj predavanja

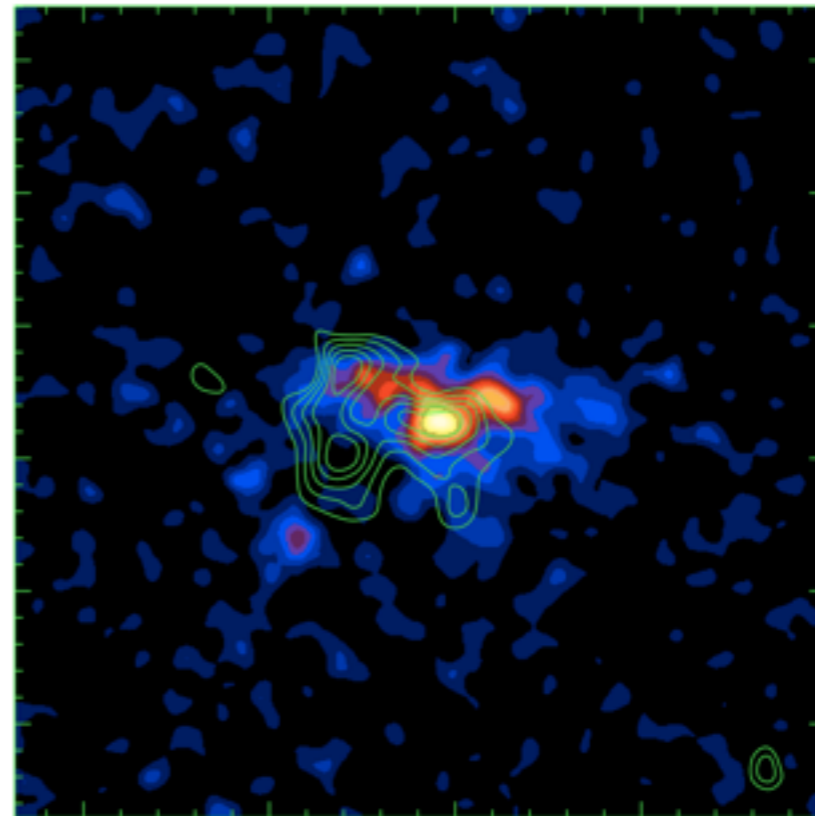
- Koliko poznajemo posmatračku kosmologiju danas?
- Zašto je važno tražiti protojata galaksija?
- Čime i kako ih tražimo?
- Čemu to služi?
- Astrofizika izučavanjem galaksija u protojatima

Mala kosmološka vremenska kapsula



1.1. Galaktički ID

- Ne znamo baš kako su nastale...ali zato... NE znamo ni kako evoluiraju :)
- Prve zvezde (redshift ~ 20), prve galaksije ($z\sim 10$).
- Najvažniji parametri:
- Masa zvezdane populacije-masa haloa (barioni vs. tamna materija)
- Luminoznost
- Stopa rađanja zvezda
- Dijagram boje
- Galaktičko okruženje

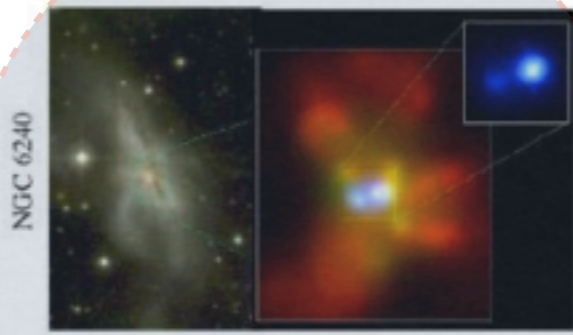


(c) Interaction/“Merger”



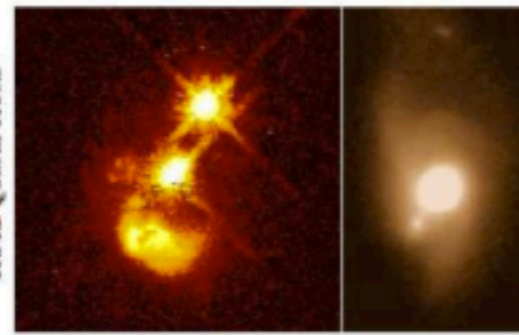
- now within one halo, galaxies interact & lose angular momentum
- SFR starts to increase
- stellar winds dominate feedback
- rarely excite QSOs (only special orbits)

(d) Coalescence/(U)LIRG



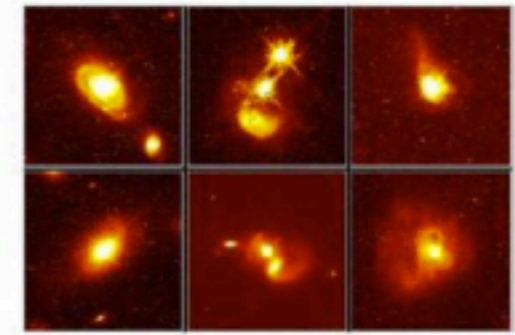
- galaxies coalesce: violent relaxation in core
- gas inflows to center: starburst & buried (X-ray) AGN
- starburst dominates luminosity/feedback, but, total stellar mass formed is small

(e) “Blowout”



- BH grows rapidly: briefly dominates luminosity/feedback
- remaining dust/gas expelled
- get reddened (but not Type II) QSO: recent/ongoing SF in host
- high Eddington ratios
- merger signatures still visible

(f) Quasar



- dust removed: now a “traditional” QSO
- host morphology difficult to observe: tidal features fade rapidly
- characteristically blue/young spheroid

(b) “Small Group”



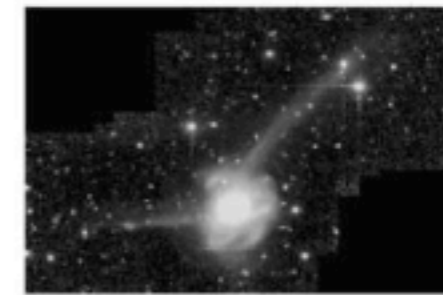
- halo accretes similar-mass companion(s)
- can occur over a wide mass range
- M_{halo} still similar to before: dynamical friction merges the subhalos efficiently

(a) Isolated Disk



- halo & disk grow, most stars formed
- secular growth builds bars & pseudobulges
- “Seyfert” fueling (AGN with $M_b > -23$)
- cannot redden to the red sequence

(g) Decay/K+A

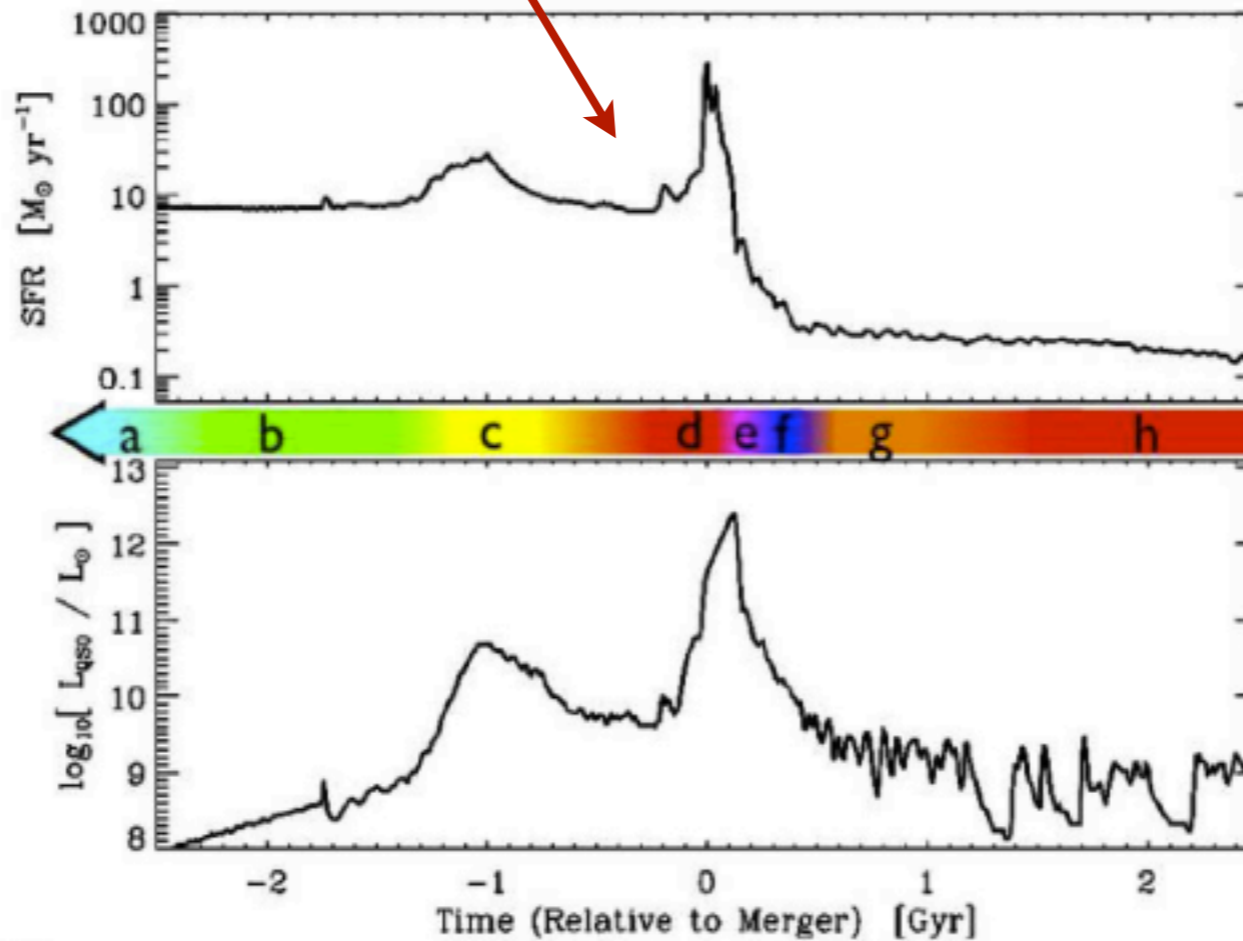


- QSO luminosity fades rapidly
- tidal features visible only with very deep observations
- remnant reddens rapidly (E+A/K+A)
- “hot halo” from feedback
- sets up quasi-static cooling

(h) “Dead” Elliptical



- star formation terminated
- large BH/spheroid - efficient feedback
- halo grows to “large group” scales: mergers become inefficient
- growth by “dry” mergers

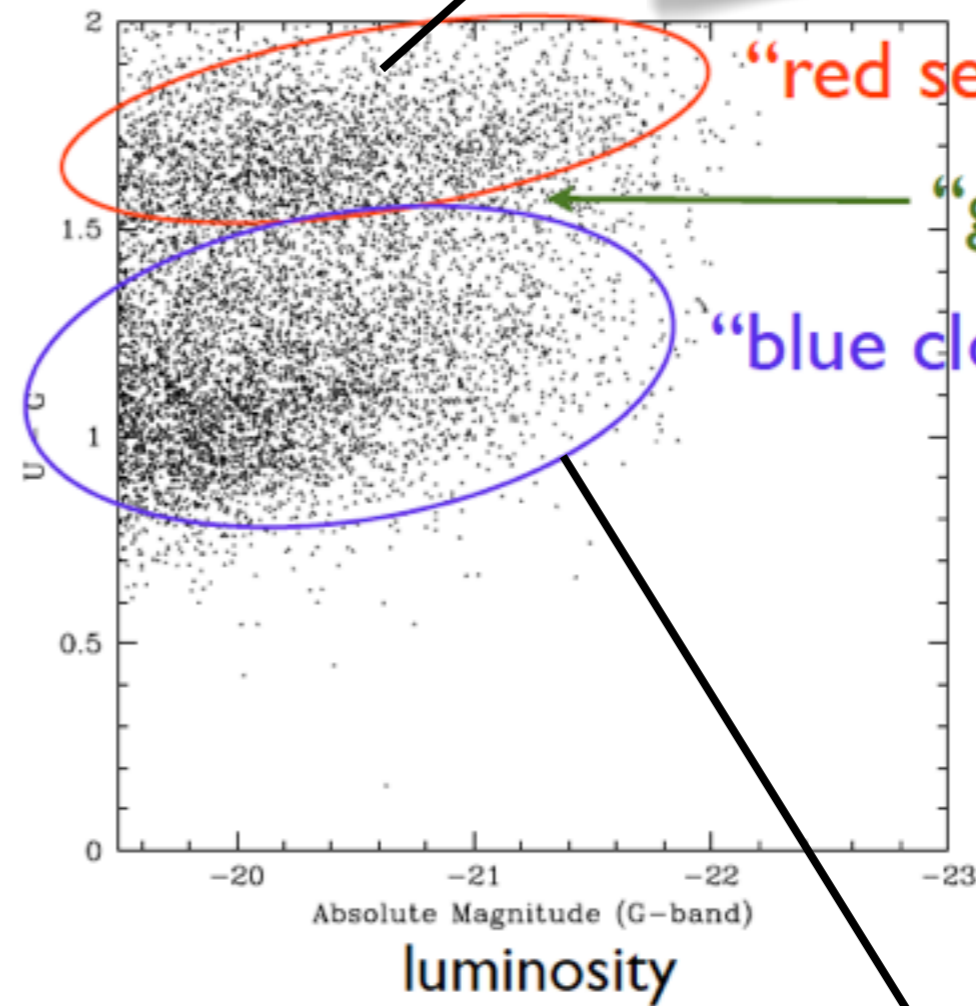


Evolucija galaksija / današnji status

1.2. Evolucija galaksija = **BOJE** galaksija

- U Svemiru - mnogo manje svetlih galaksija od onih koje su slabo vidljive ("faint")
- Eliptične galaksije uglavnom **CRVENE**
- Spiralne galaksije **PLAVE**

color



Puno vrelog gasa= nema stvaranja zvezda

"red sequence"

"green valley"

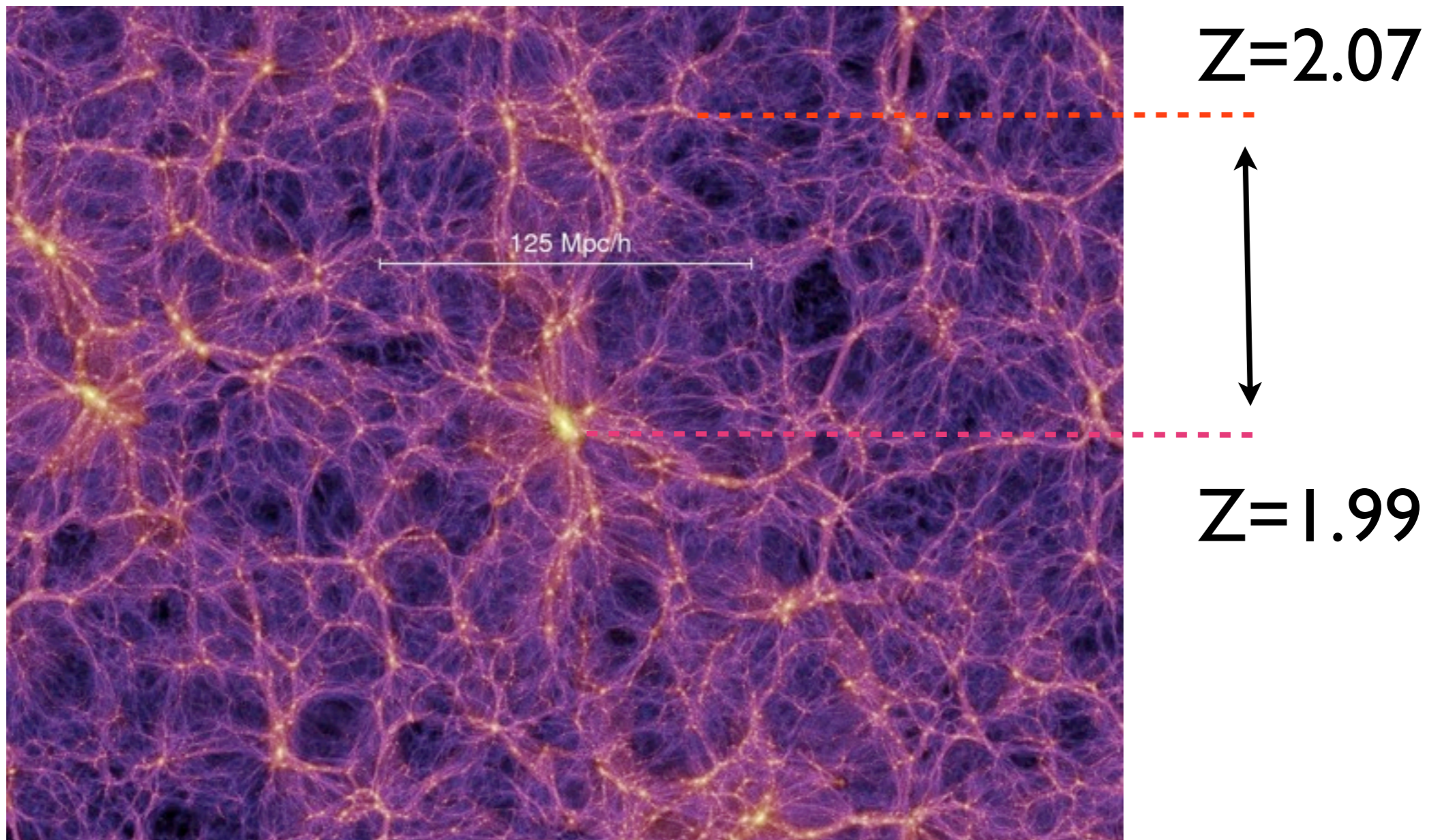
"blue cloud"

Puno hladnog gasa koji se konvertuje u zvezde !

Intenzitet luminoznosti kroz 2 fotometrijska filtera

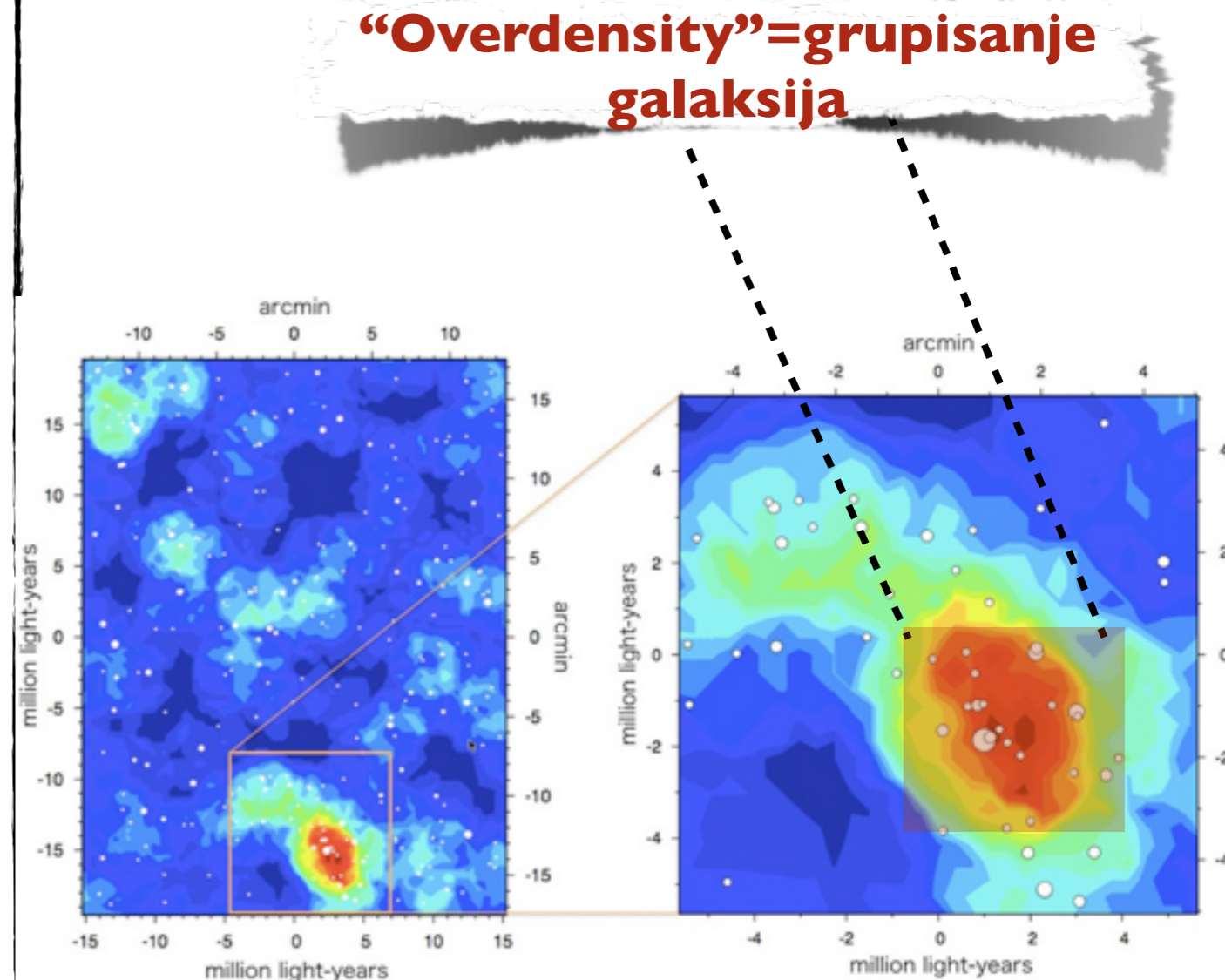
1.3. Šta nam kaže teorija?

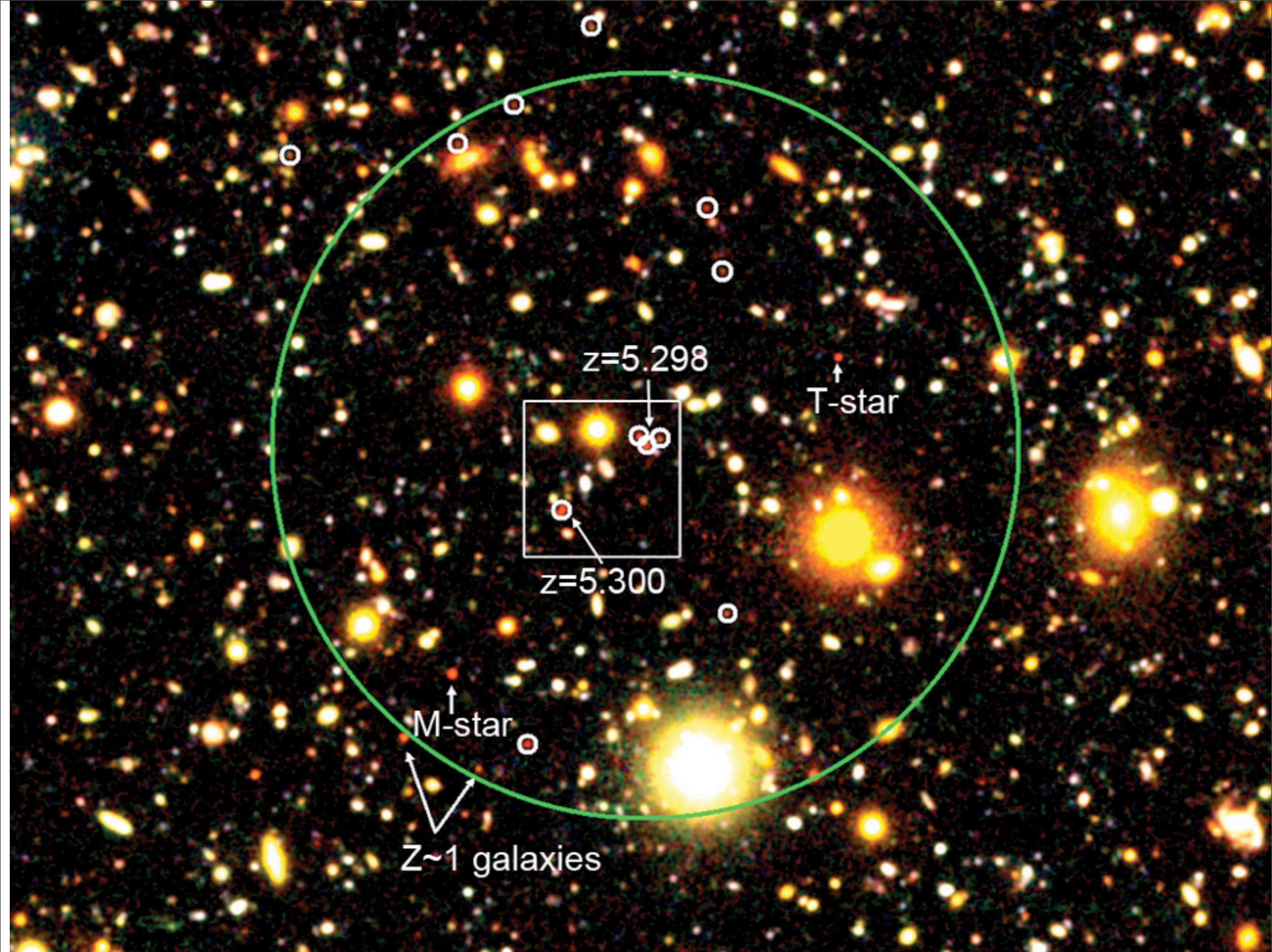
- N-čestične simulacije (Milenium simulation, Springel et al. 2006)



1.4. Šta nam kažu posmatranja (a šta teorija) ?

- **Matematika** - mora da se računa korelacija između tačaka da bi se proverilo udruživanje galaksija u strukturu
- **Astronomija** - mora da se nađe način kako da se traga za protojatomima !
- **Astrofizika** - radijacioni mehanizmi + evolucija pojedinačnih delova strukture + evolucija hemijskih elemenata
- **Kosmologija** - kako da pratimo šta se dešava sa tamnom materijom





1.5. Osnovni sastojak proto-jata=ULIRG

Ultraluminous Infra-Red Galaxies

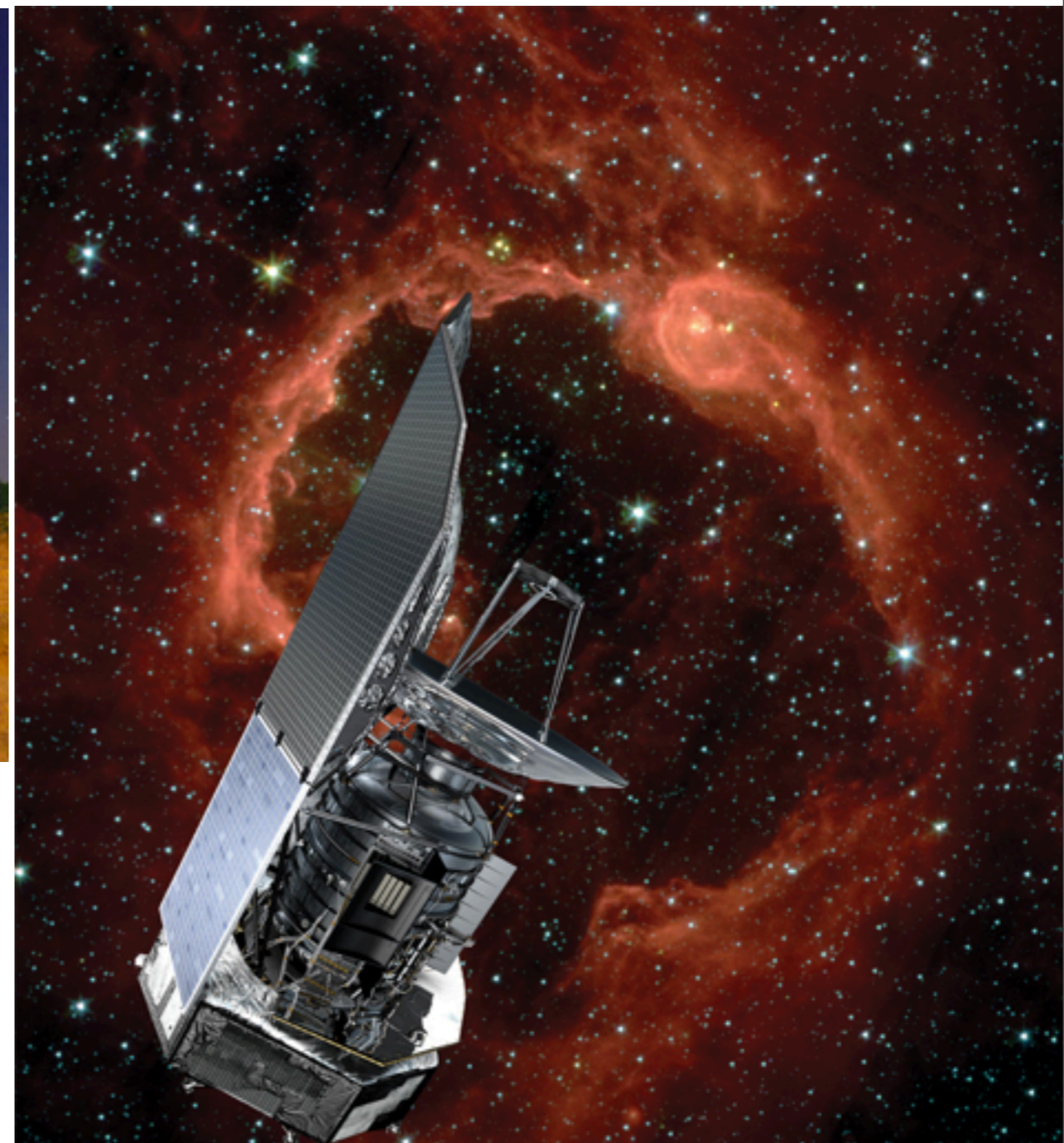
- Obične LIRG = Singl-galaksije (uglavnom) koje imaju spiralnu strukturu (80%)
- ULIRG= stadijum tzv. “galaktičkih sudara”
- Puno gasa (= star-forming) Luminoznost $> 10^{12}$ Sunčevih
- Puno prašnjave (problem sa galaktičkom higijenom?)
- Određeni udeo zračenja dolazi od AGN-ova a ne od samog star-forming regiona (potrebno je nekako to razgraničiti... više reči u narednim slajdovima)

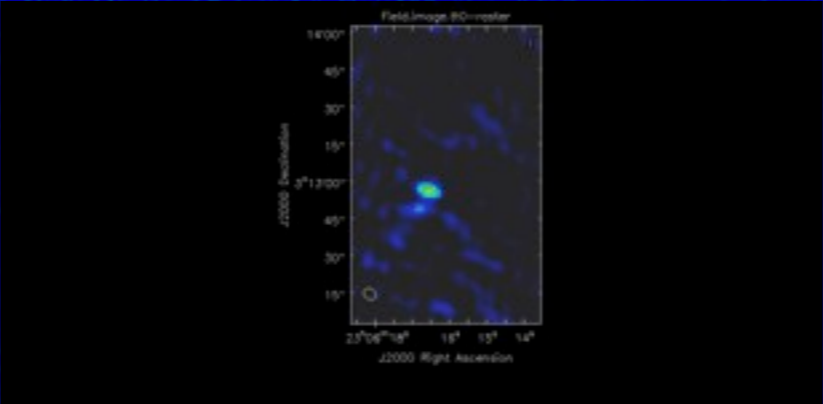
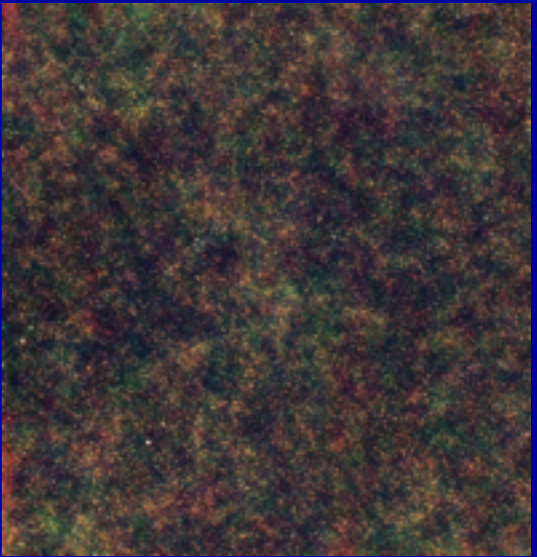
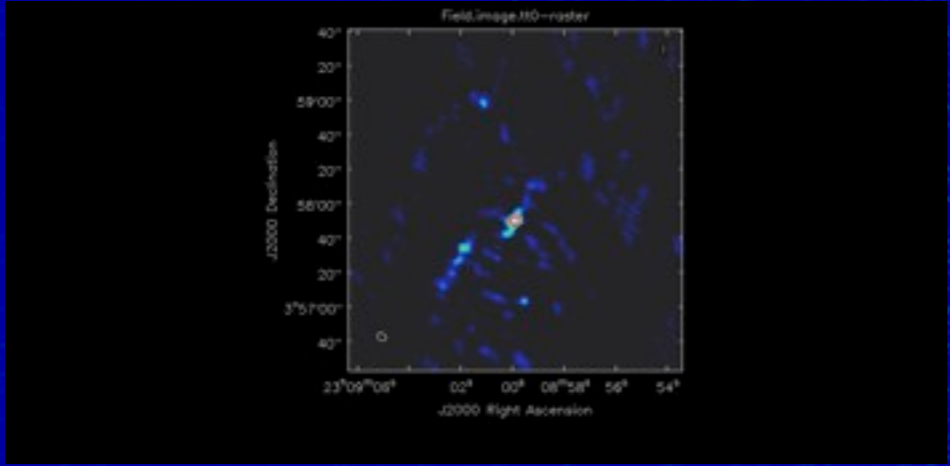
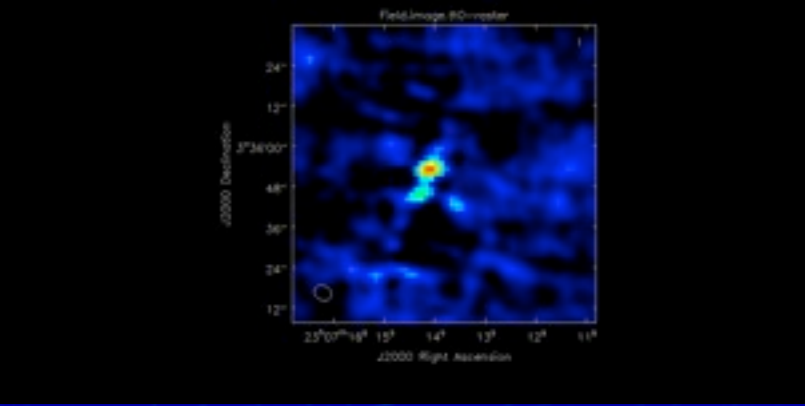
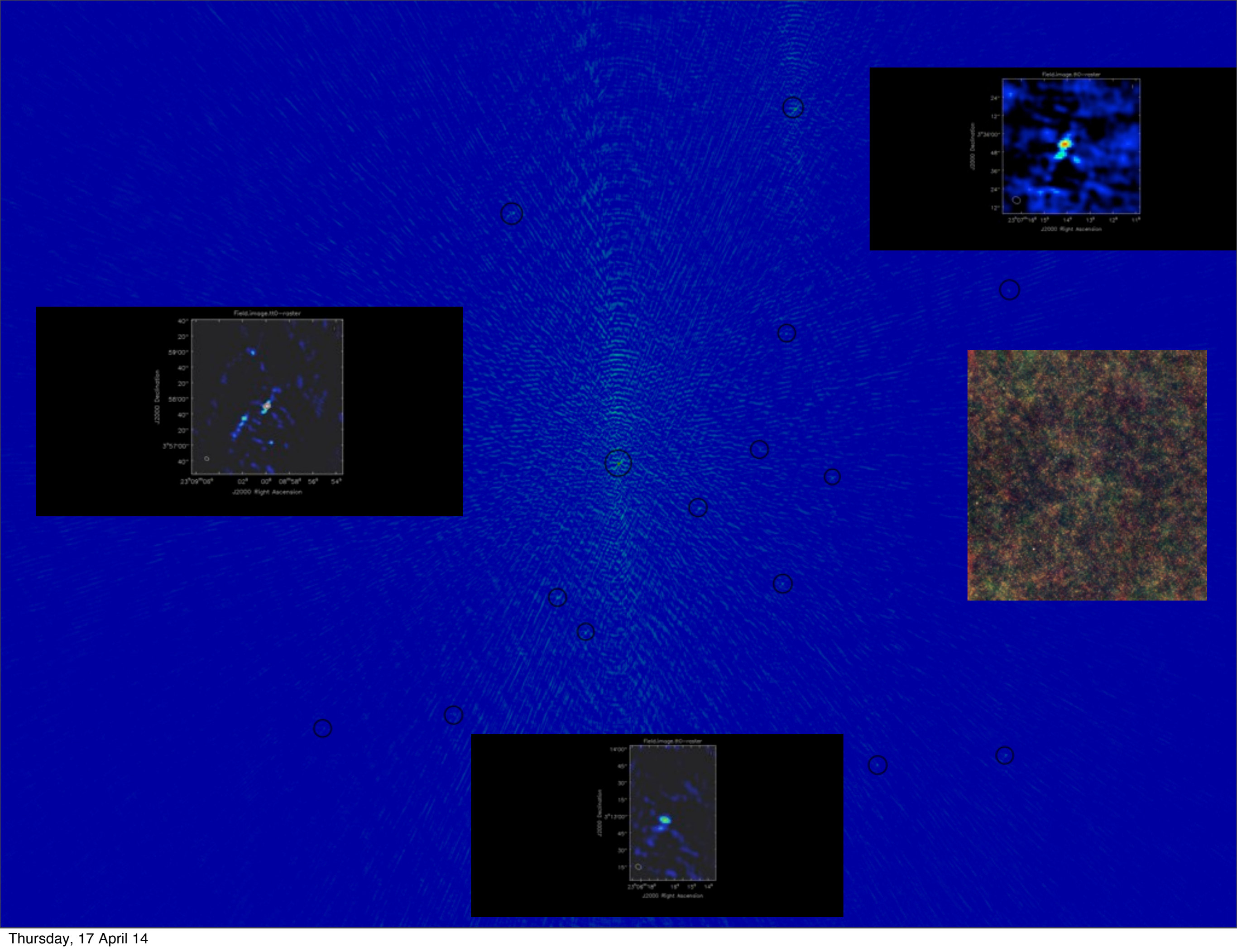


2. (a) Radio teleskopi današnjice LOFAR i VLA



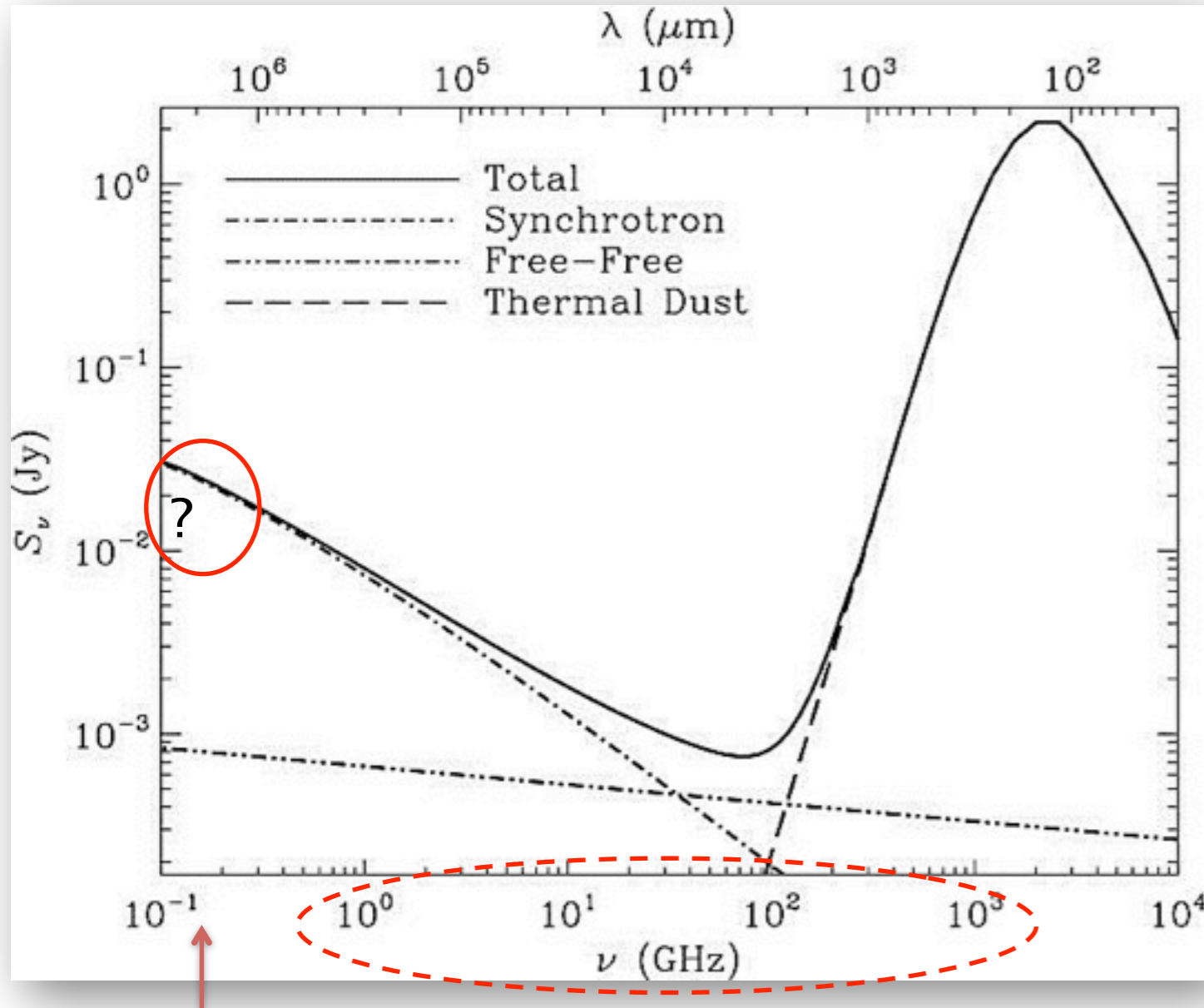
2. (b) Ostali važni teleskopi GMRT ; HERSCHEL;





3. Astrofizika

3.1 SED kriva za "star-forming" galaksije



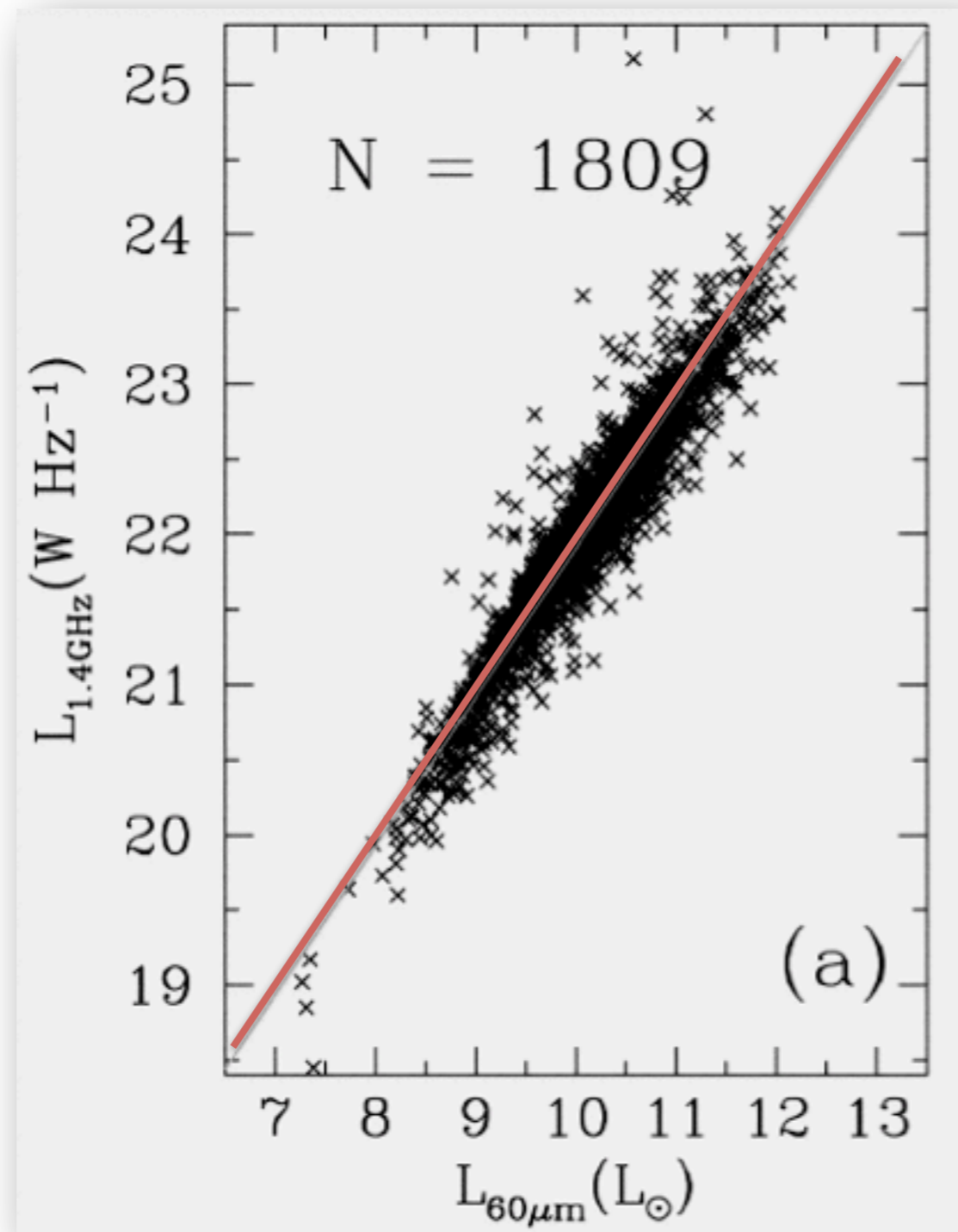
- **Više radio frekvencije**

- Na GHz frekvencijamaa spektar sinhrotronog zračenja $S(\nu) \propto \nu^\alpha$, pri čemu je $\alpha \sim -0.8$, dok je za free/free emisiju stepen mnogo ravniji ($\alpha = -0.1$).

- **Niže radio frekvencije**

- Free-free optička dubina postaje mnogo veća i spektar sinhrotronog zračenja postaje mnogo podložniji apsorpciji.

3.2 Šta je Far IR - Radio korelacija?

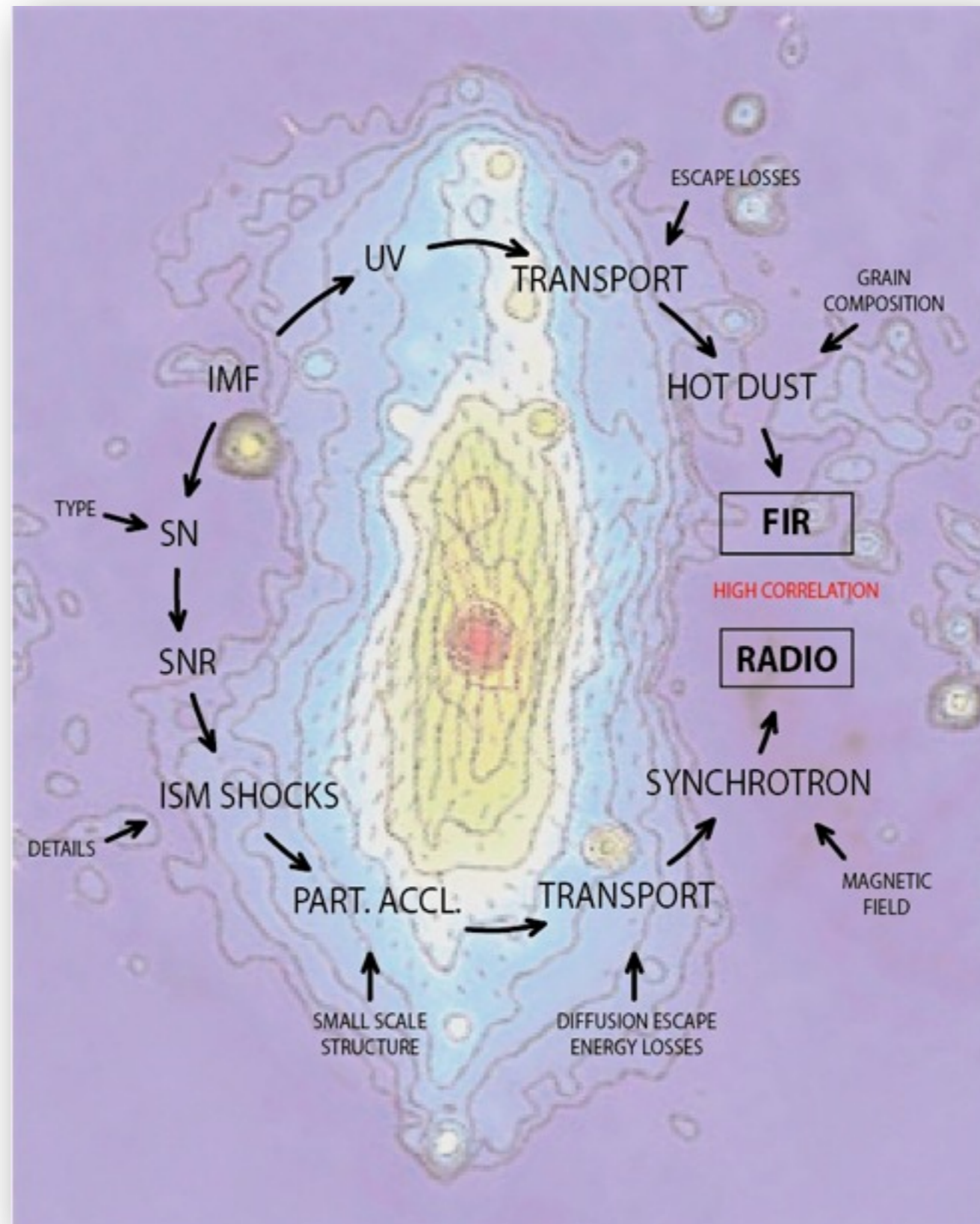


Bell (2003)

3.3. Mehanizmi zračenja / poreklo

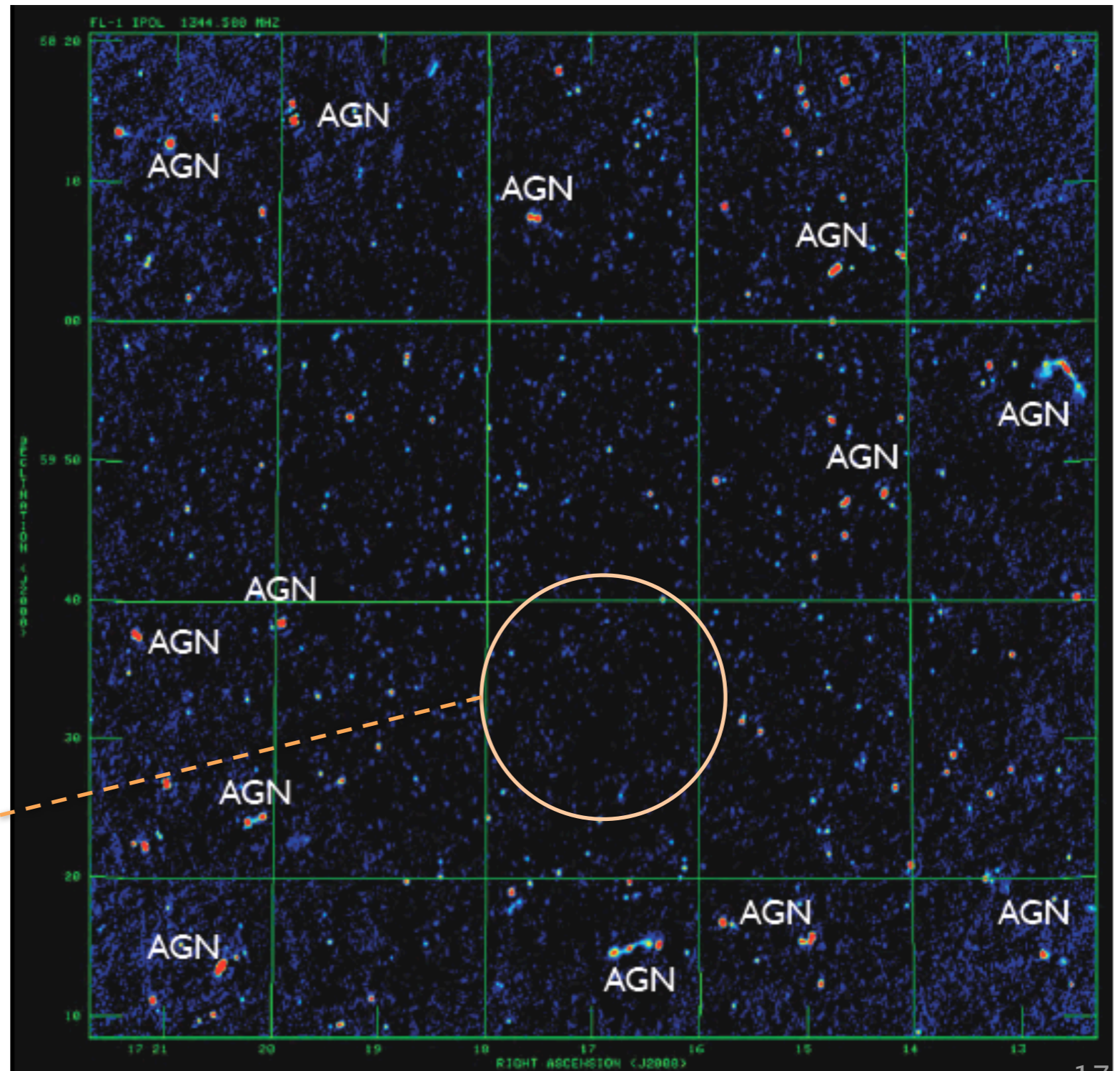
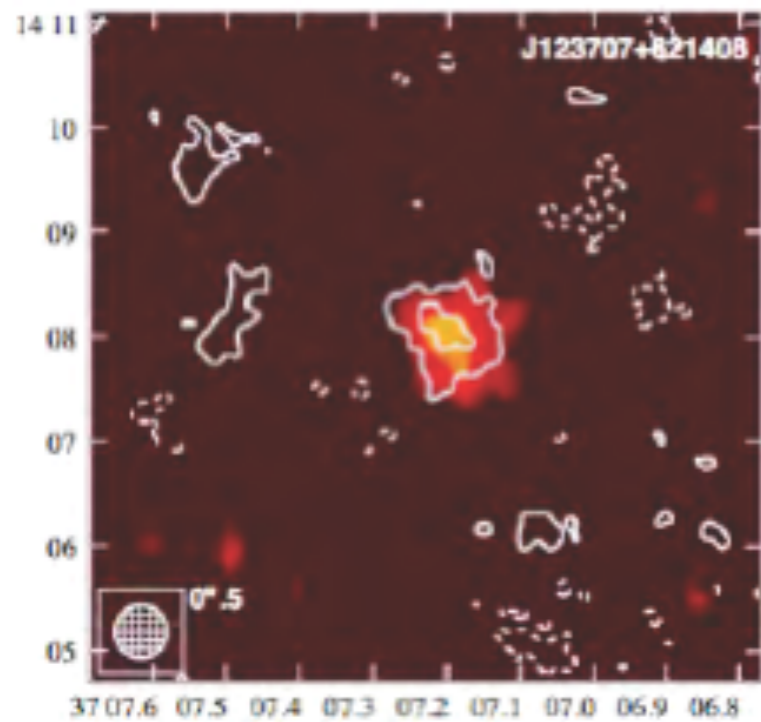
FRC čvrsta na skoro 6
MAGNITUDA merenih
luminoznosti!!!
(od MHz to 10^4 GHz !)

- Kombinacija procesa na manjim i većim skalama.



3.4. Radio mape – kakva su okruženja dalekih

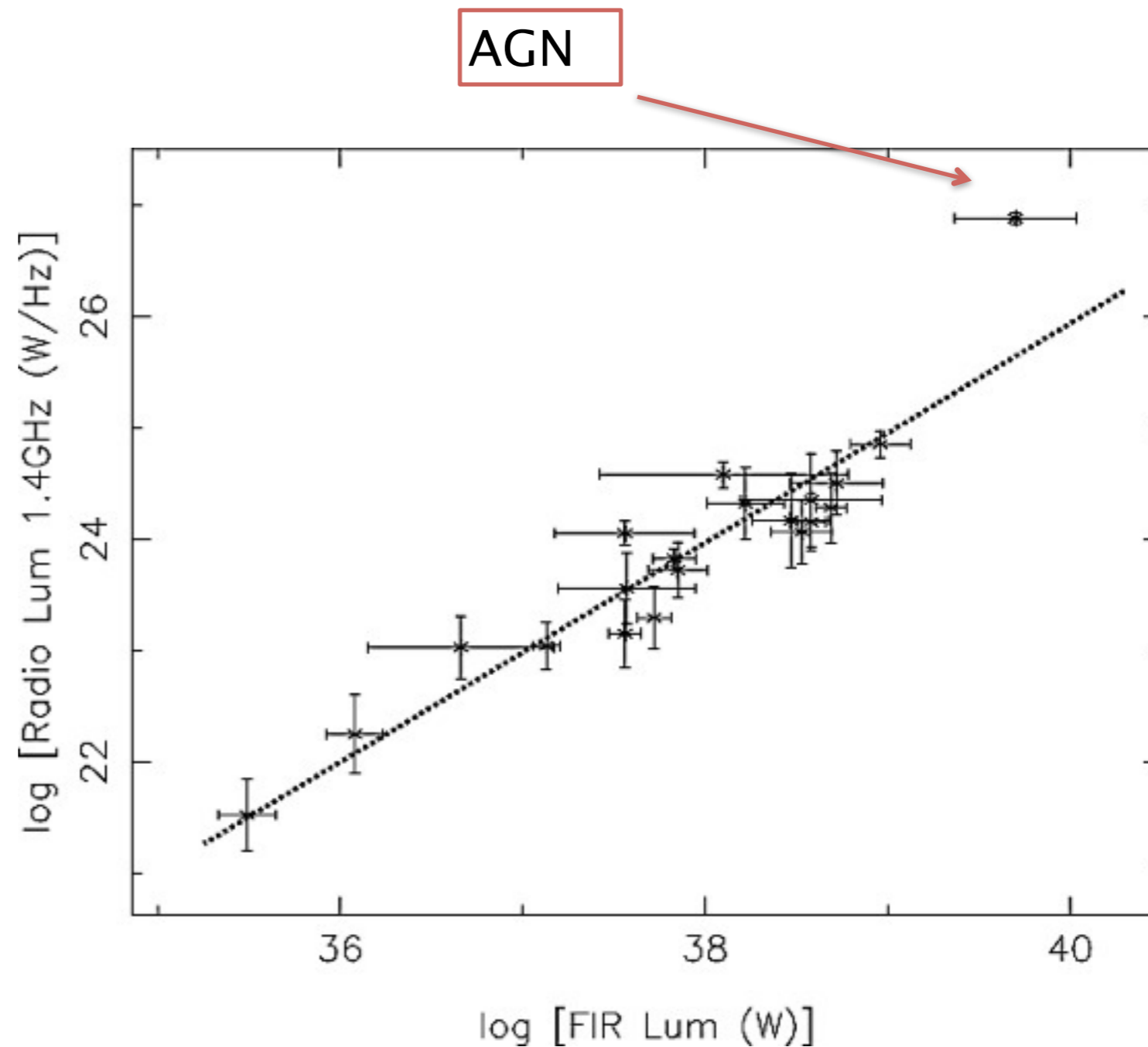
star former (~60%)



Na najdubljem i najtamnijem nivou radio mapa, ULIRG dominiraju nad AGN-ovima

3.5. Kako koristiti FRC relaciju kao alat?

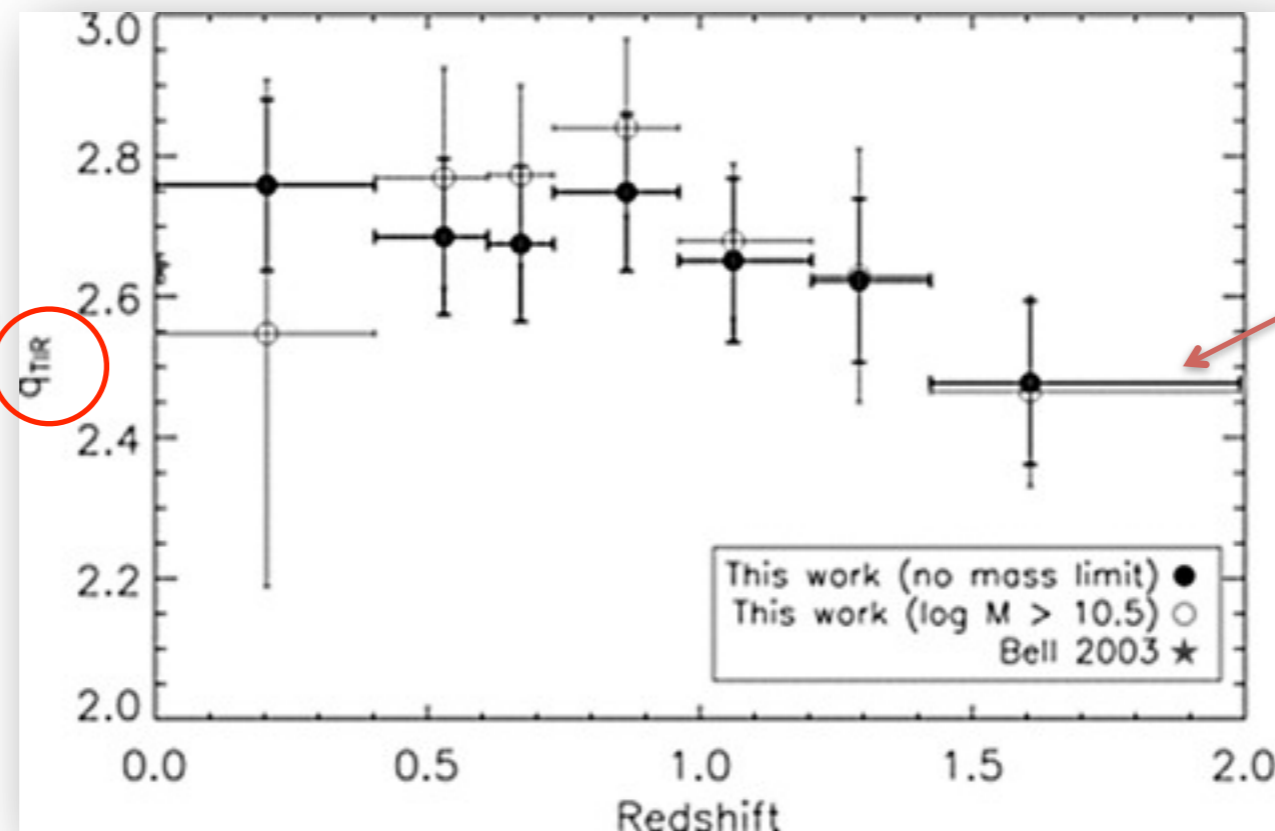
- Identifikacija višaka (AGN)
- Lociramo AGN zagađivače kroz 2 faktora:
- **T_b** and spektralni indeks



3.6. Duboka radio posmatranja na većim z pokazuju naznake evolucije?

Vrednost između IC i radio luminoznosti za uzorak ULIRG galaksija

$$q_{\text{IR}} = \log_{10} \left(\frac{S_{\nu, \text{IR}}}{S_{\nu, 1.4 \text{ GHz}}} \right).$$



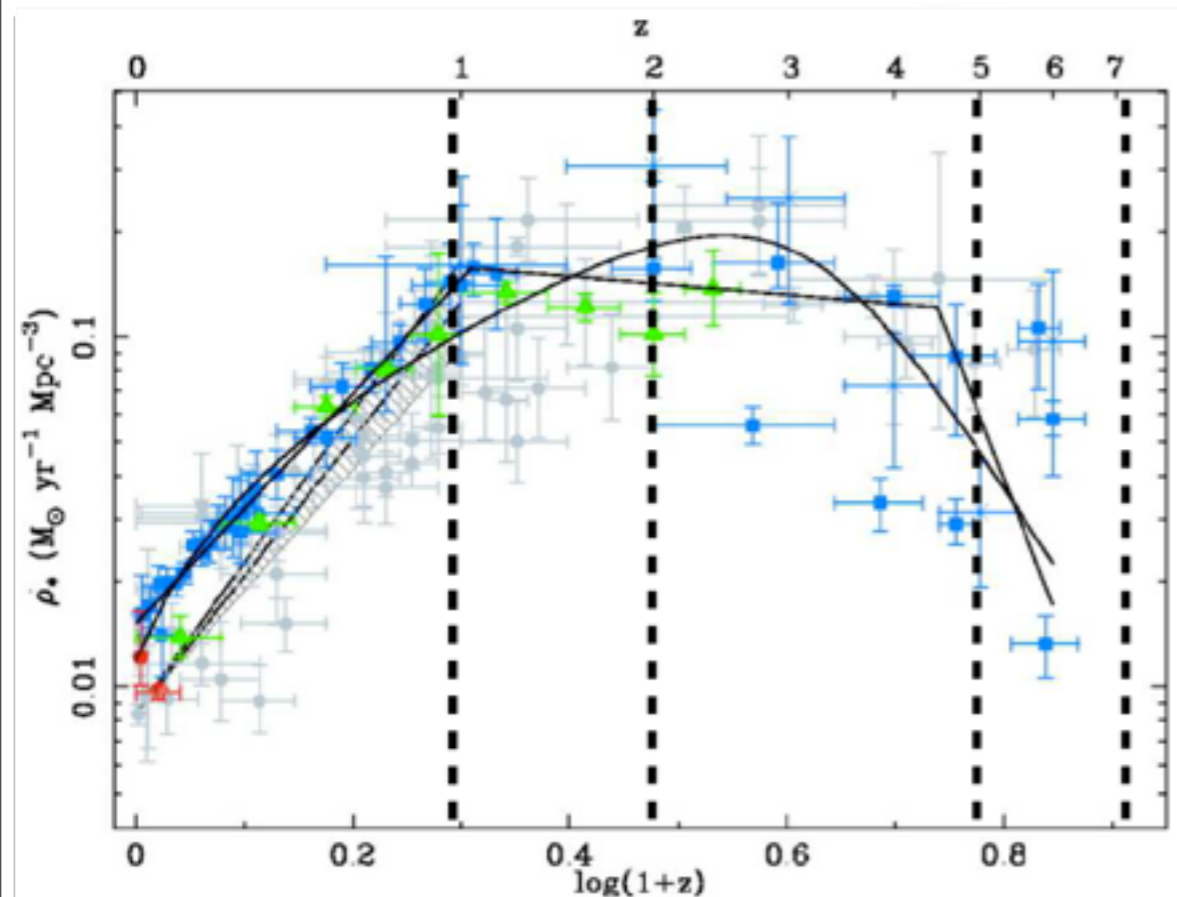
Merenja 610 MHz fluksa na većim crvenim pomacima (blizu 2) pokazuju naznake da se spektralni indeks drugačije ponaša.

Bourne et al. (2012)

4. Posledice na globalno ponašanje galaksija / i šta dalje?

- Šta je, zapravo, SED?

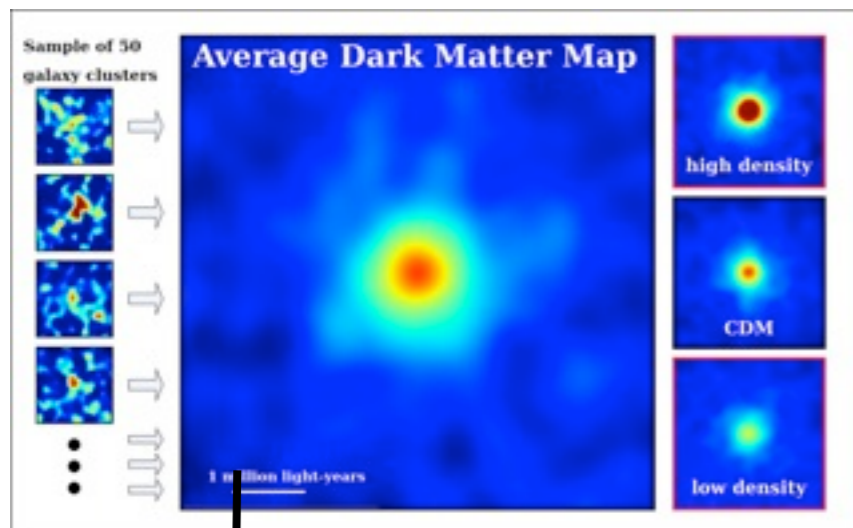
$$SED = \sum S_{dust} + S_{free} + S_{sync}$$



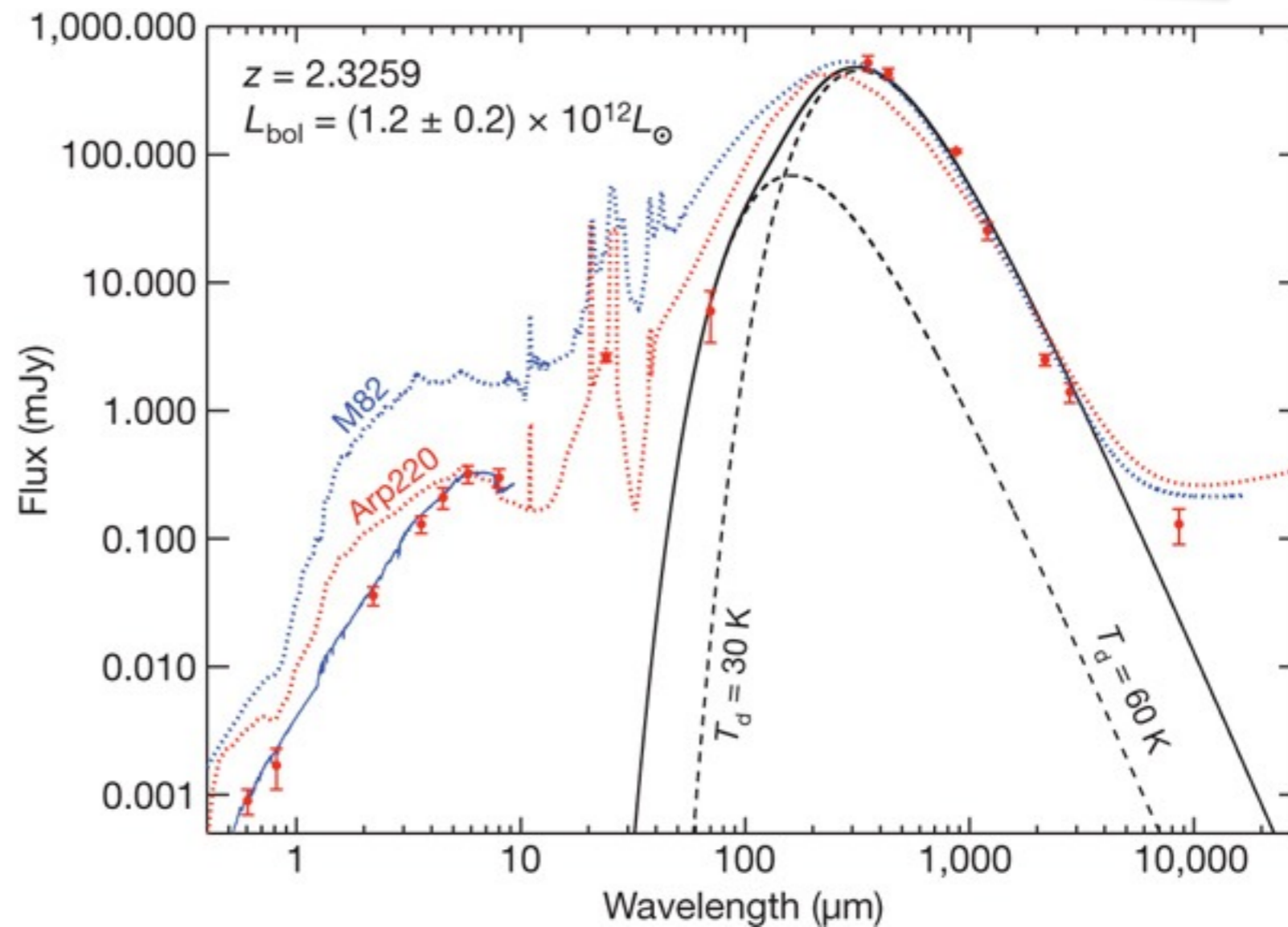
Dakle, možemo celokupnu istoriju galaksija da opišemo sa dve veličine

SFR & D_L

4.1. Kako se porede modeli i realne SED krive



Evolucija tamne materije



Evolucija galaktičkog zračenja

Zaključci... (saveti, račun za plin)

- Praćenje promene u mehanizmima zračenja → različiti uticaji na okruženje.
- Ukupna masa sistema = SFR (galaktički ID)
- Promene SFR sa crvenim pomakom = SFR istorija (kosmički ID)
- Različita evolucija galaksija = različita evolucija mase, ali i tamne materije u haloima
- Ograničenja na prisutne kosmološke modele (Lambda CDM)
- Za posmatračke podatke potrebno mnogo obrade dubokih radio pretraživanja Kosmosa !!!