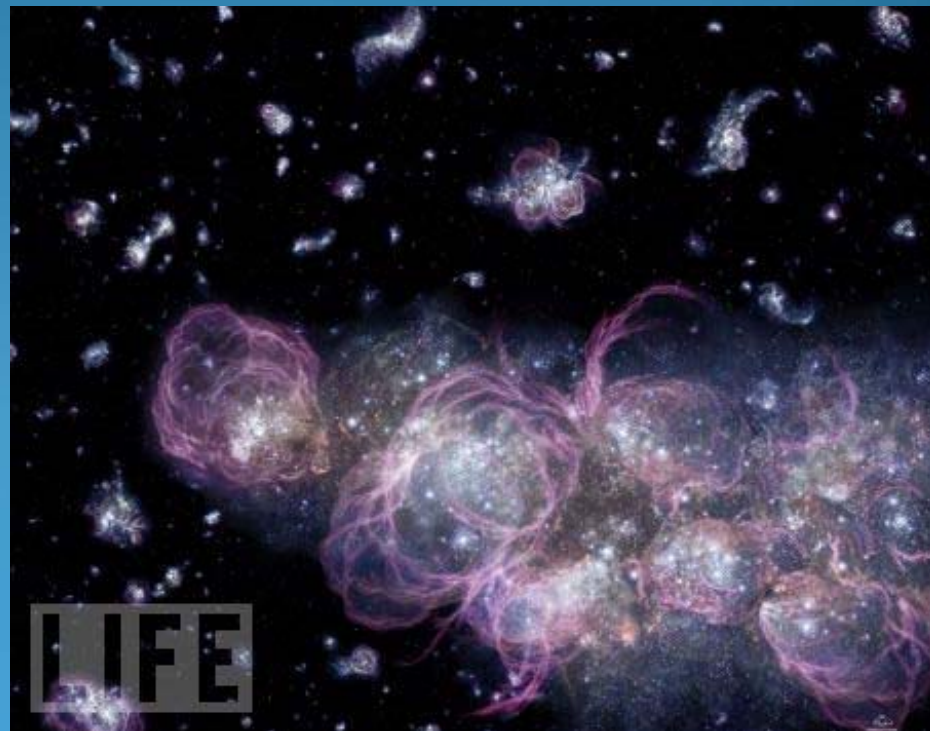


# Otkriće difuzne Lajman alfa emisije oko galaksija na crvenom pomaku $z=2.7$

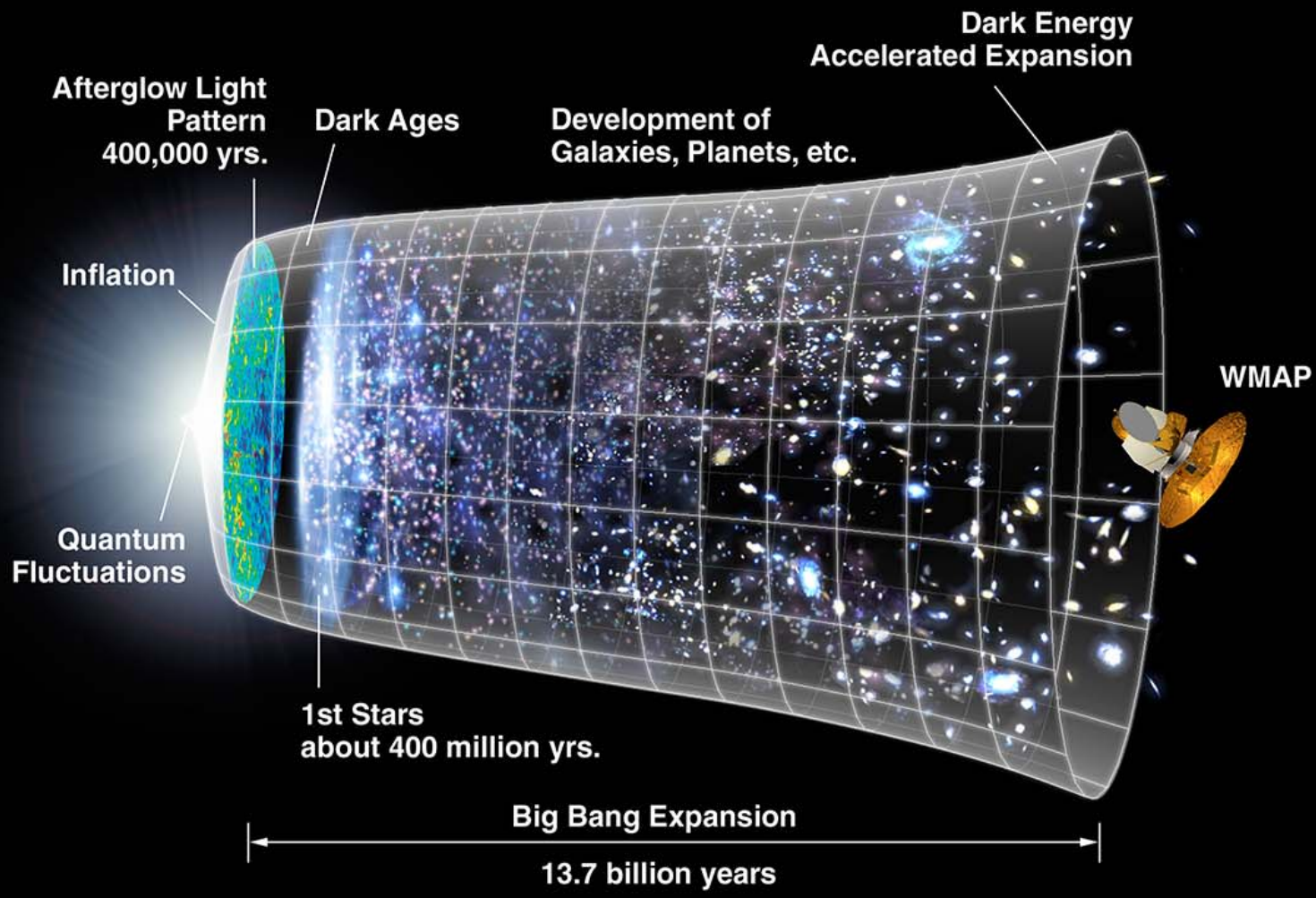
Dr Milan Bogosavljević  
Astronomska opservatorija Beograd

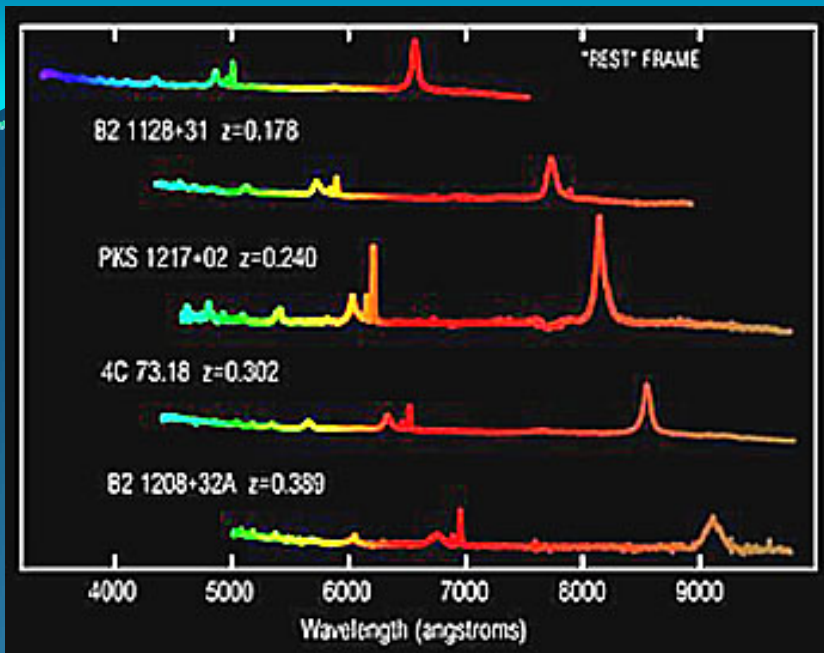
*Seminar Katedre za astronomiju  
30. novembar 2010*



# Pregled

- Crveni pomak i starost Svemira
  - Evolucija tamne materije i formiranje galaksija
  - Spektri zvezda i mladih galaksija
  - Lajman alfa linija – “najvažnija linija” za udaljene galaksije
  - “Lyman break” galaksije
- 
- Prvo otkriće Lajman alfa “grudvi” (Lyman alpha BLOBS)
  - Proto-jata galaksija i Lajman alfa “grudve”
  - Otkriće difuzne emisije i novi pogled na galaksije na visokom crvenom pomaku (IN PRESS)



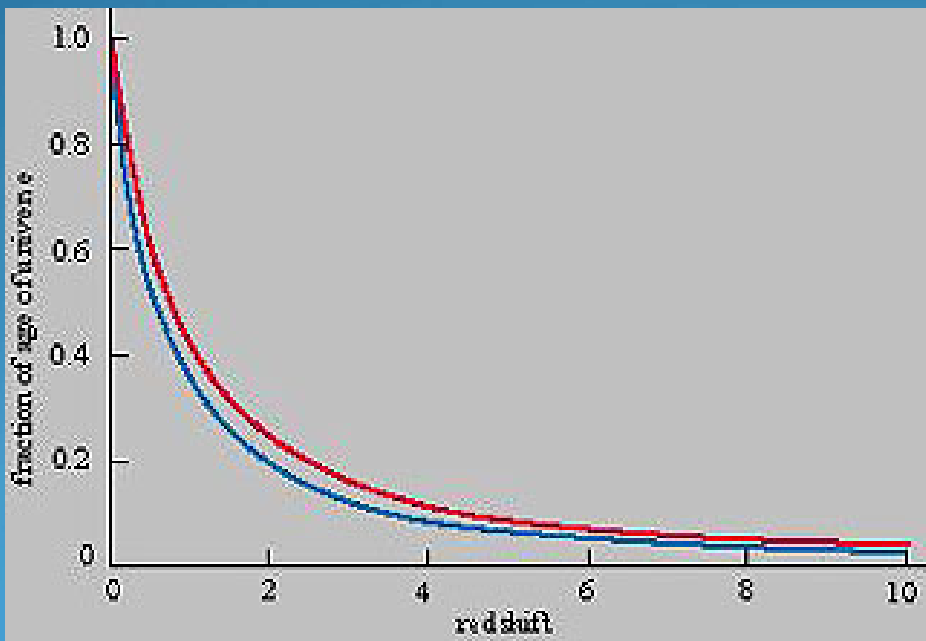


$$z = \frac{\lambda - \lambda_0}{\lambda_0}$$

$z = \text{redshift}$

$\lambda = \text{measured wavelength shift}$

$\lambda_0 = \text{true wavelength}$



M31 u Andromedi

$D = 2,555,000$  sv. godina

Starost svemira 13.66 Gyr

$z=0.1$   $D=1.3$  Gly  $t=12.4$  Gyr

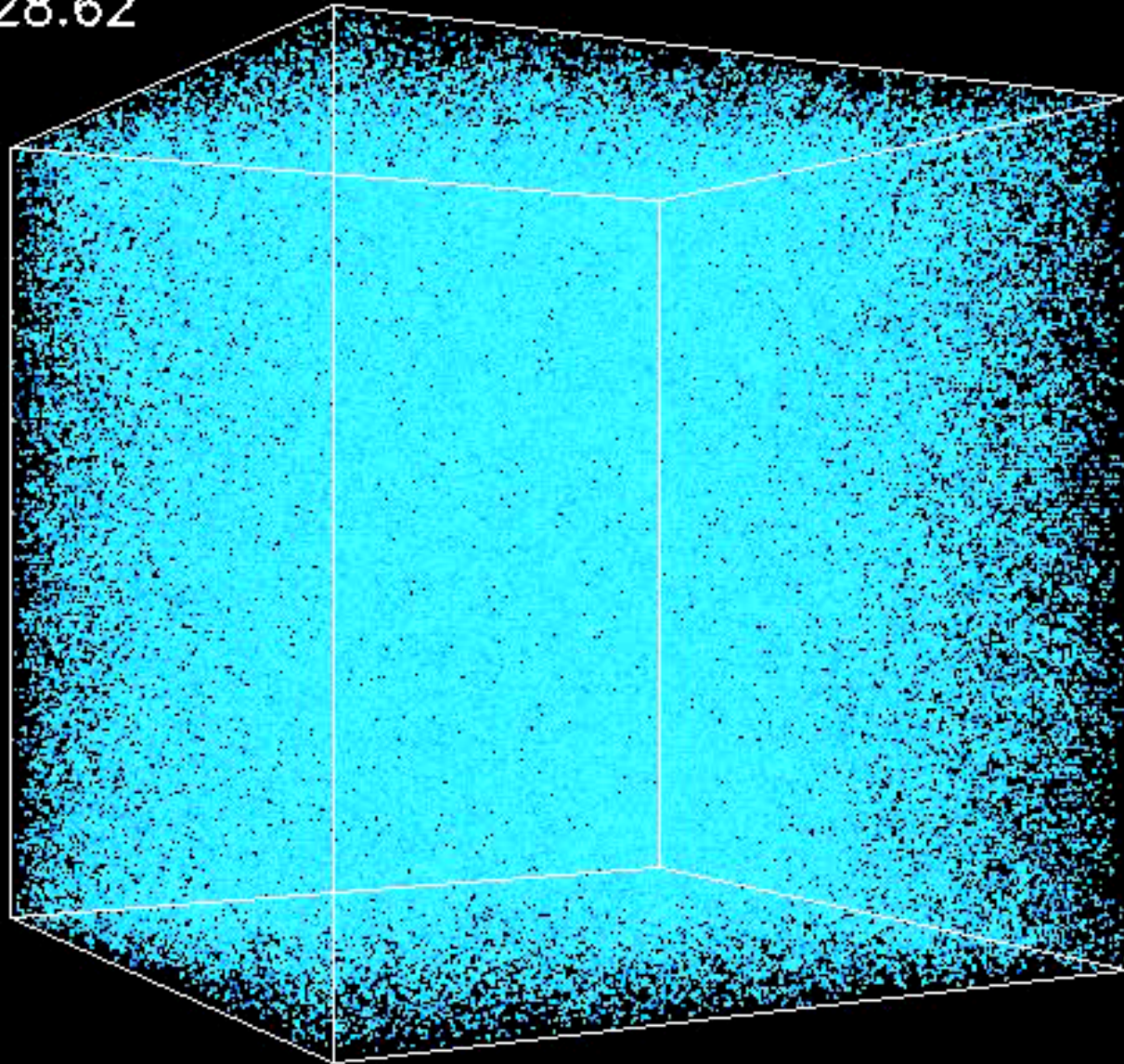
$z=1.0$   $D=11$  Gly  $t=6.0$  Gyr

$z=2.0$   $D=17$  Gly  $t=3.3$  Gyr

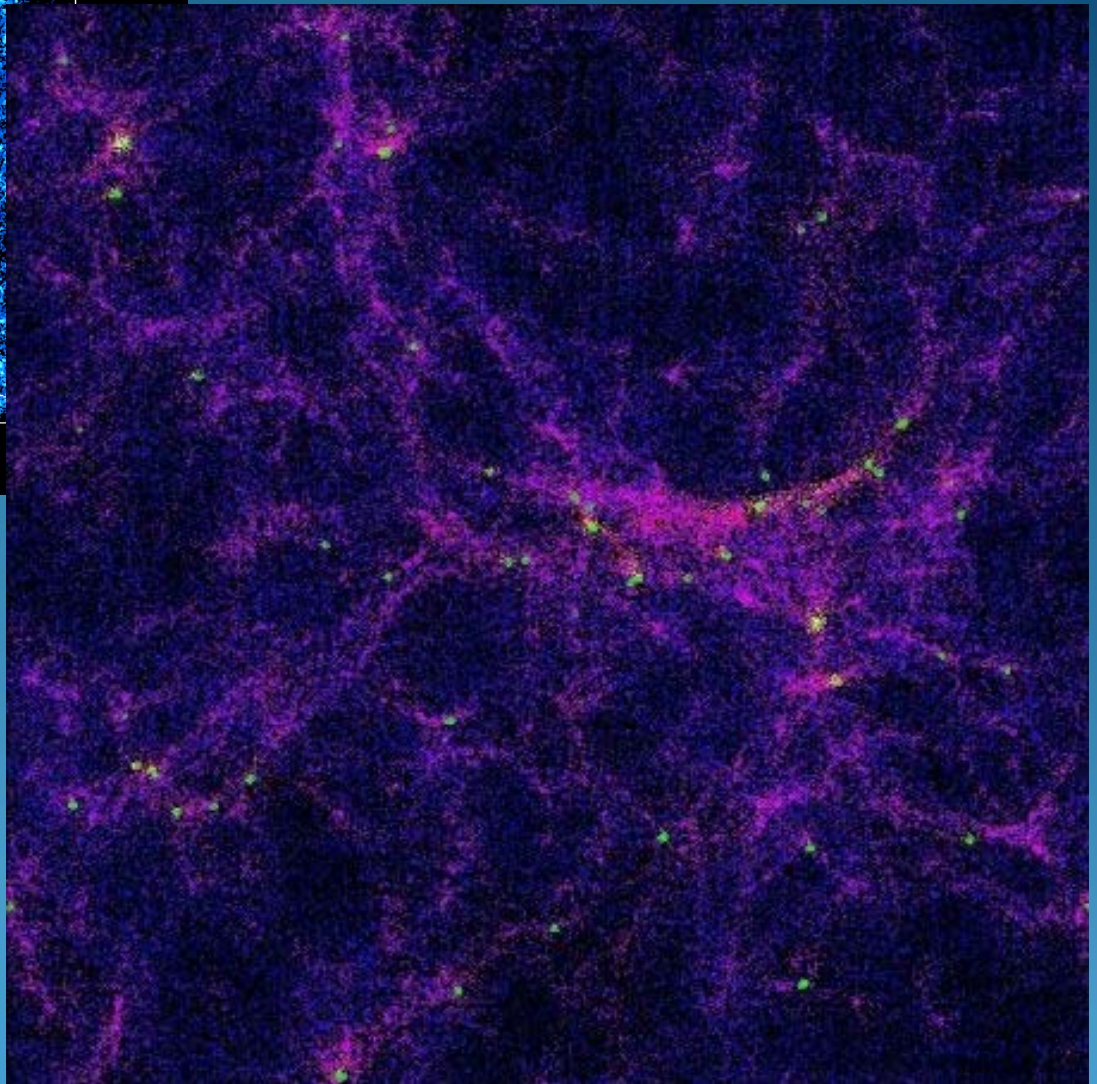
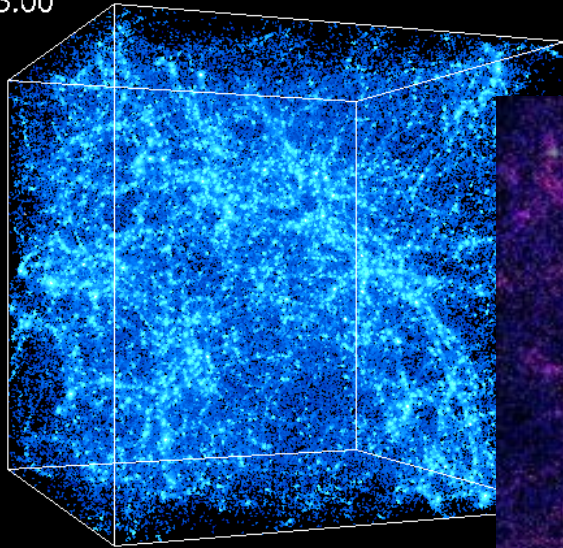
$z=4.0$   $D=24$  Gly  $t=1.6$  Gyr

$z=8.6$   $D=30$  Gly  $t=0.6$  Gyr

$Z=28.62$



$z = 3.00$



- Medjugalakticka materija na  $z > 1.5$  sadrži 90% bariona
- Visoko jonizovano stanje i dalje od  $z = 6$  (Svemir mlađi od 1Gyr).

# Predloženo rešenje – “hladni” modalitet akrecije

Dušan Kereš: “How do galaxies  
get their gas?”

(Hubble Fellow, Berkeley)

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- 
- [Translate This Page](#)

**Title:** How do galaxies get their gas?

**Authors:** [Kereš, Dušan](#); [Katz, Neal](#); [Weinberg, David H.](#); [Davé, Romeel](#)

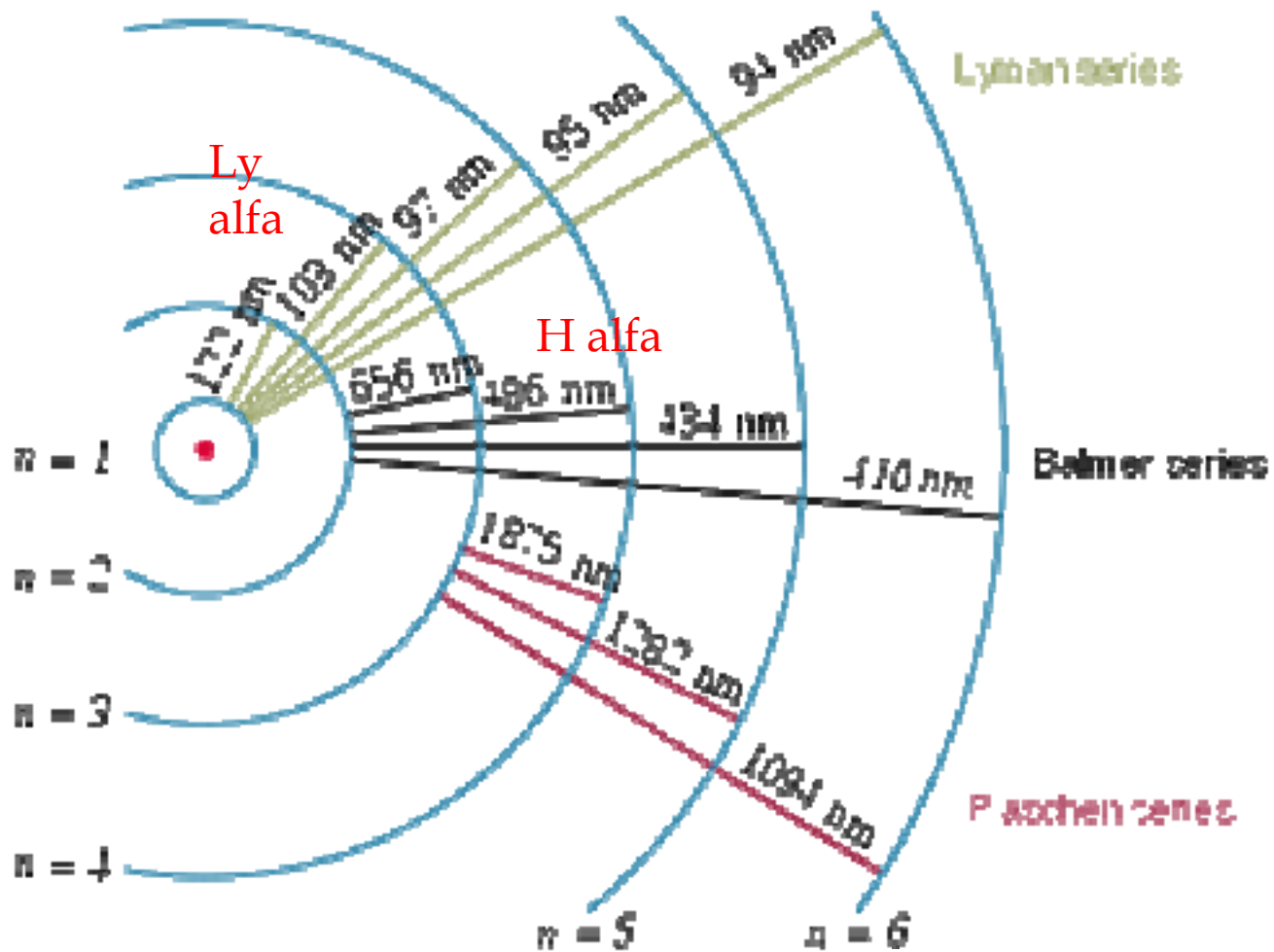
**Affiliation:** AA(Astronomy Department, University of Massachusetts at Amherst, MA 01003, USA), AB(Astronomy Department, University of Massachusetts at  
AC(Ohio State University, Department of Astronomy, Columbus, OH 43210, USA), AD(University of Arizona, Steward Observatory, Tucson, AZ 857

**Publication:** Monthly Notices of the Royal Astronomical Society, Volume 363, Issue 1, pp. 2-28. ([MNRAS Homepage](#))

**Publication Date:** 10/2005

**Origin:** [MNRAS](#)

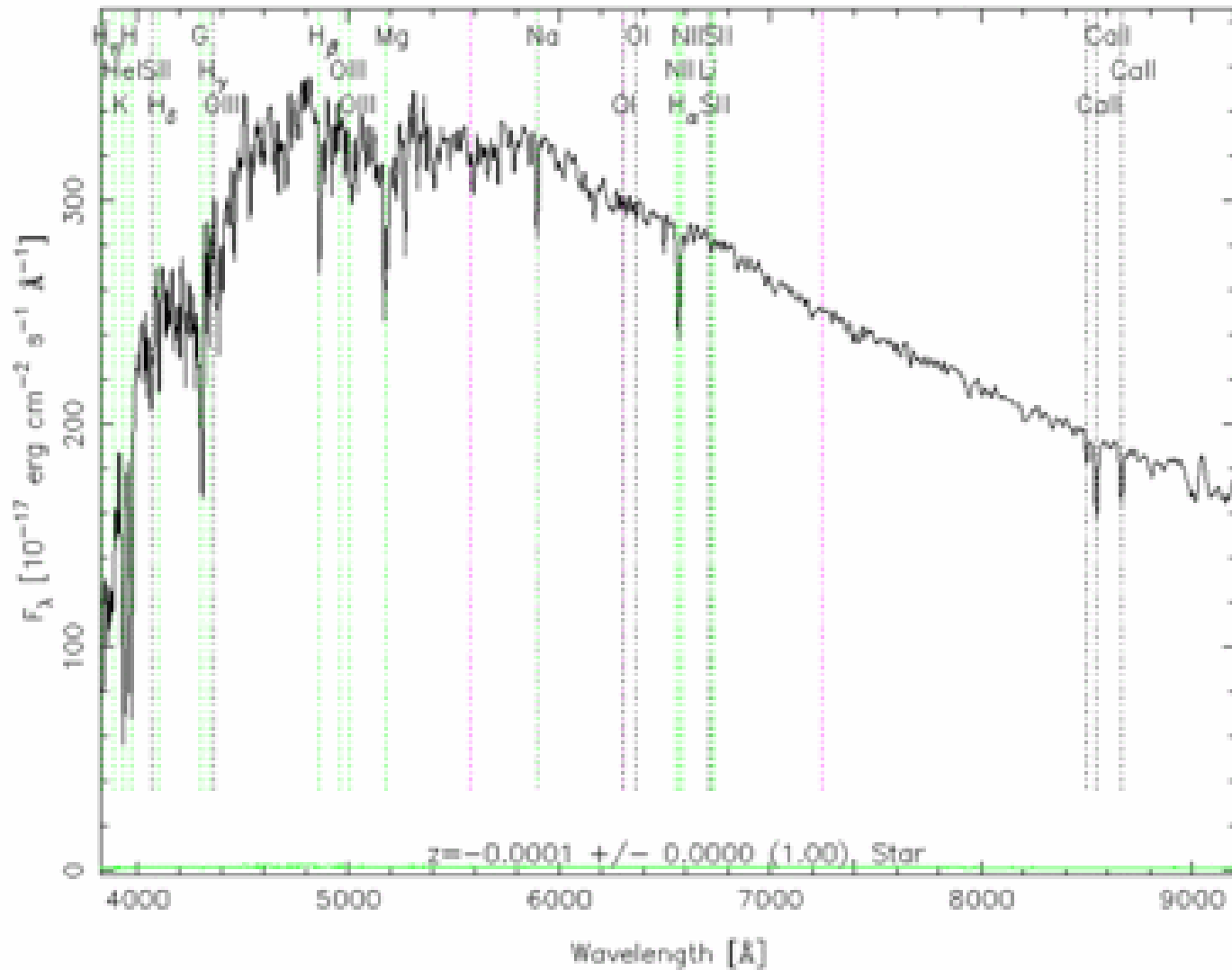
**MNRAS Keywords:** methods: numerical, cooling flows, galaxies: evolution, galaxies: formation



Glavne serije prelaza u vodonikovom atomu

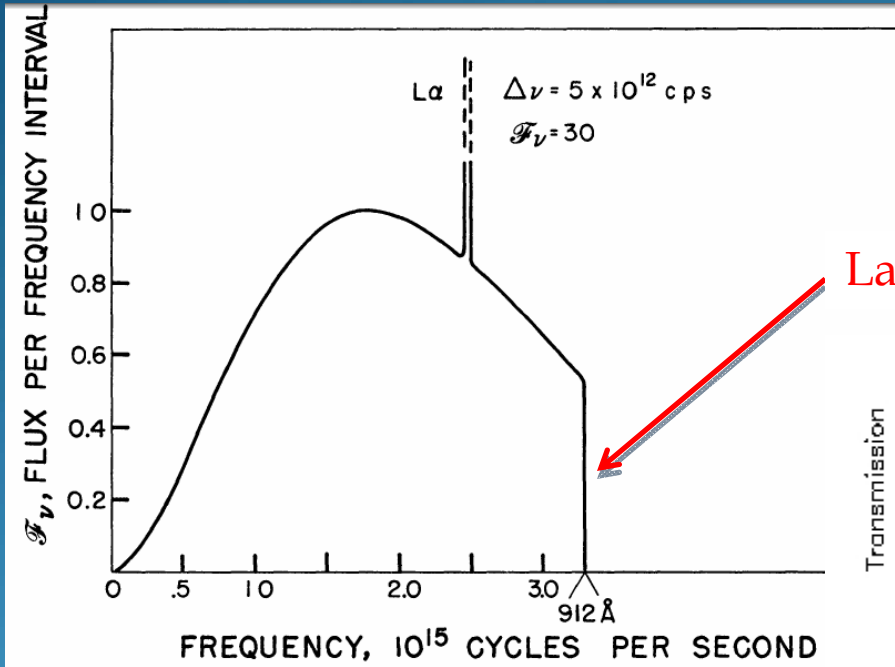


RA=224.53599, DEC= 0.15418, MJD=51990, Plate= 310, Fiber=356



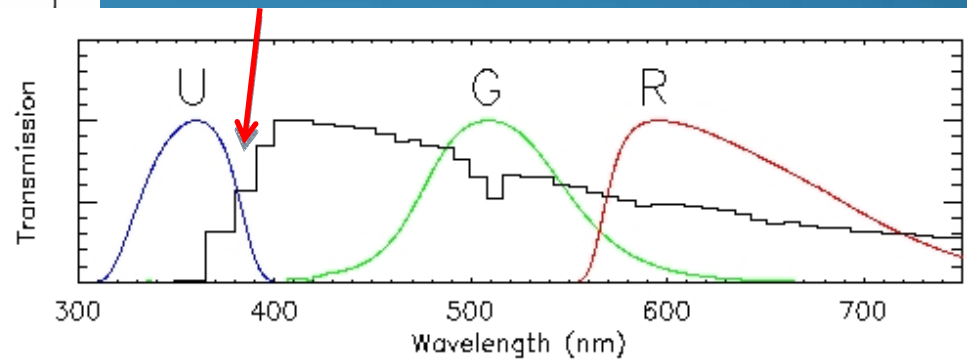
Primeri spektara zvezda, ka višoj temperaturi (F do O/B)

# Kako treba da izgleda "prvobitna" (primordijalna) galaksija?



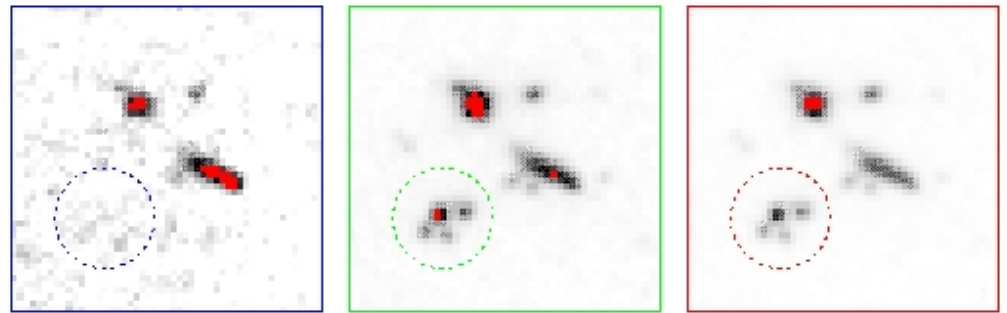
Moguće ih je naći metodom kolor selekcije – snimci u tri filtera (npr. UGR)

Lajmanov prekid (Lyman break)



Partridge & Peebles, 1967

Ali – vrlo slabog sjaja!



# Neophodni su veliki teleskopi, ali i još ponešto

Keck 10m



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iau1004 — News Release

**Steidel Receives Cosmology Prize for Observations**

2 June 2010, Paris

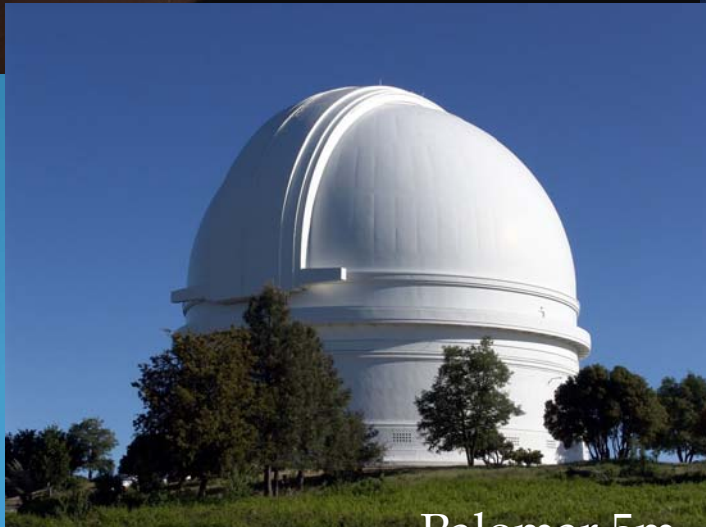
**Charles Steidel, the Lee A. DuBridge Professor of Astronomy at the California Institute of Technology, is the recipient of the 2010 Cosmology Prize of The Peter and Patricia Gruber Foundation in recognition of his revolutionary studies of the most distant galaxies in the Universe.**

*"Professor Steidel pioneered the techniques needed to find young galaxies and led the efforts that have opened a direct observational window to a time when the Universe was only about one tenth of its current age," reads the official citation. Steidel will receive the \$500,000 award, as well as a gold medal, in October at the University of Chicago in Chicago, Illinois, where he will also deliver a lecture.*

As recently as the 1920s, astronomers were uncertain whether our galaxy, the Milky Way, was the Universe in its entirety. In 1923, Edwin Hubble found conclusive evidence that other galaxies exist outside our own. Six years later, he discovered that galaxies tend to be receding from one another at rates roughly proportional to their distances — the farther, the faster. While the discovery of cosmic expansion inaugurated a decades-long investigation into the implications of a Universe that changes over time — including the Big Bang, the rate of the expansion, and the fate of the Universe — Steidel's work is in a way a return to cosmology's roots: the galaxies themselves.



Prize

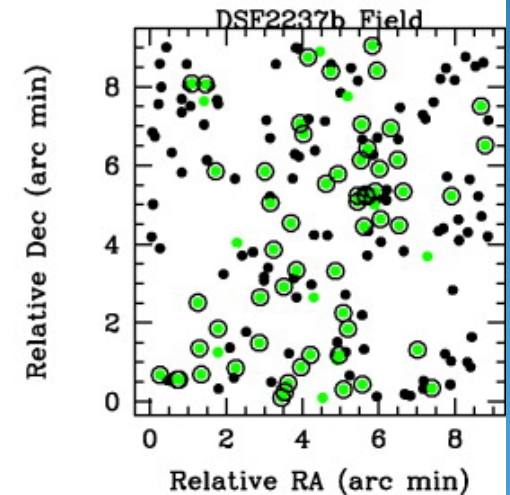
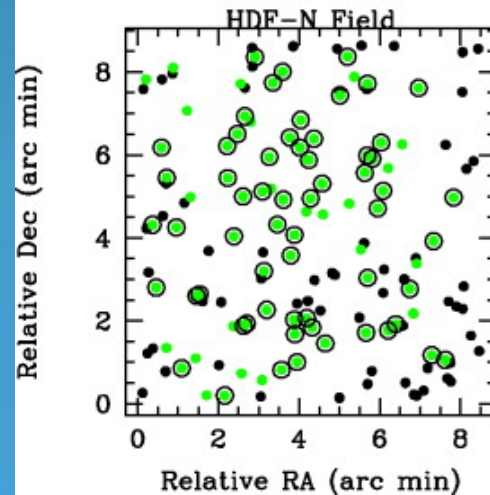
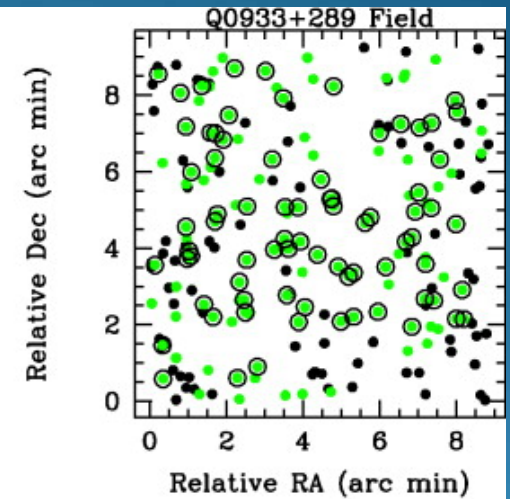
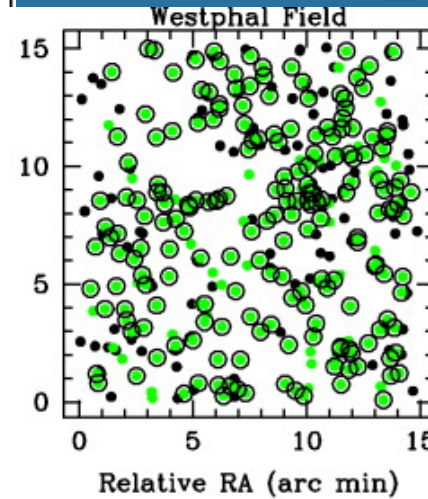
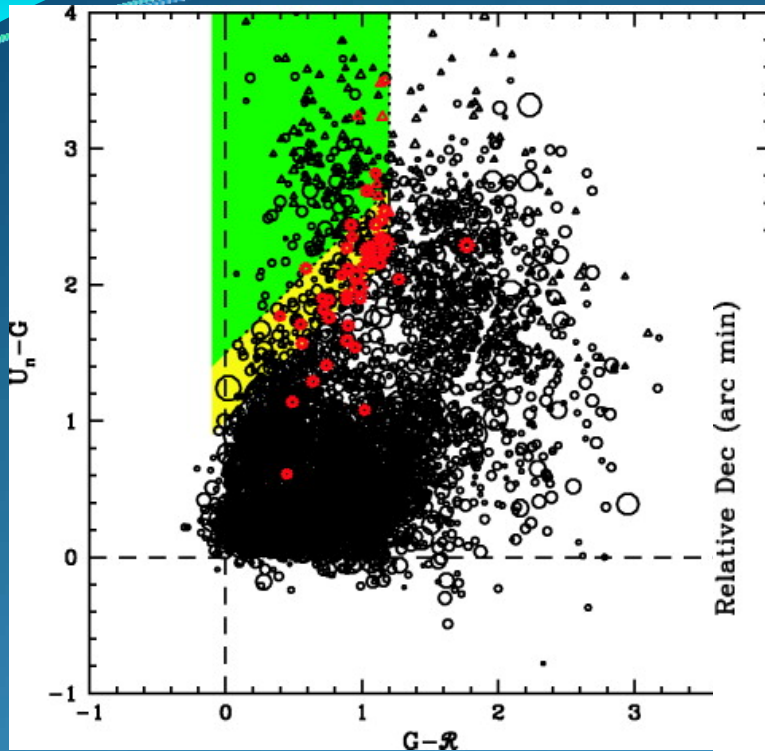


Palomar 5m



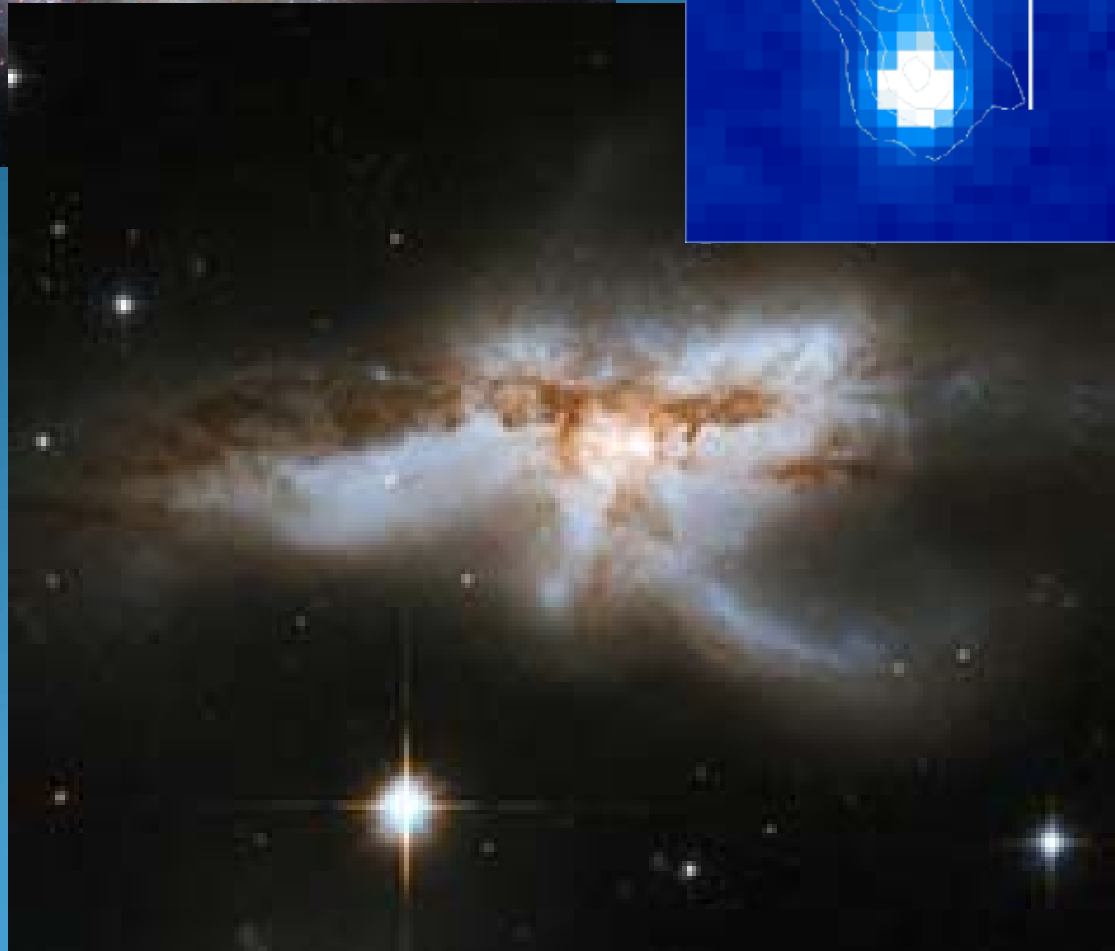
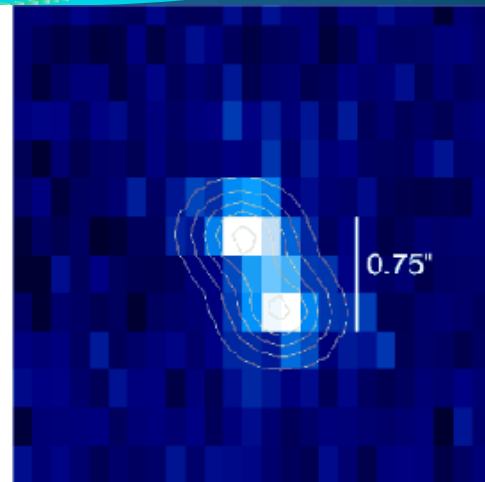
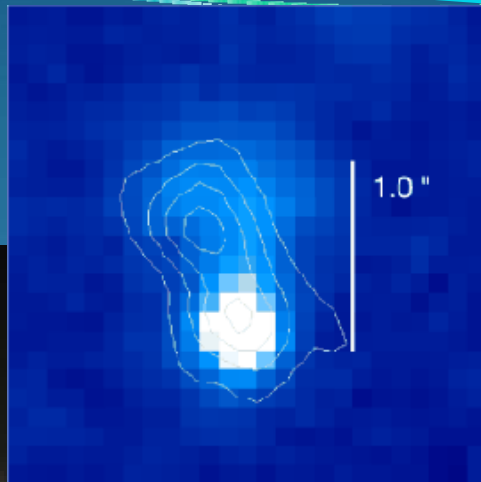
Chuck Steidel

# Fotometrija, pa sistematična spektroskopija



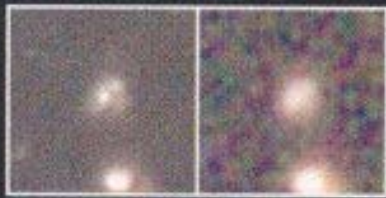
Do danas katalogizovano  
na hiljade galaksija  $z > 2$

(Magnitude  $R \sim 21 - 26$ )

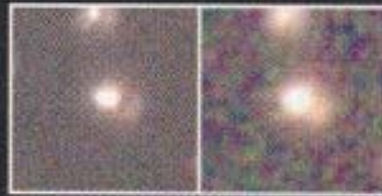


Nažalost, primordijalne galaksije su vrlo daleko a time i malih ugaonih veličina!

Svi detalji se gube, da upoznamo njihove karakteristike moramo dešifrovati spektre



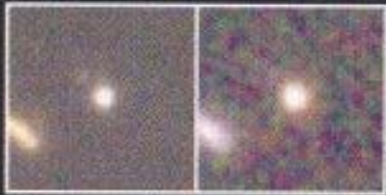
2-454.0 Z=2.008



2-449.0 Z=2.000



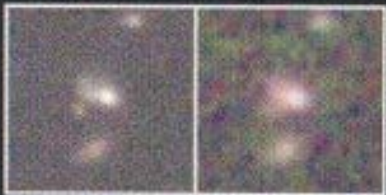
2-505.0 Z=2.000



3-118.1 Z=2.232



2-903.0 Z=2.000



2-82.1 Z=2.267



4-445.0 Z=2.000



2-239.0 Z=2.427



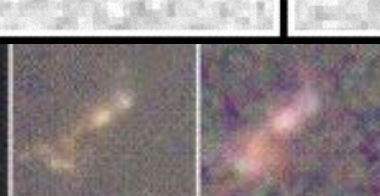
2-591.2 Z=2.000



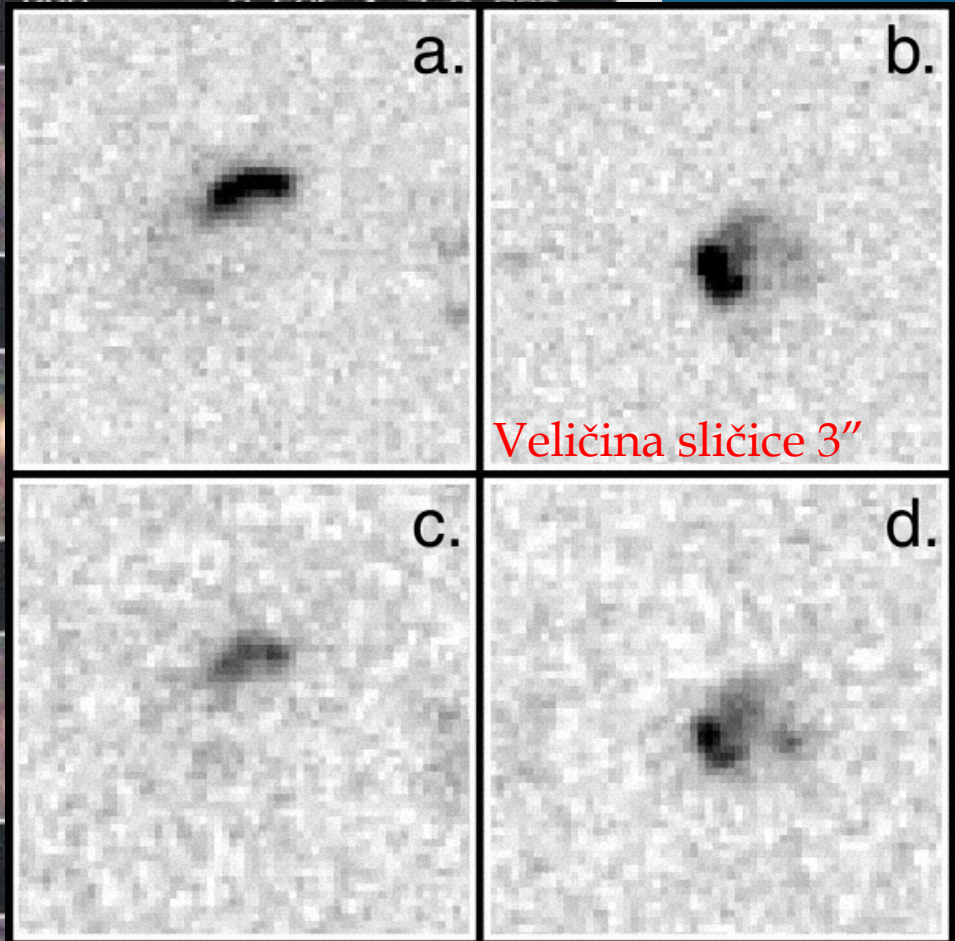
4-555.1 Z=2.803



1-54.0 Z=2.929

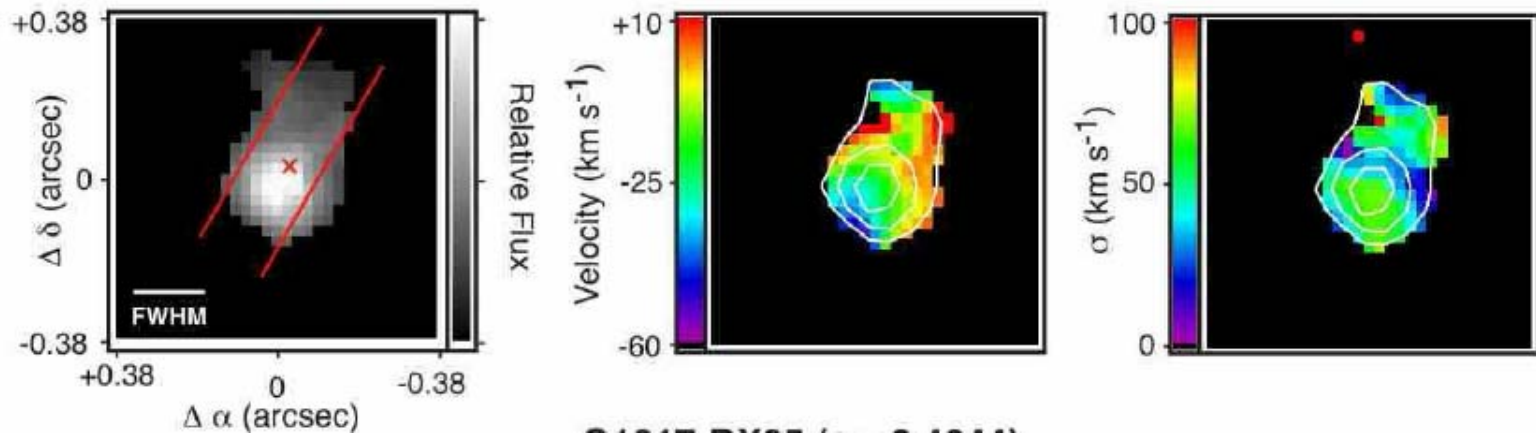


4-52.0 Z=2.931



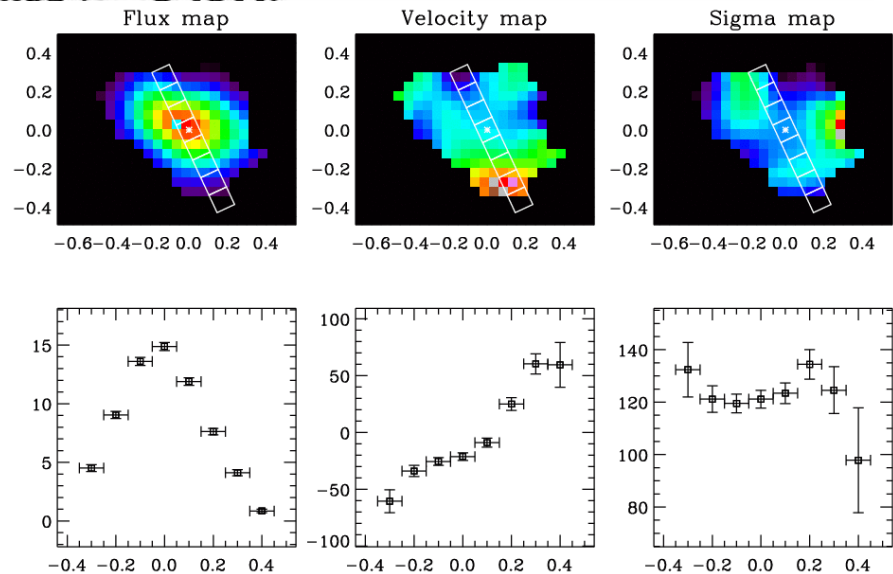
# Uz pomoć adaptivne optike...

Q0449-BX93 ( $z = 2.0067$ )



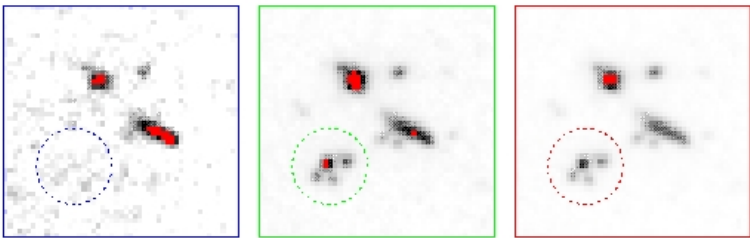
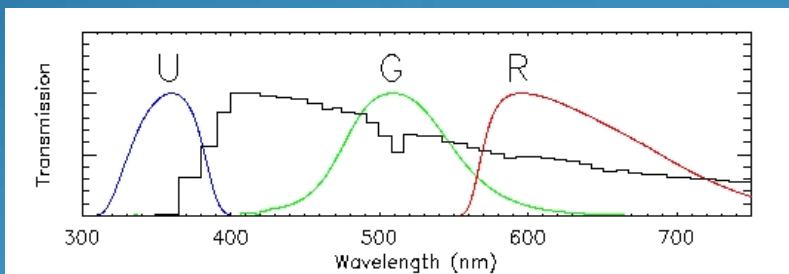
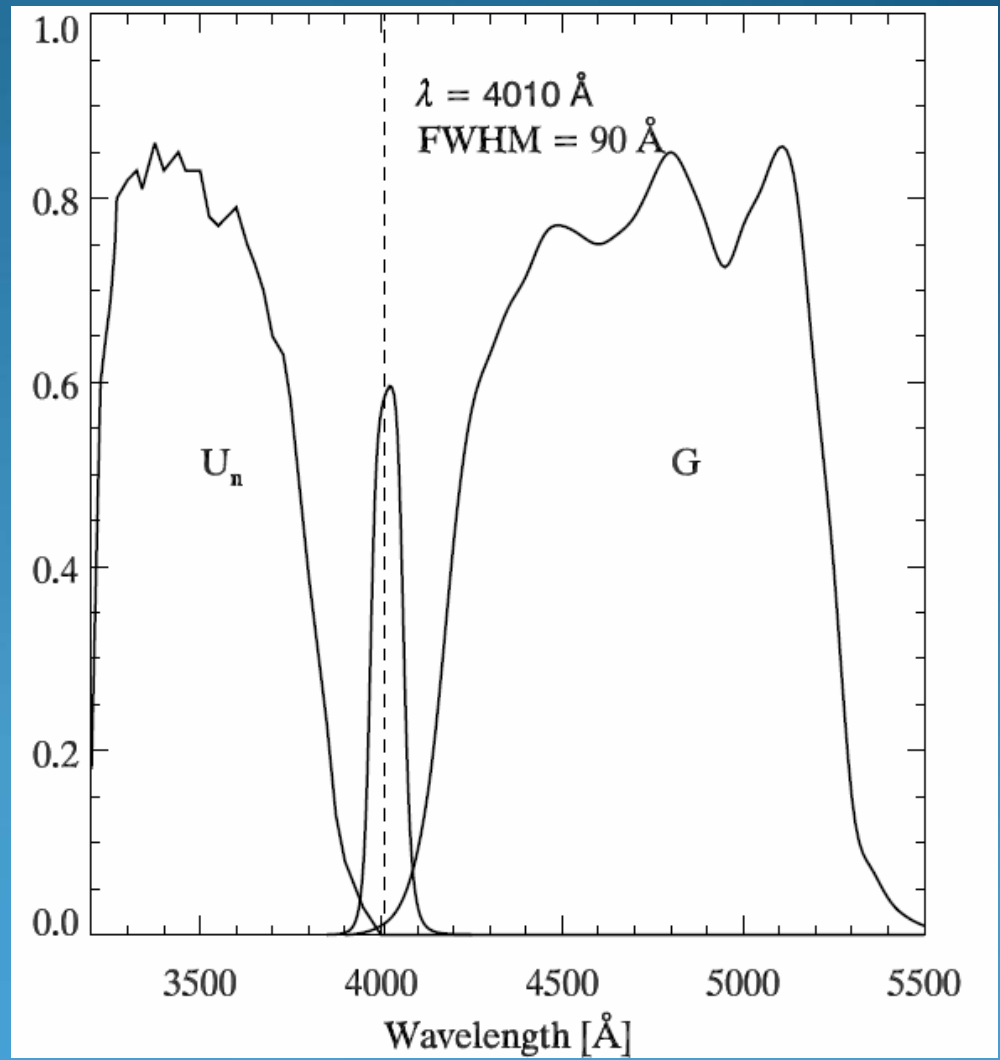
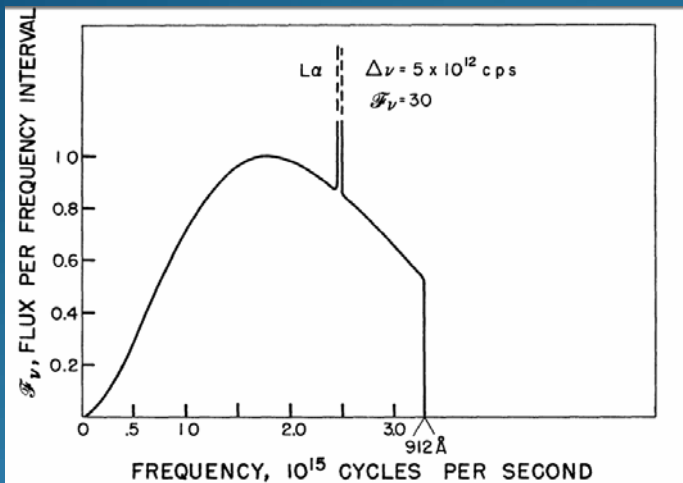
Law et al, 2009

Mannucci et al,  
2009



# Može li to i dalje?

## Potruga za Lajman alfa emiterima





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## Letter

*Nature* **467**, 940–942 (21 October 2010) doi:10.1038/nature09462; Received 8 May 2010; Accepted 25 August 2010; Published online 20 October 2010

## Spectroscopic confirmation of a galaxy at redshift $z = 8.6$

M. D. Lehnert<sup>1</sup>, N. P. H. Nesvadba<sup>2</sup>, J.-G. Cuby<sup>3</sup>, A. M. Swinbank<sup>4</sup>, S. Morris<sup>5</sup>, B. Clément<sup>3</sup>, C. J. Evans<sup>6</sup>, M. N. Bremer<sup>7</sup> & S. Basa<sup>3</sup>

1. GEPI, Observatoire de Paris, CNRS, Université Paris Diderot, 5 Place Jules Janssen, 92190 Meudon, France

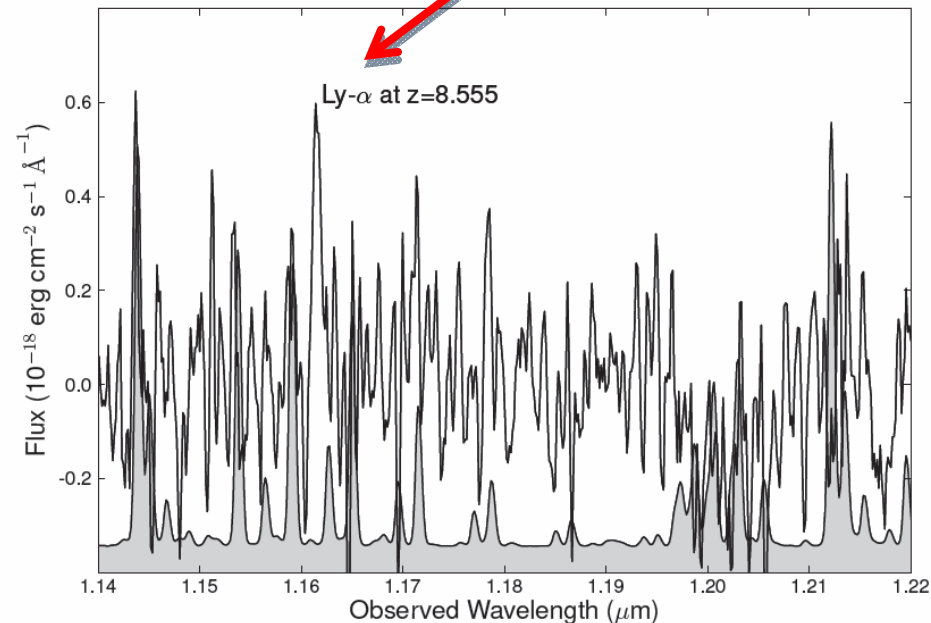
2. Institut d'Astrophysique Spatiale, UMR 8617, CNRS, Université Paris-Sud, Bâtiment 121, F-91405 Orsay Cedex, France

3. Laboratoire d'Astrophysique de Marseille, OAMP, Université Aix-Marseille & CNRS 38 Rue Frédéric Joliot Curie, 13388 Marseille Cedex 13, France

4. Institute for Computational Cosmology, Department of Physics, Durham University, South Road, Durham DH1 3LE, UK

### ARTICLE LINKS

- ▶ [Figures and tables](#)
- ▶ [Supplementary information](#)

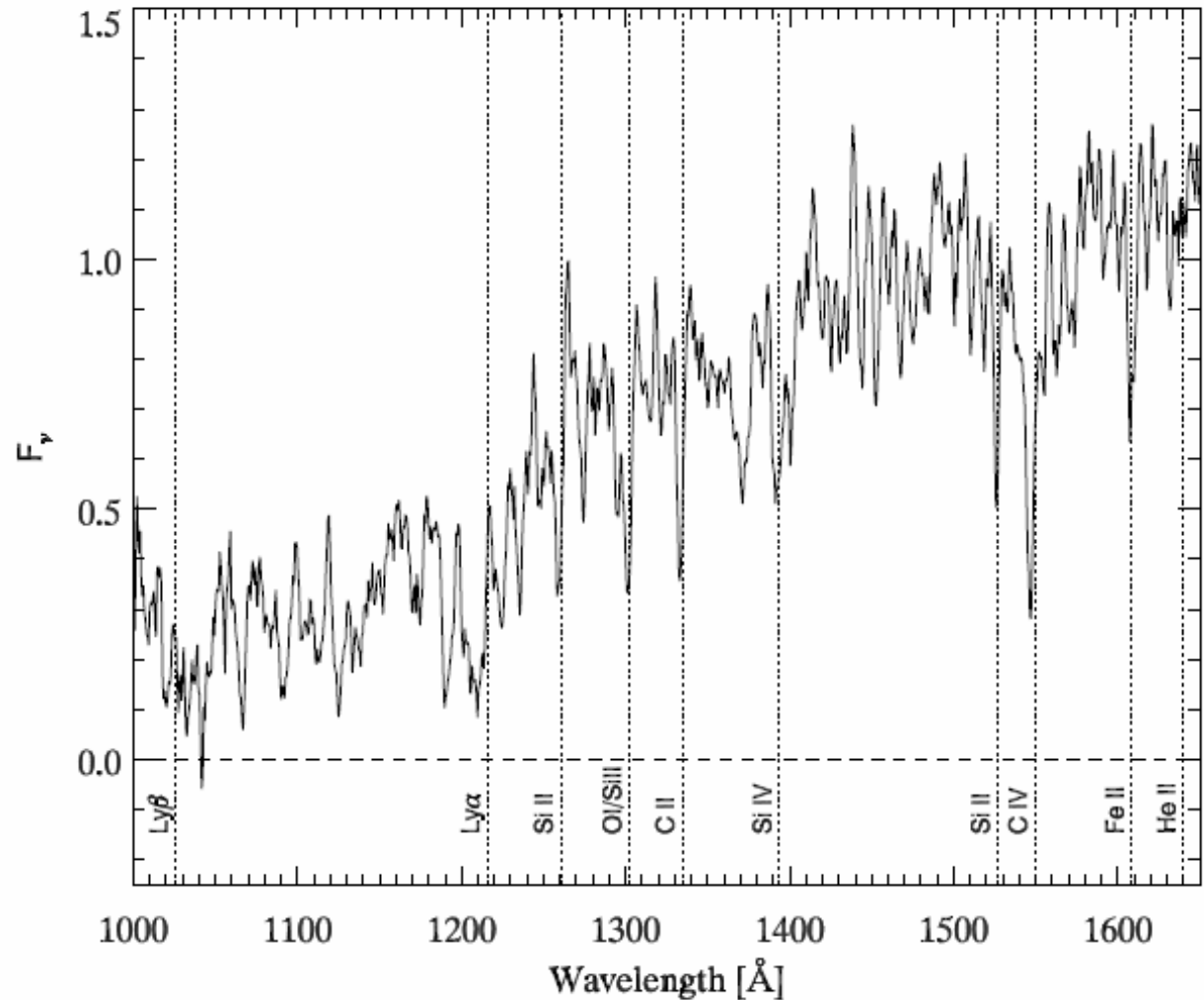


# Ali postoje i galaksije bez vidljive Lajman alfa emisione linije

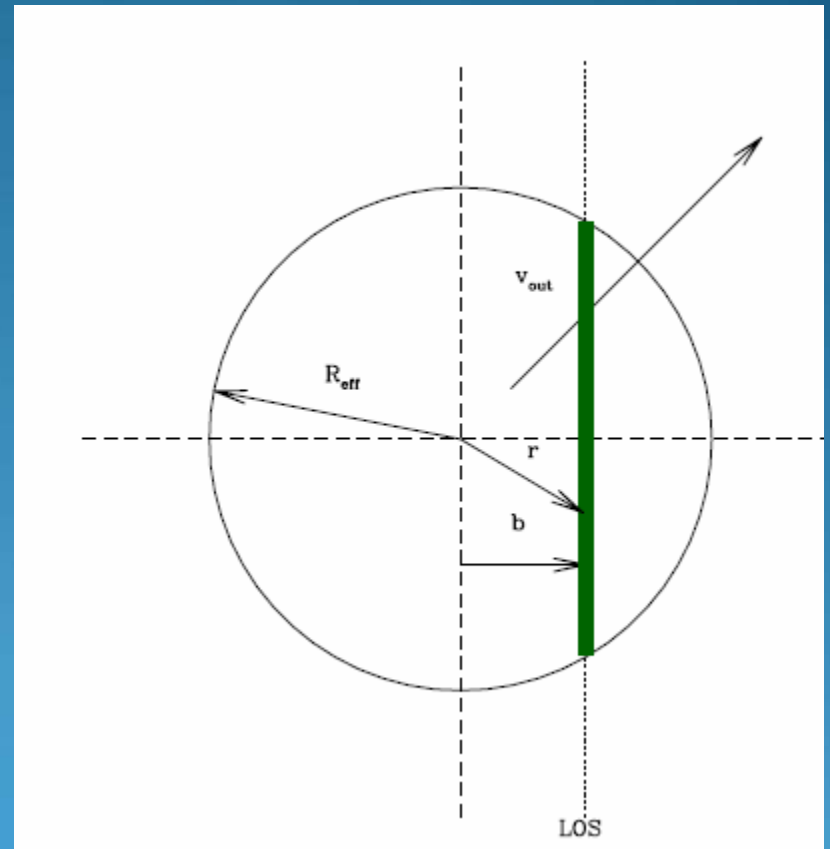
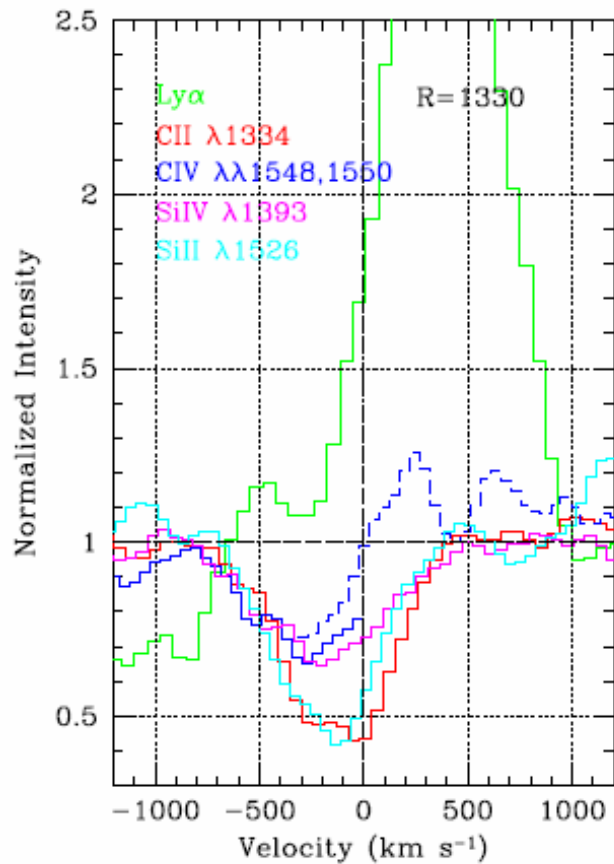
Lajman alfa se lako “uništava” u prisustvu međuzvezdane prašine

Problem prenosa zračenja postaje vrlo složen

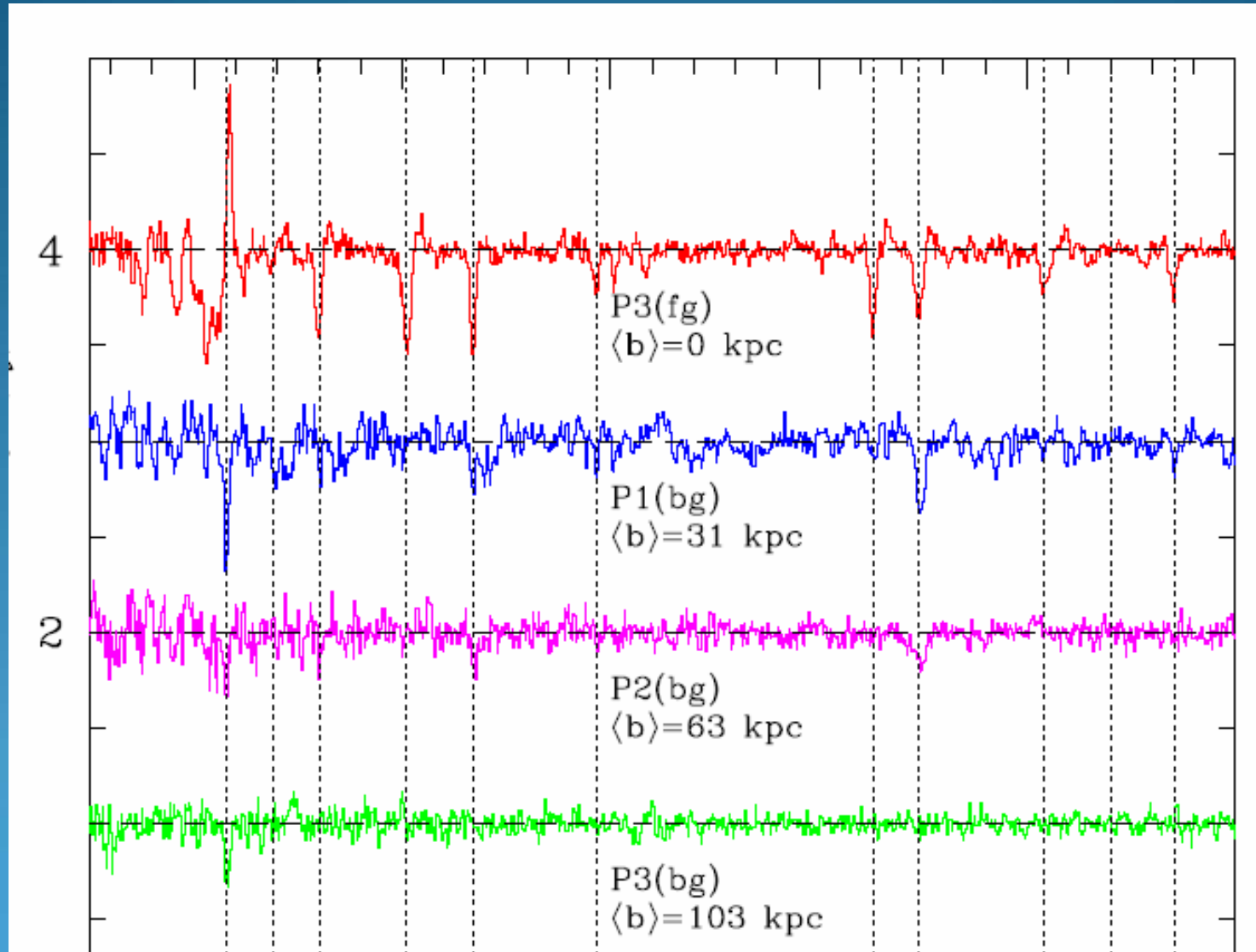
*Bogosaavljević,  
disertacija*



# Lajman alfa u poređenju sa apsorpcionim linijama – analog galaktičke “fontane”

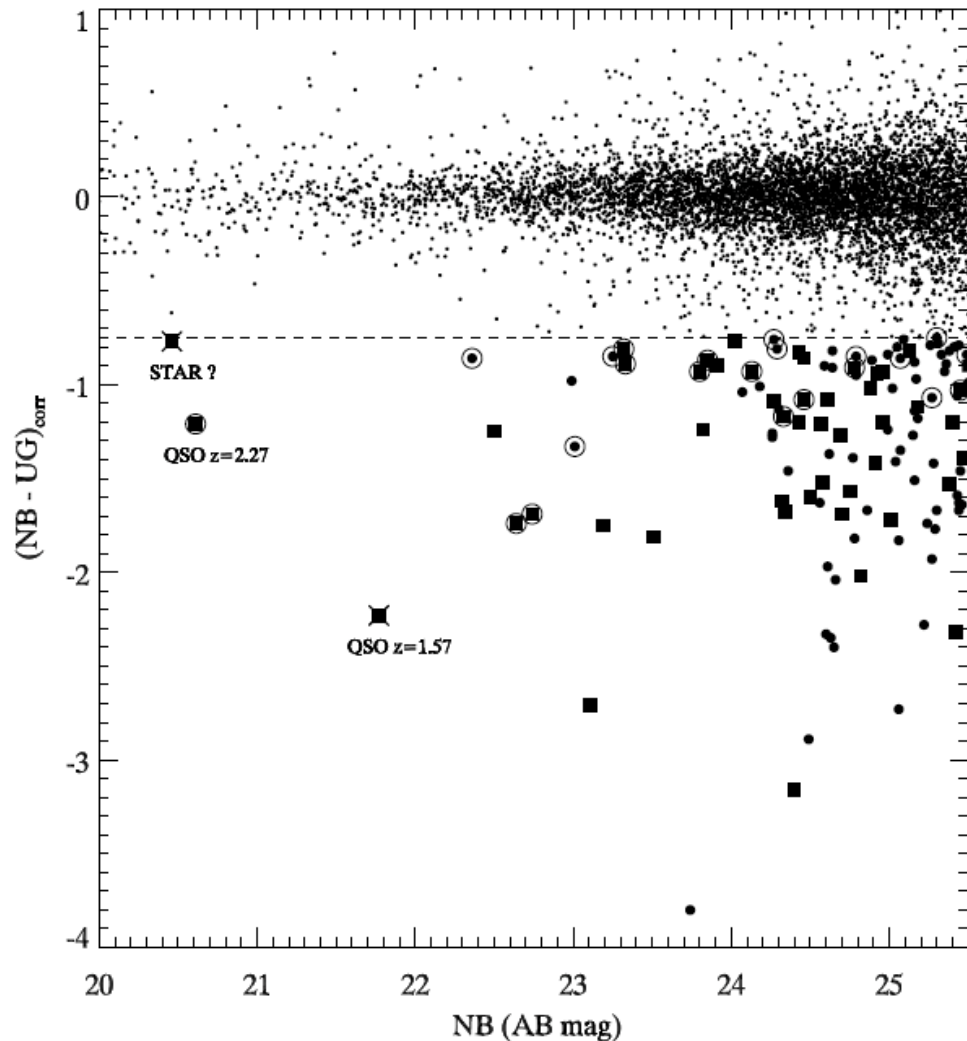


# Gas oko galaksija se sigurno prostire preko 50kpc

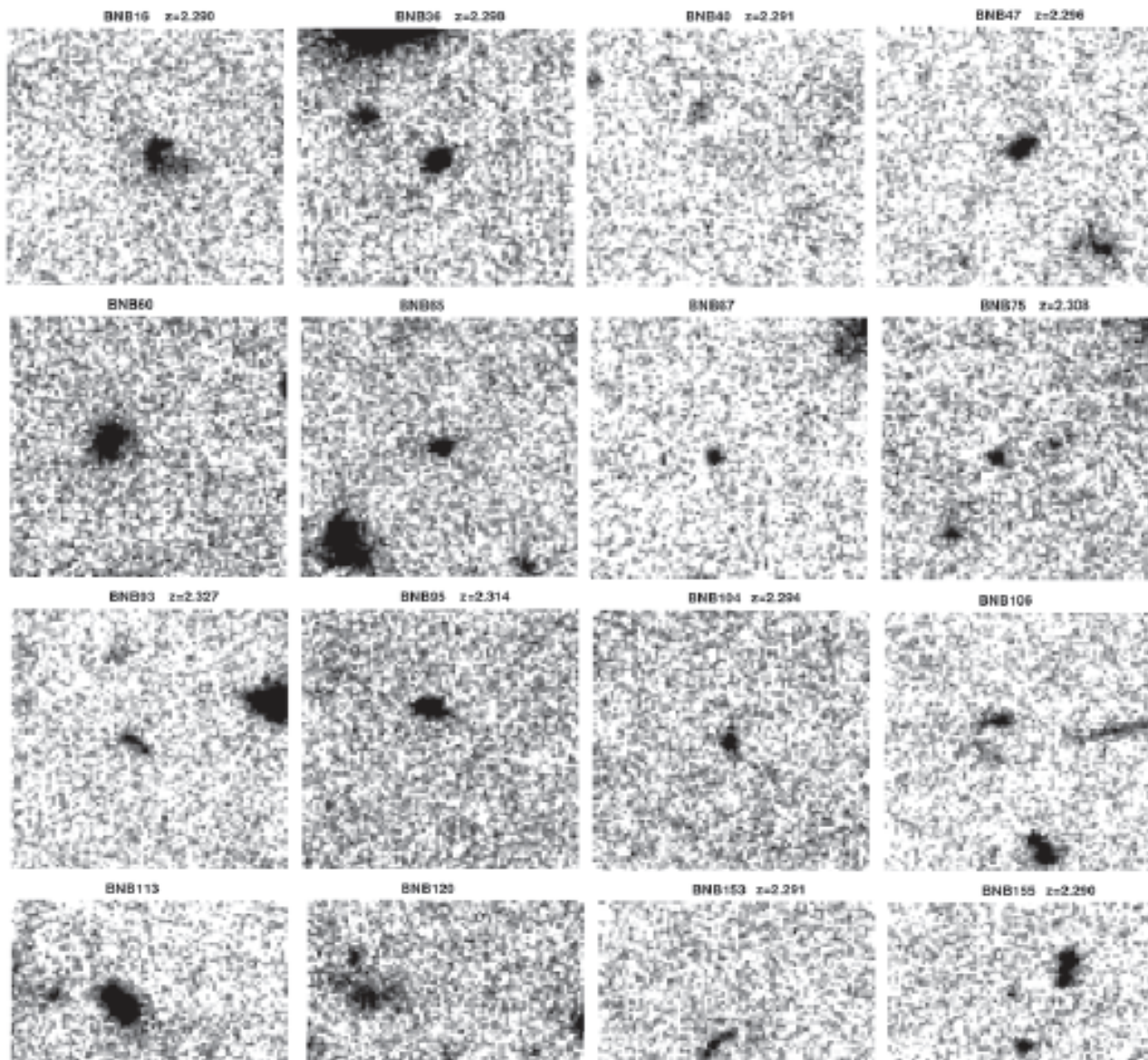


# Kako se traže Ly $\alpha$ emiteri

- Mt Palomar 5m teleskop
- Optička (CCD) kamera sa širokim poljem (30 lučnih minuta)
- 22 sata ekspozicije u uskom filteru – jedan od najdubljih takvih snimaka ikad
- 119 kandidata
- 47 potvrđena spektroskopijom – bez kontaminacije



# HST/ACS snimci Ly $\alpha$ emitera



# Neočekivano otkriće Lajman alfa “grudvi” (BLOBS)

Vrlo sjajni ( $22 \text{ mag}$ ,  $10^{44} \text{ erg s}^{-1}$ )  
i ogromnih dimenzija!

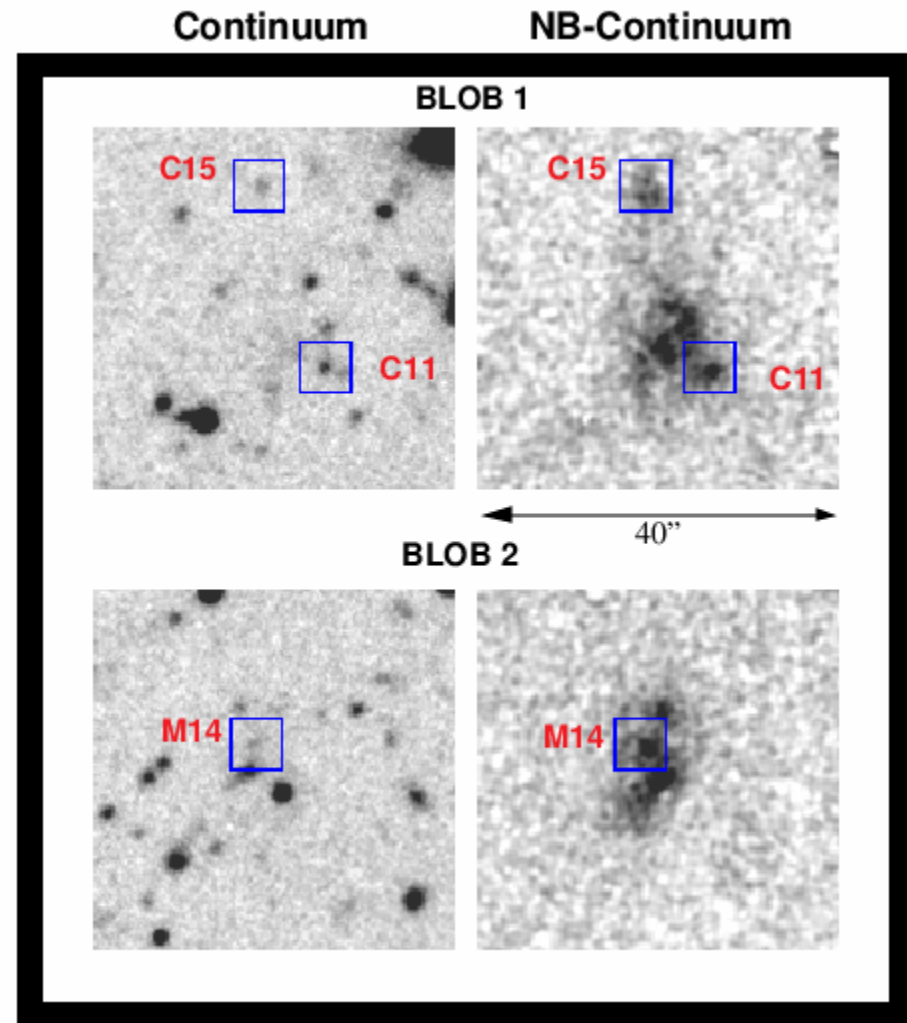
100kpc, preko 10 puta  
veći od galaksije!

Deset godina debate oko pitanja:  
Šta je izvor njihove energije?

Aktivno galaktičko jezgro ili  
eksplozivno formiranje zvezda?

Do danas poznato samo desetak  
“velikih”

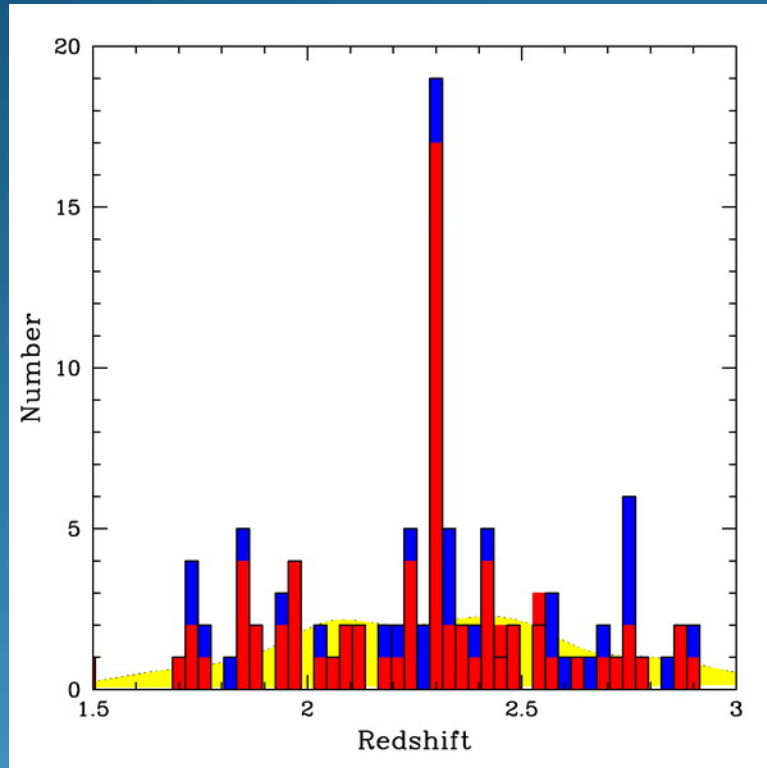
Steidel et al, 2000



# Proto-jata galaksija

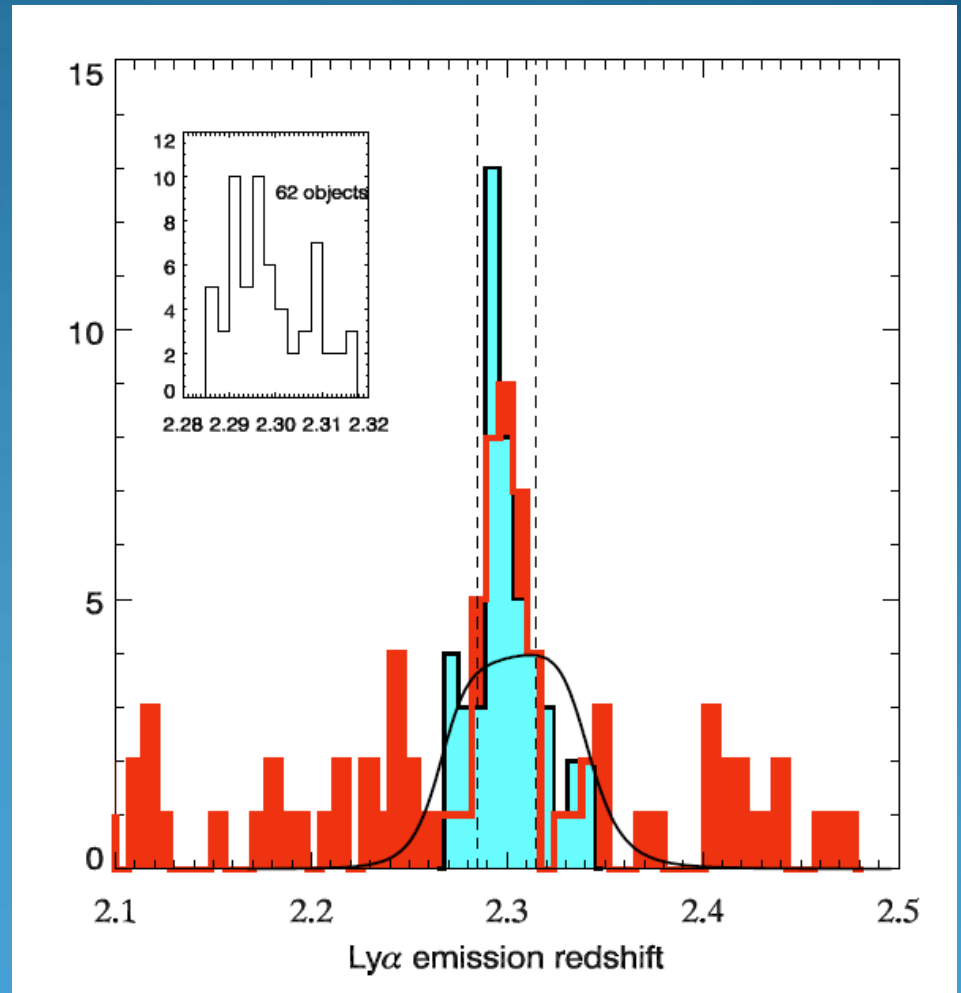
Bogosavljević, 2010

$z=2.3$



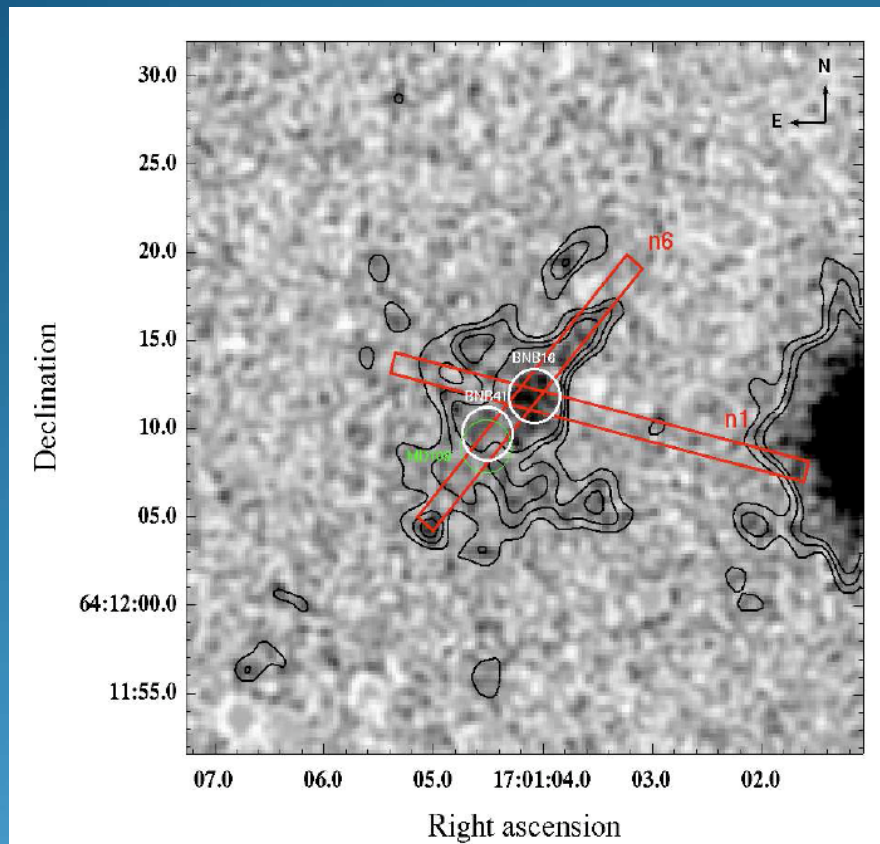
$z=3.09$

Steidel et al, 2005

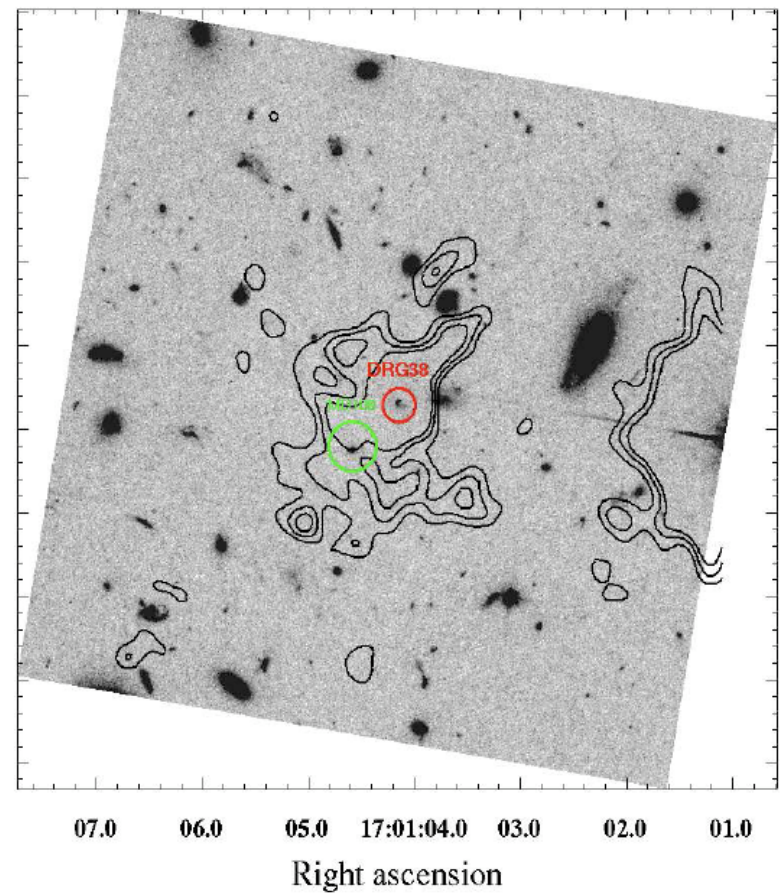




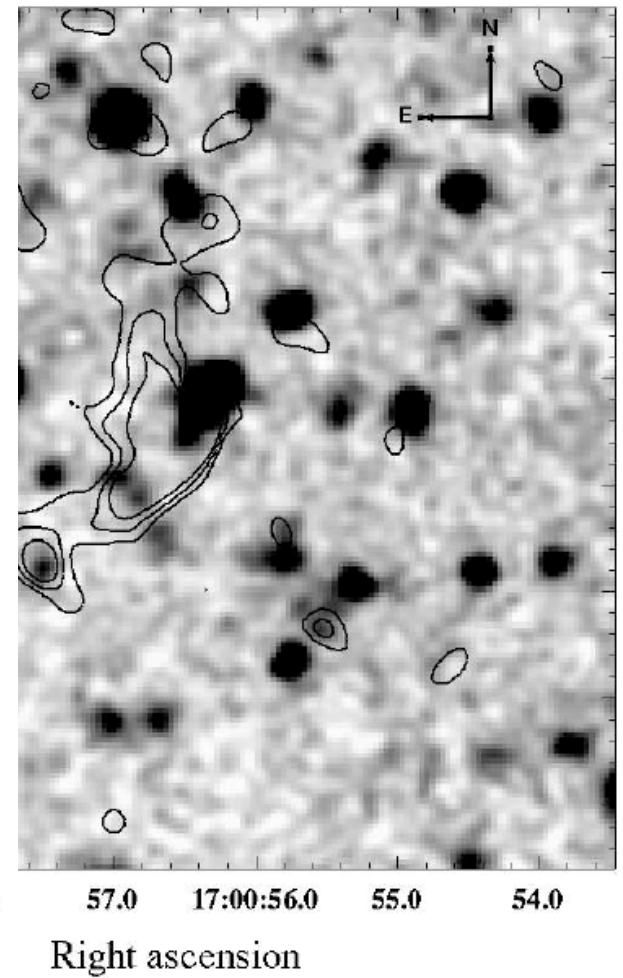
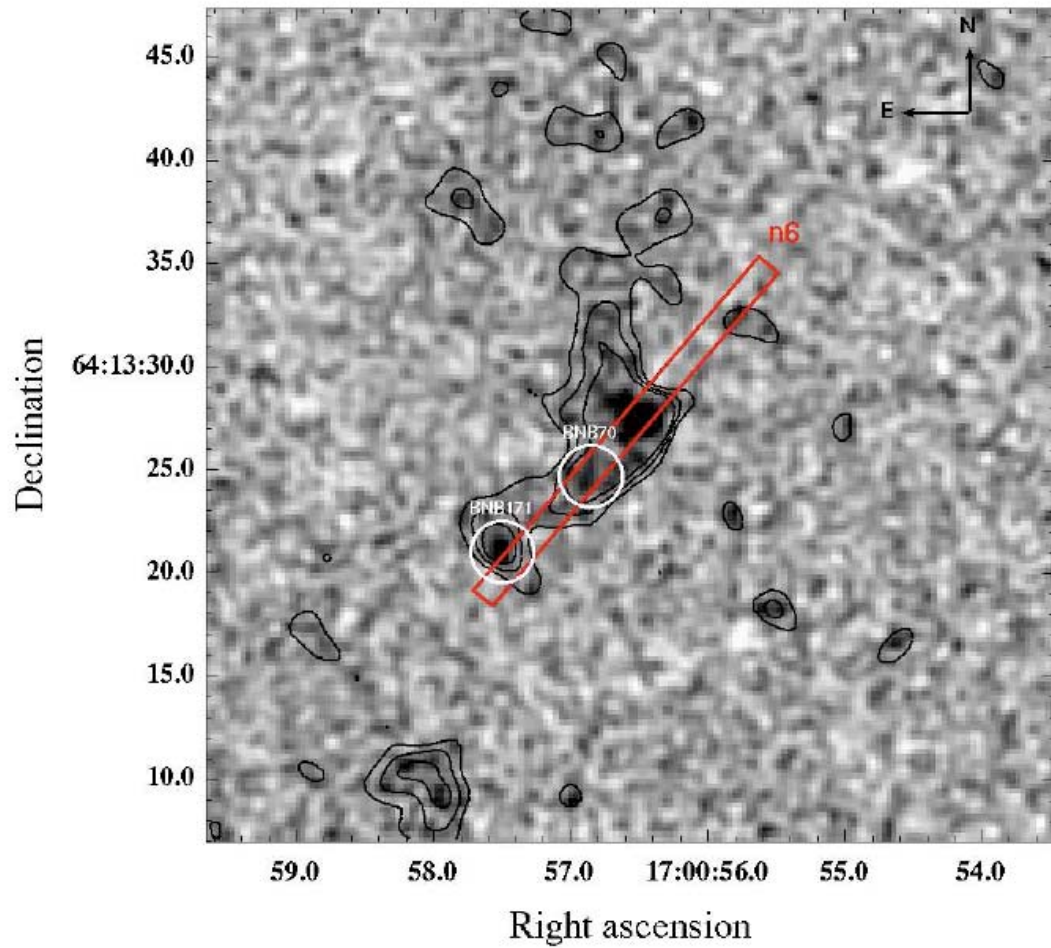
# Blob-1 – emission over 100kpc



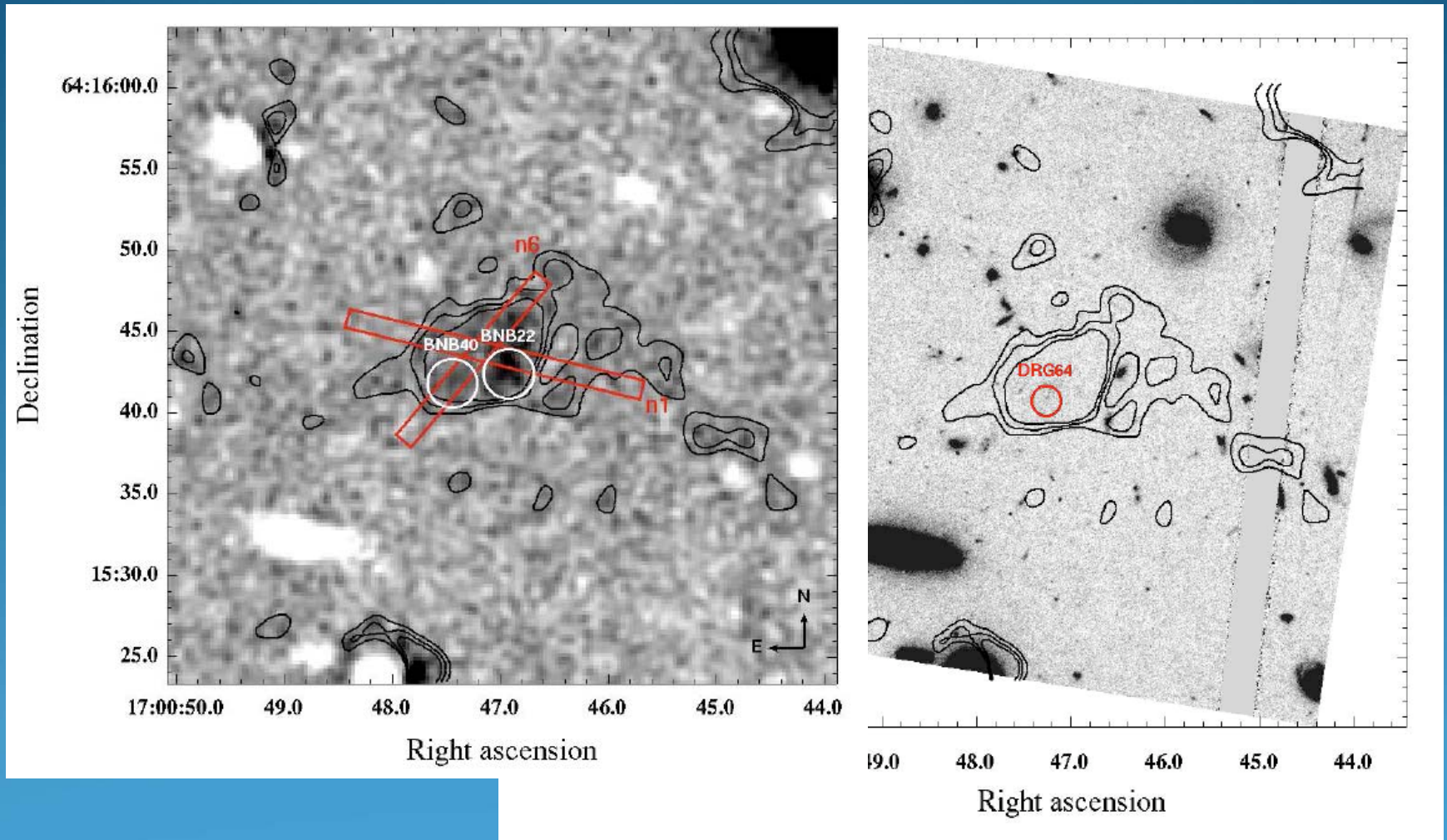
HST/ACS



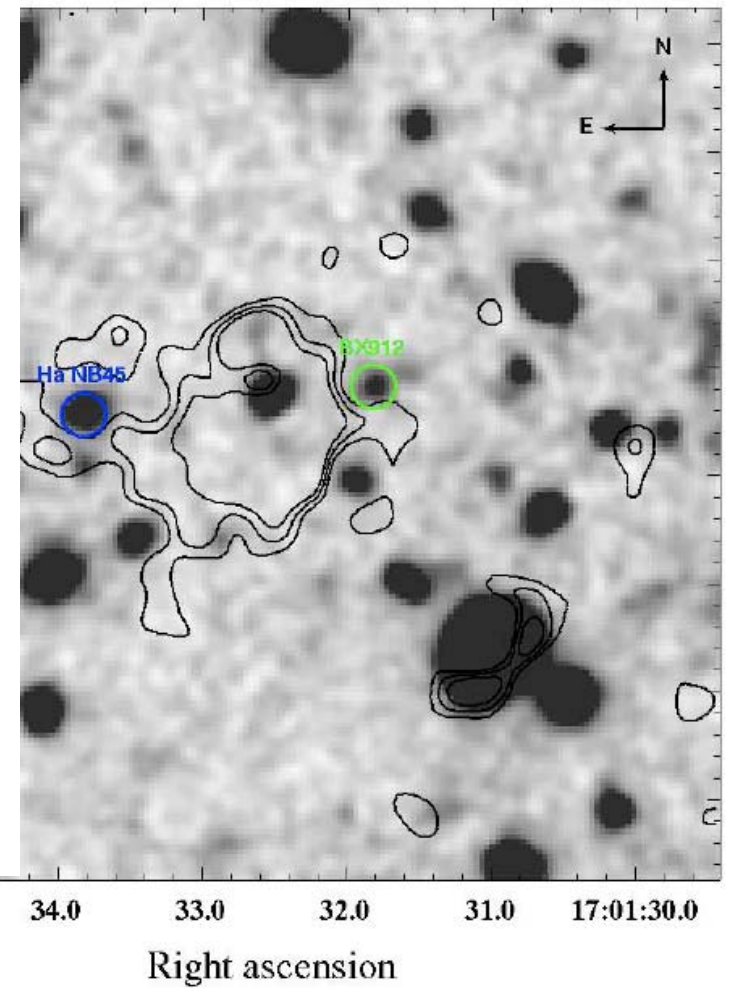
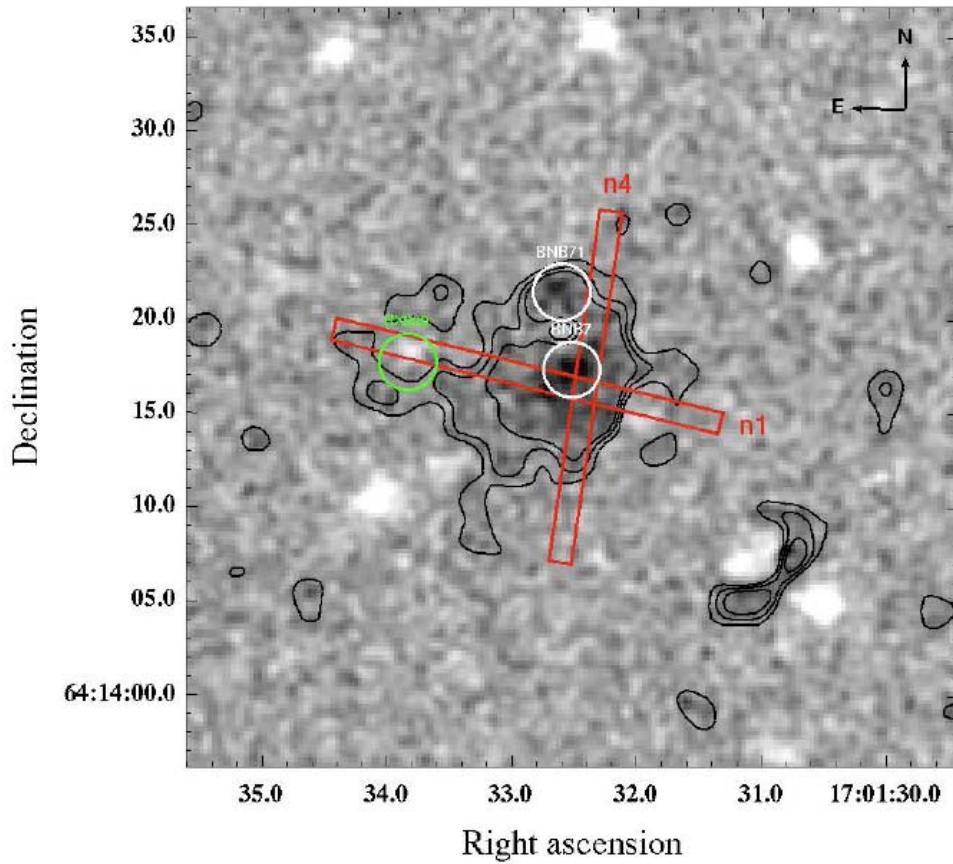
# Blob - 2



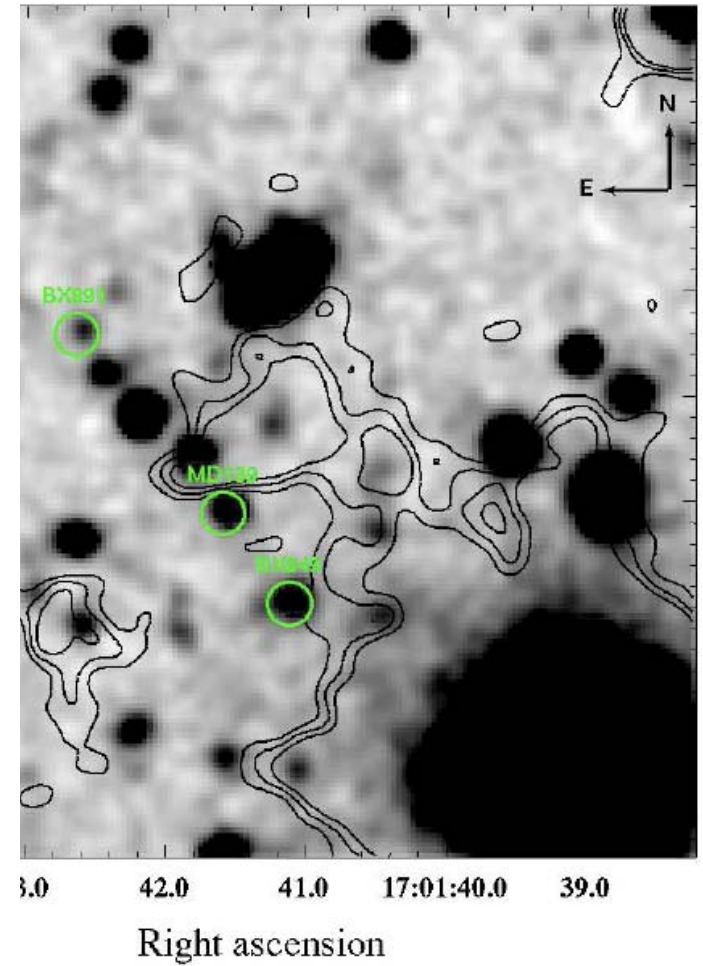
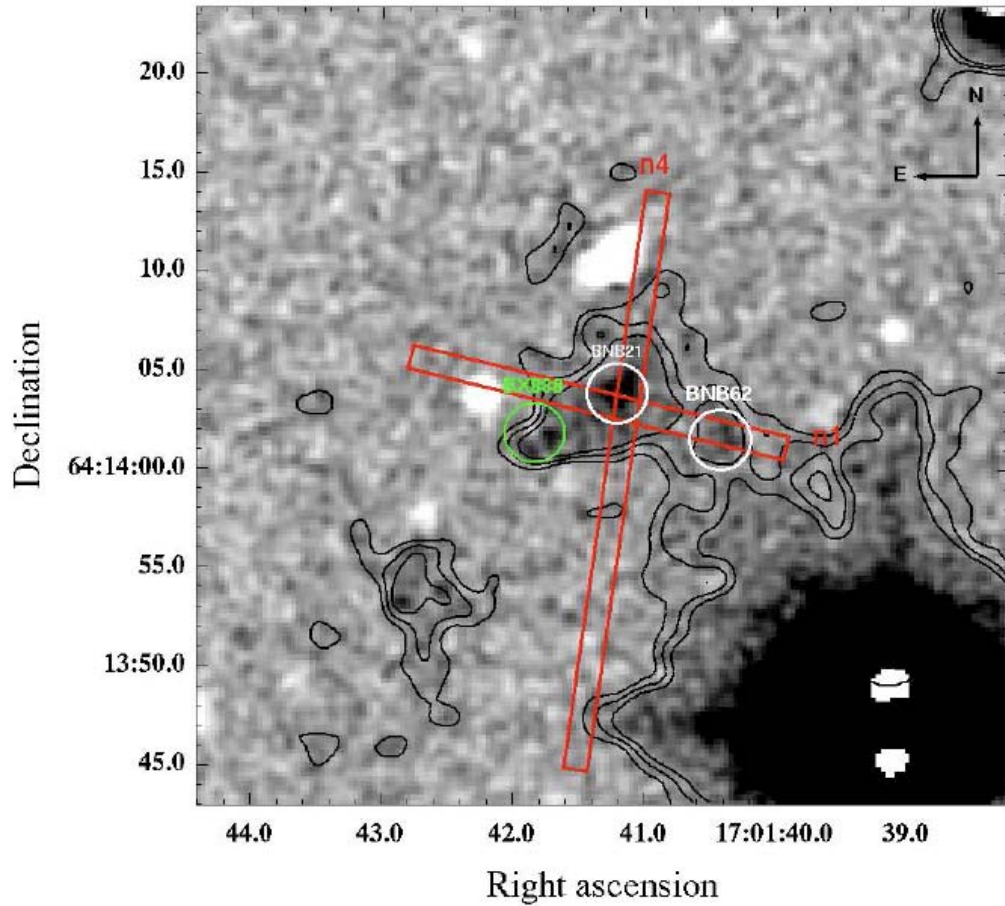
# Blob-3



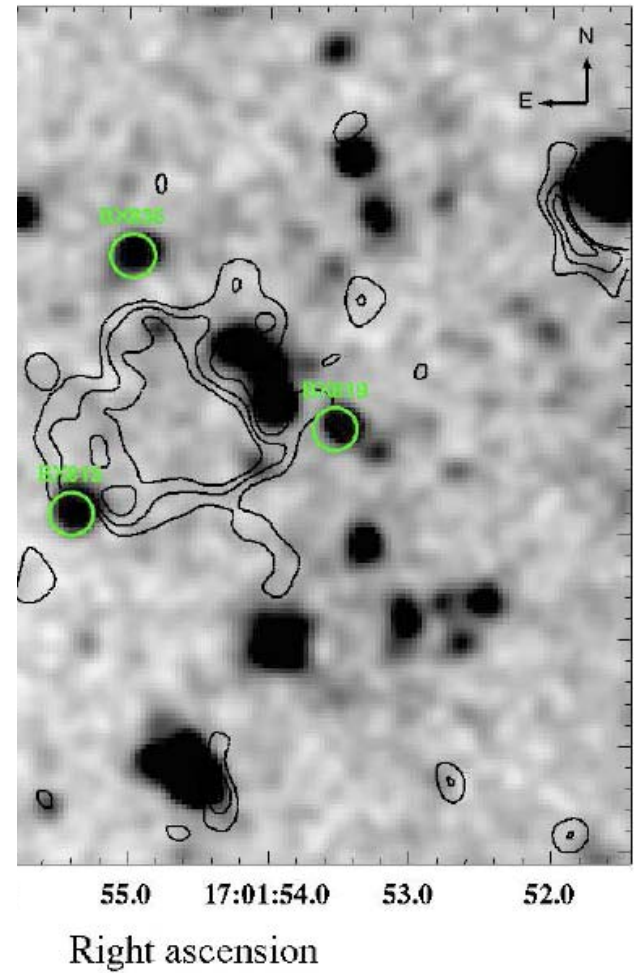
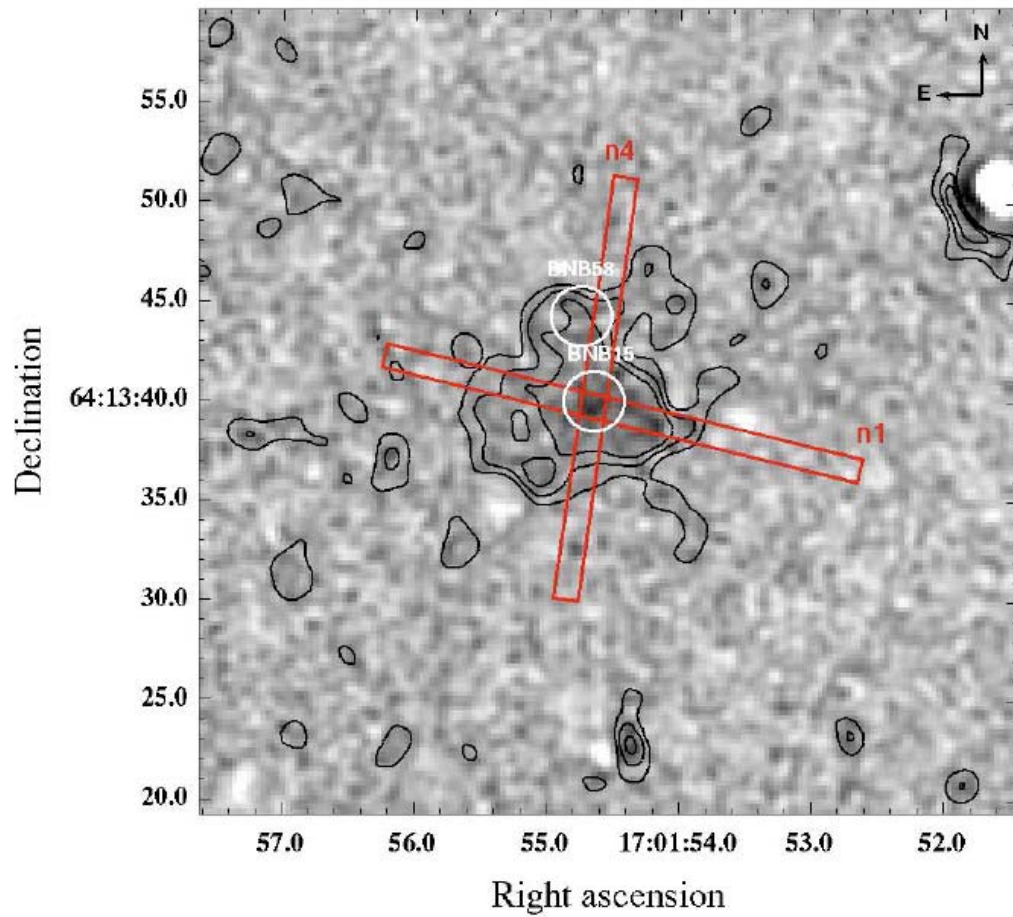
# Blob-4



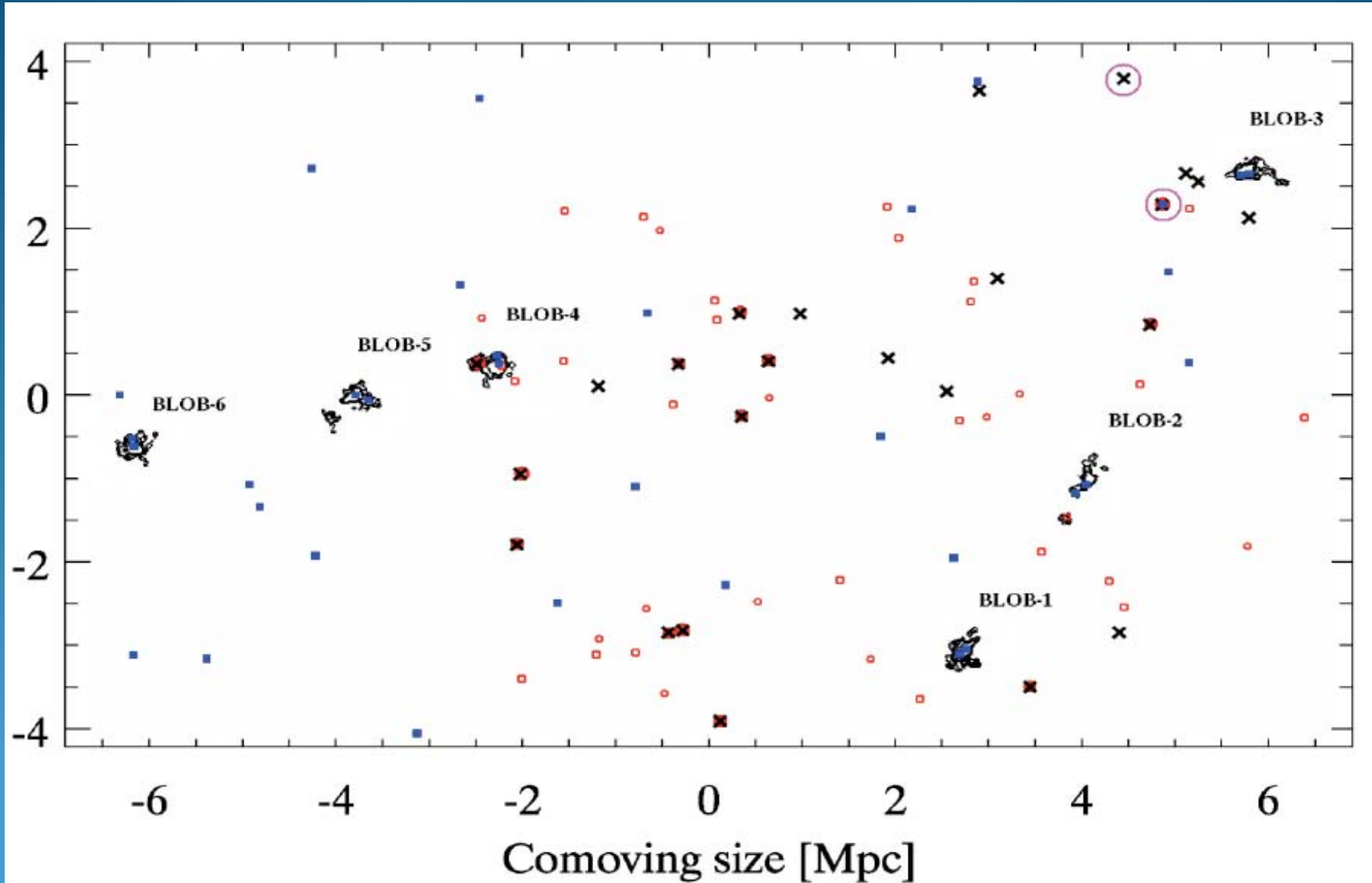
# Blob-5



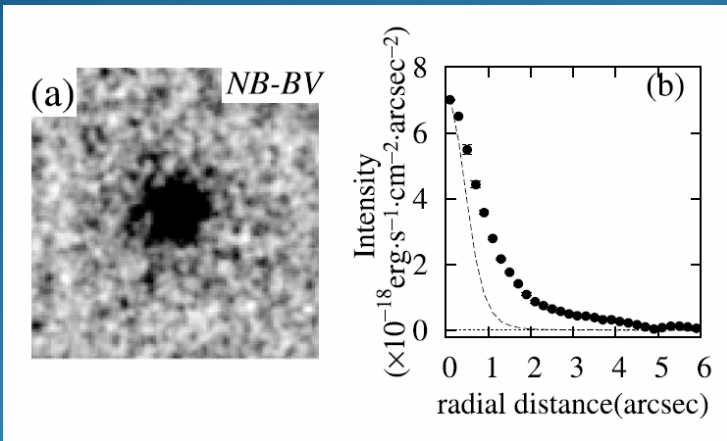
# Blob-6



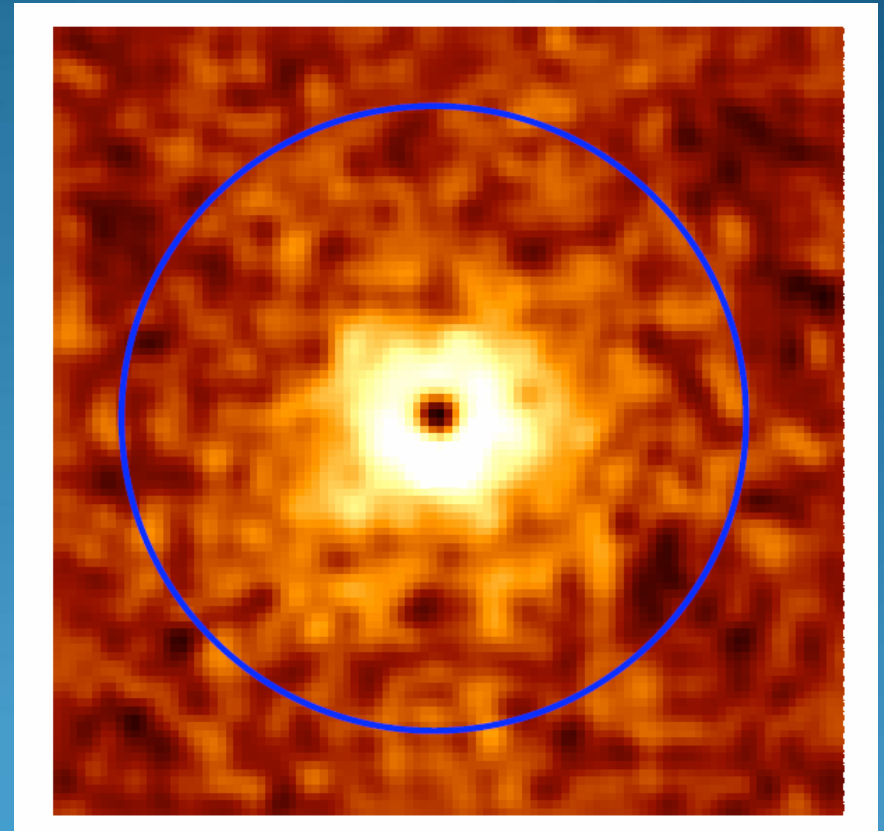
# Polje Q1700 – polje najbogatije velikim “grudvama”



# Najdublji snimak galaskija u Lajman alfa svetlosti do sada napravljen



Hayashino et al 2003



Steidel et al,  
upravo završavamo  
manuskript



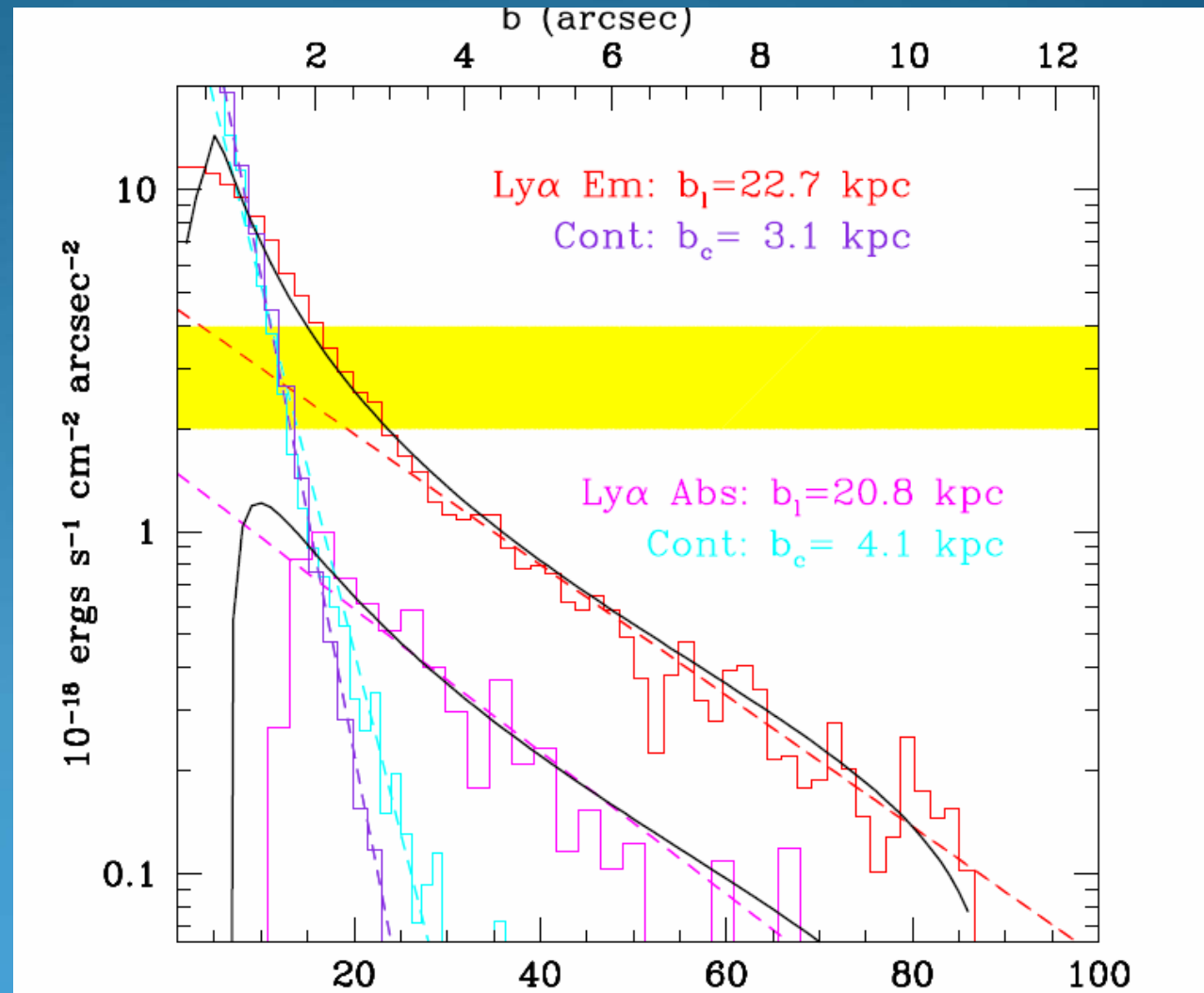
8'' (64kpc na  $z=2.7$ )



# Radijalni profil intenziteta Lajman alfa emisije

Na udaljenostima preko 20kpc sličan za sve galaksije, bez obzira na to da li u "centru" imaju Lajman alfa emisiju ili apsorpciju

Rasejanje na gasu koji je izbačen tokom burne epizode formiranja zvezda ("starburst")



# Zaključci

- Lajman alfa emiteri su naš “prozor” u najraniju fazu formiranja galaksija
- Lajman alfa “grudve” (B lobs), kada su otkriveni 2000-te godine bili su neobični i retki. Otkrili smo još 6 velikih primeraka, sve u jednom proto-jatu galaksija.
- Deset godina kasnije, pomoću sto puta “dubljih” snimaka, ispostavlja se da je difuzna emisija na skali 50-100kpc karakteristika svih mladih galaksija koje aktivno formiraju zvezde na  $z=2-3$
- Krucijalna komponenta je gusti međugalaktički prostor koji rasejava Lajman alfa, i intenzitet zračenja se može objasniti ako se uzmu o obzir snažni “galaktički vetrovi”.



## Artist's View of Star Formation in the Early Universe

Painting by Adolf Schaller • STScI-PRC02-02