Infra Luminous Ultra-Violet Lyman-α galaxies

(I LUV Ly-α Galaxies)

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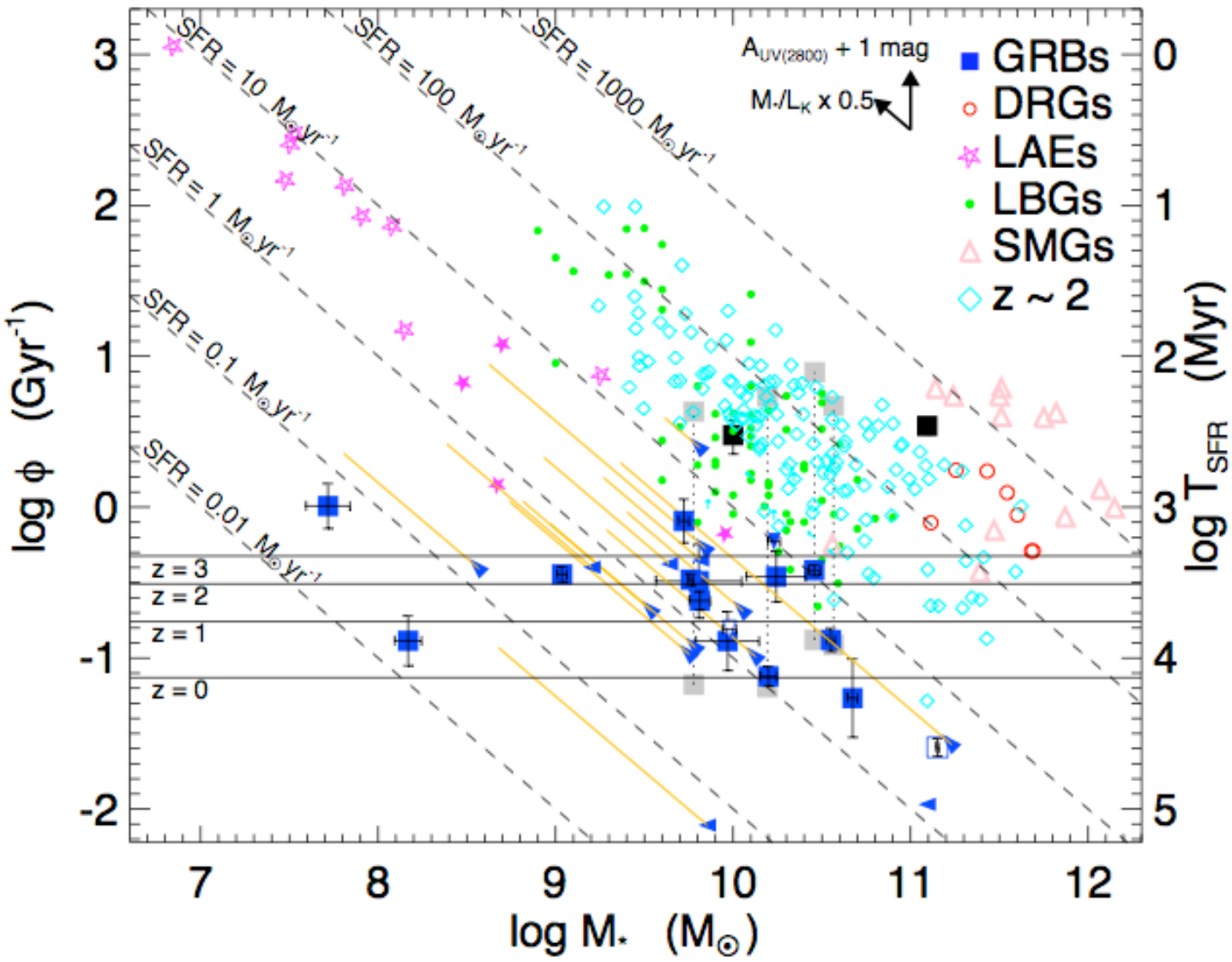
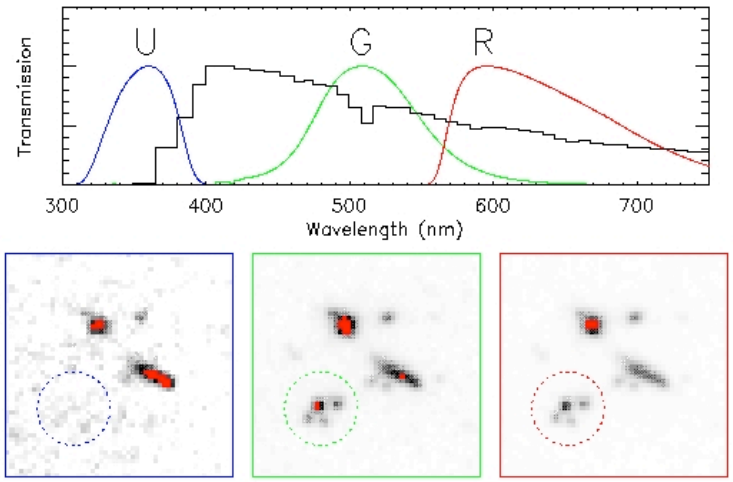
Underperforming, difficult and unpredictable …

in other words, interesting



Castro Ceron et al. 2008, astro-ph

Nomenclature = Function?

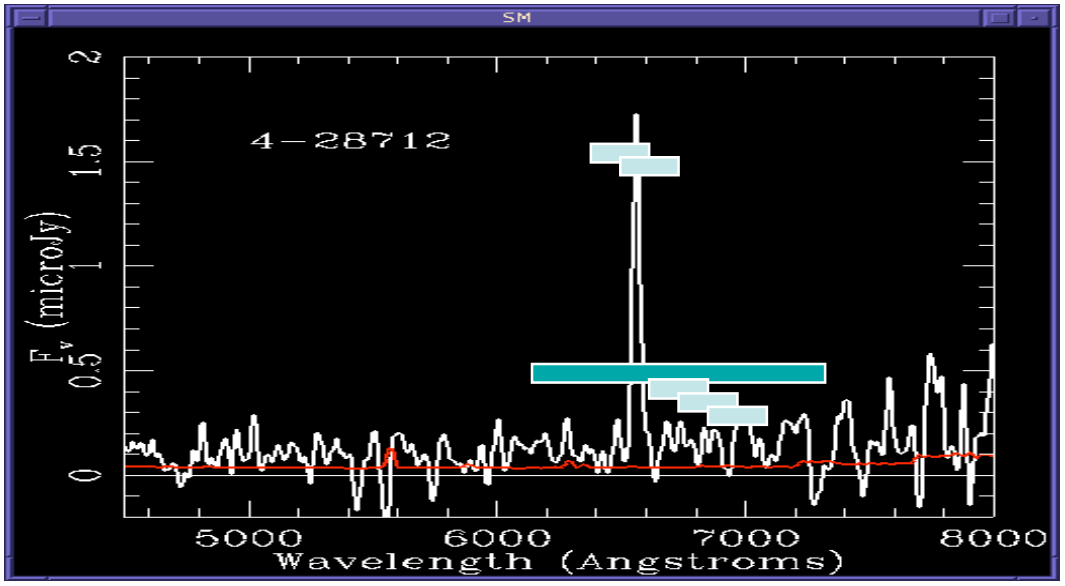


Lyman-break galaxies

- Break at 912A and 1216A
- (a property of the IGM)
- blue FUV slope

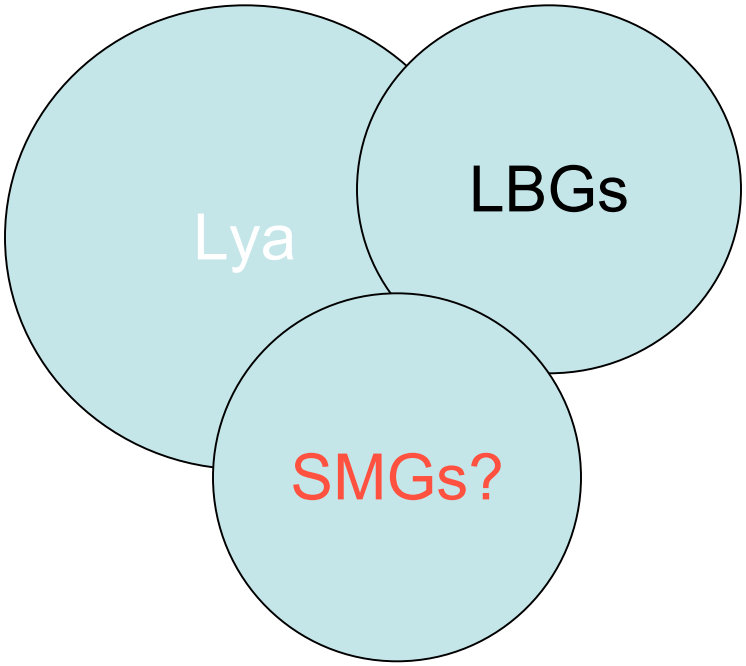
Lyman-α galaxies

- Large NB/BB ratio, line EW
- Does not depend on continuum properties.



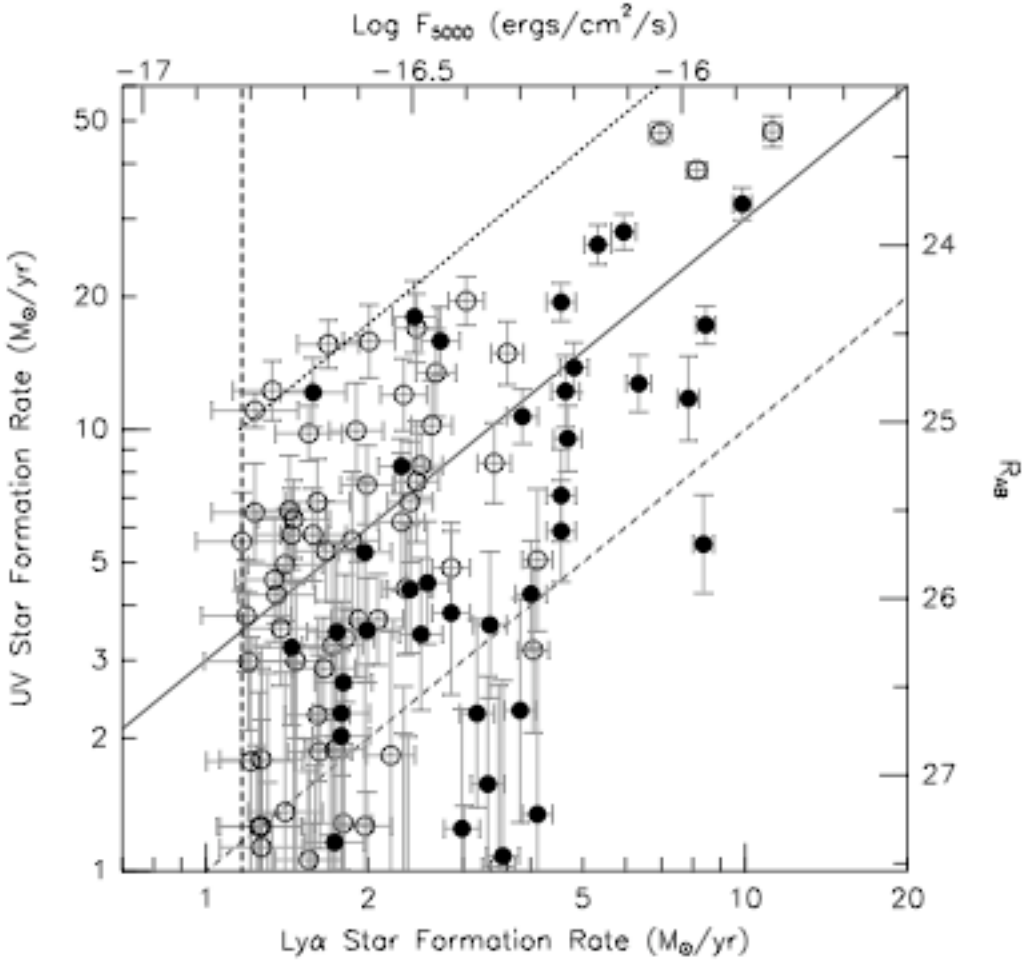
1. Yes, some of the LBGs show Lya in emission
2. And when we detect continuum for Lya galaxies
   they better show breaks at 1216 and 912 A

25-50% overlap in the samples so far, depending on redshift, magnitude limits, selection….



1. Star-formation rates ~10 M_{sun}/year

not ~100 M_{sun}/year



Gronwall et al. 07

Ouchi et al. 08 +

Dawson et al. 04, 07

Almost everyone else [See X-ray upper limits by Zhenya Zheng's poster]

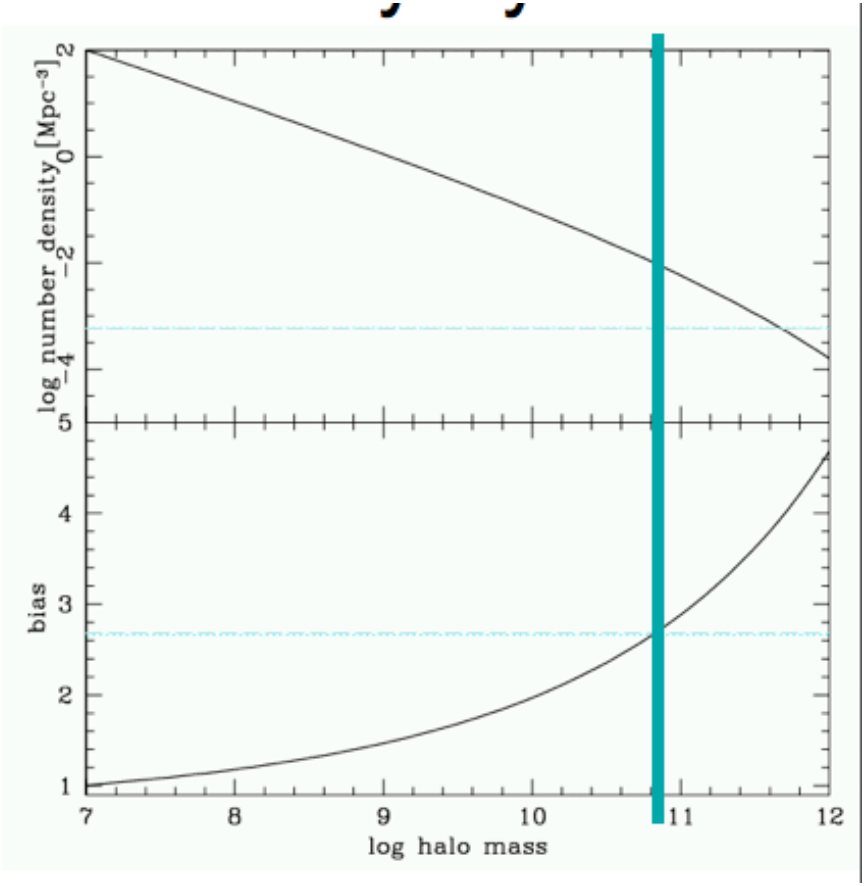
2. are mostly young: ~ 10^7 years (Pirzkal et al. 07, Gawiser 06, Finkelstein et al. 08, Venemans et al. 05)

3. are not massive: 10^7-10^9 M_{sun} (Pirzkal et al. 2007, Finkelstein et al. 2008, Gawiser et al. 06, Gawiser et al., Veneman's et al., Reddy et al., Lai et al. 08, Pentericci et al. 2009)
(but see Lai et al. 07, Finkelstein 08 for exceptions: beware of the detection bias)

4. have modest amounts of dust or not much dust

5. have halo masses ~ 10^{11} M_{sun} (Kovac et al 2007; Gawiser et al 07)

6. Only ~ 5-10% of such halos host LyA galaxies (Kovac et al 2007, Gawiser et al. 07).

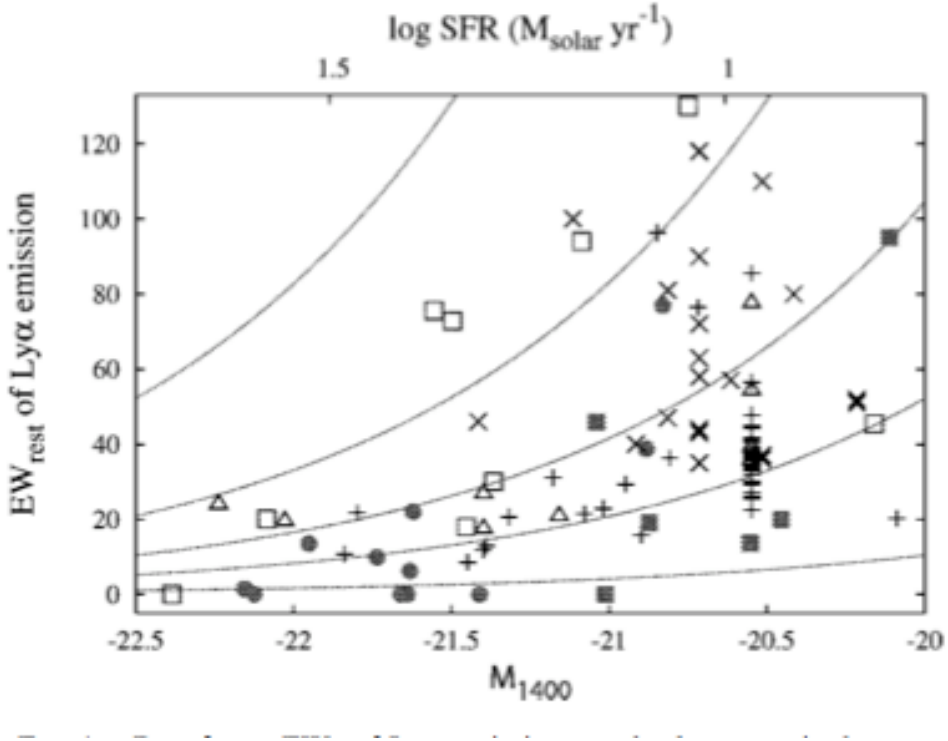


~10% duty cycle is naturally explained by models of Tilvi et al. 2009 (see poster at this meeting and arXiv:0906.5159)

7. Continuum bright galaxies show a lack of bright Lya (Ando et al. 2006)

(e.g. Ando et al. 2006)

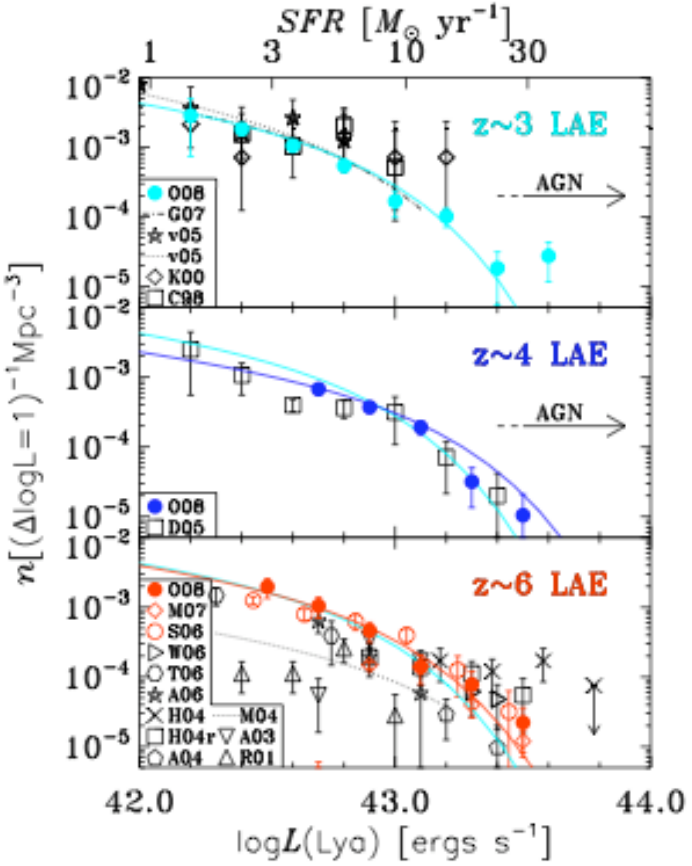
Small number statistics, see Nilsson et al. 2009 for more

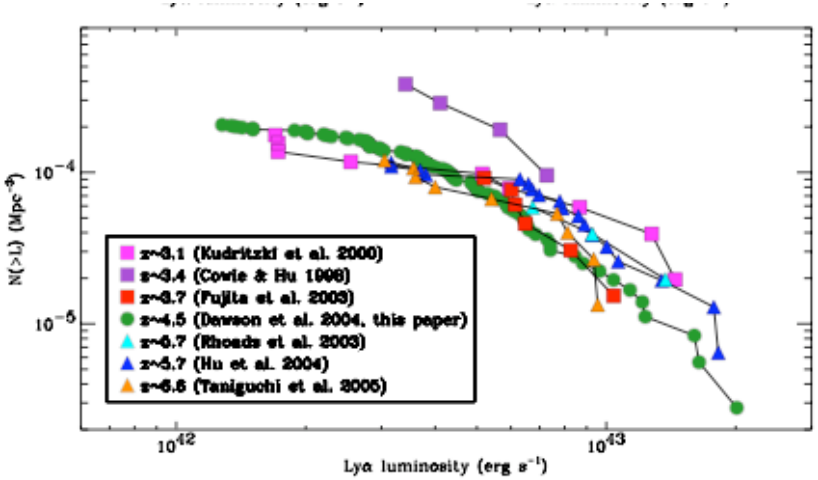


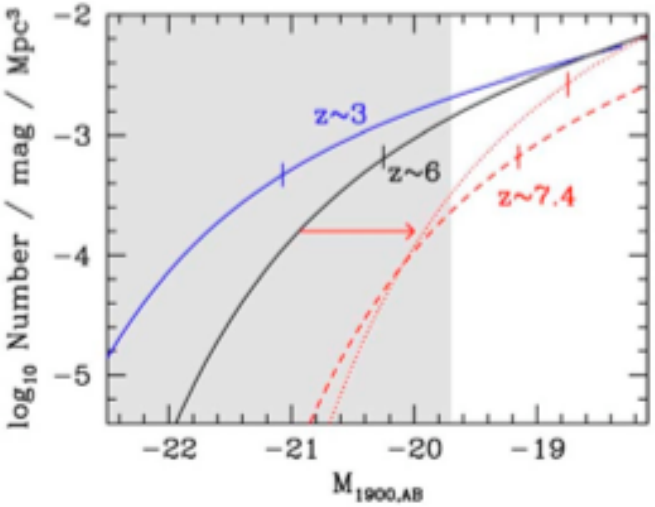
8. Very little redshift evolution in luminosity function compared to LBGs

(Dawson et al. 2007, Ouchi et al. 2008)

Compare to LBGs seen by Bouwens et al. 2004-2009)







Ly-α galaxies:

- have star-formation rates ~1-10 M_{sun}/year
- are young: ~ 10^7 years (Pirzkal et al. 07, Finkelstein et al. 08; Nilsson et al. ….)
- are not massive: 10^7-10^9 M_{sun} (Pirzkal et al. 2007, Finkelstein et al. 2008, Gawiser et al. 2007)
- have modest amounts of dust or not much dust
- have halo masses ~ 10^{11} M_{sun} (Kovac et al 2007; Gawiser et al 07; Ouchi et al 07)
- Only ~ 10% of such halos host LyA galaxies (Kovac et al 2007).
- Continuum bright galaxies show a lack of bright Lya (Ando et al. 2006)
- Very little redshift evolution in luminosity function compared to Lyman-break Galaxies.

What makes a Lyman-alpha emitter a Lyman-alpha emitter?

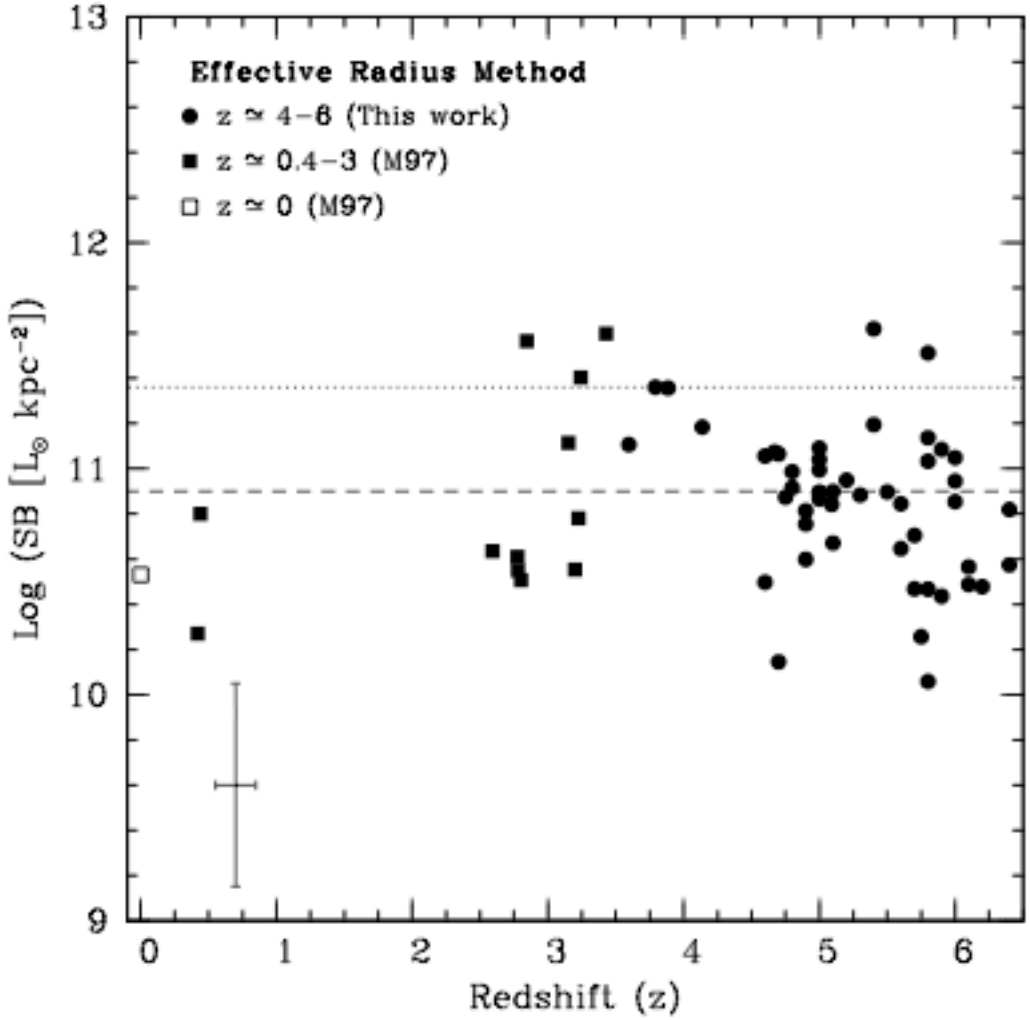
- Clumpy dust as enhancer (Neufeld, Hansen & Oh)?
  - Observational evidence from Finkelstein et al. 2008-2009)
- Lack of dust : bluer colors
- Metallicity (no clue)
- Kinematics
- Age of star-burst
- Geometry & chance
  - a favorable line of sight?

Star-formation has to be a self-limiting process.

- Need negative feedback in simulations
  - Otherwise get galaxies that are too compact and too bright.
- And we see the effects of the feedback quite directly: at low as well as high z.
  - maximum pressure that we measure in the ISM of starbursts (e.g. Heckman et al. 1999, Malhotra et al. 2001)
  - Maximum Luminosity/Area in starbursts.
  - Starburst winds
  - Metal lines in the IGM far away from known galaxies

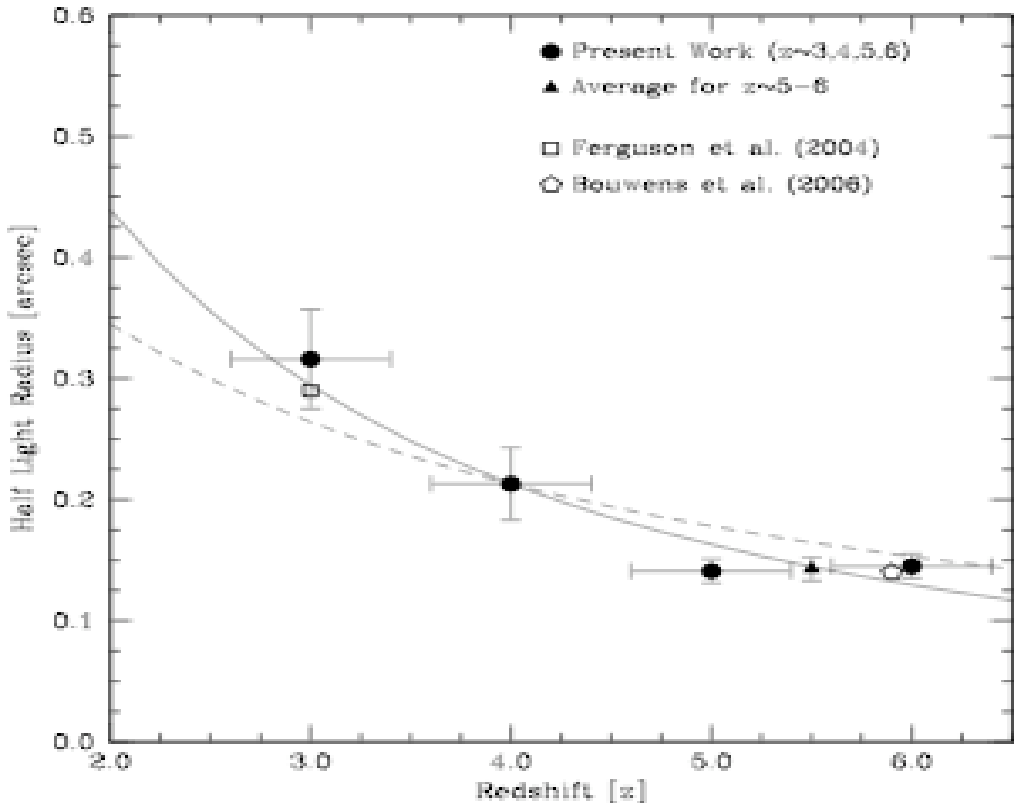
Hathi, Malhotra, Rhoads 08

Meurer et al. 1997.

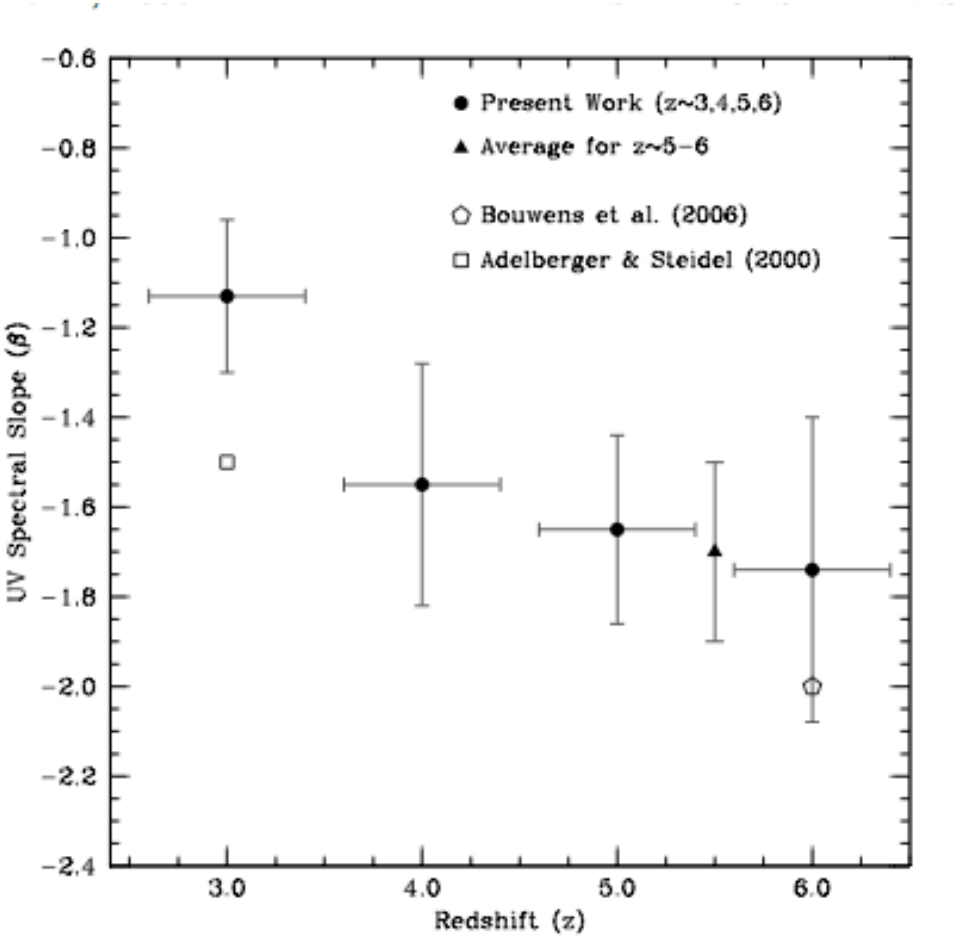


Size evolution:

(Ferguson et al. 2004, Bouwens et al. 2006, Hathi et al. 2008)

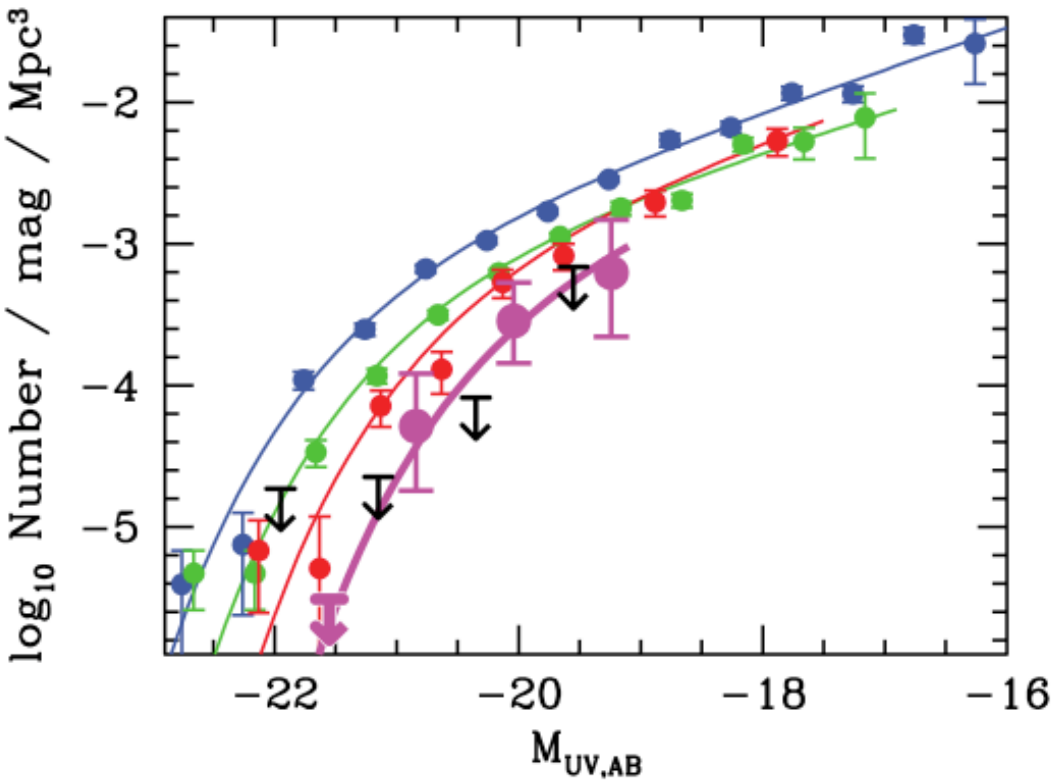


Dust evolution:



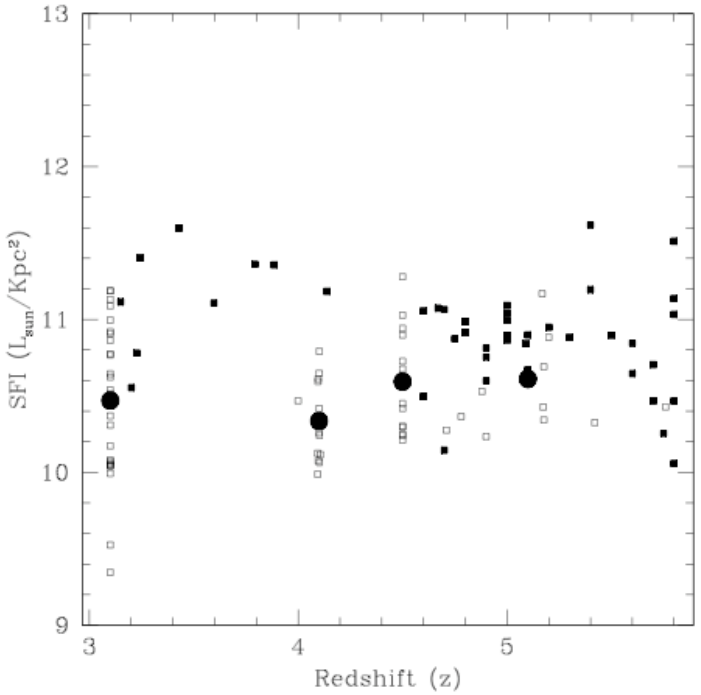
Luminosity Evolution:

Bouwens et al 2006 cj



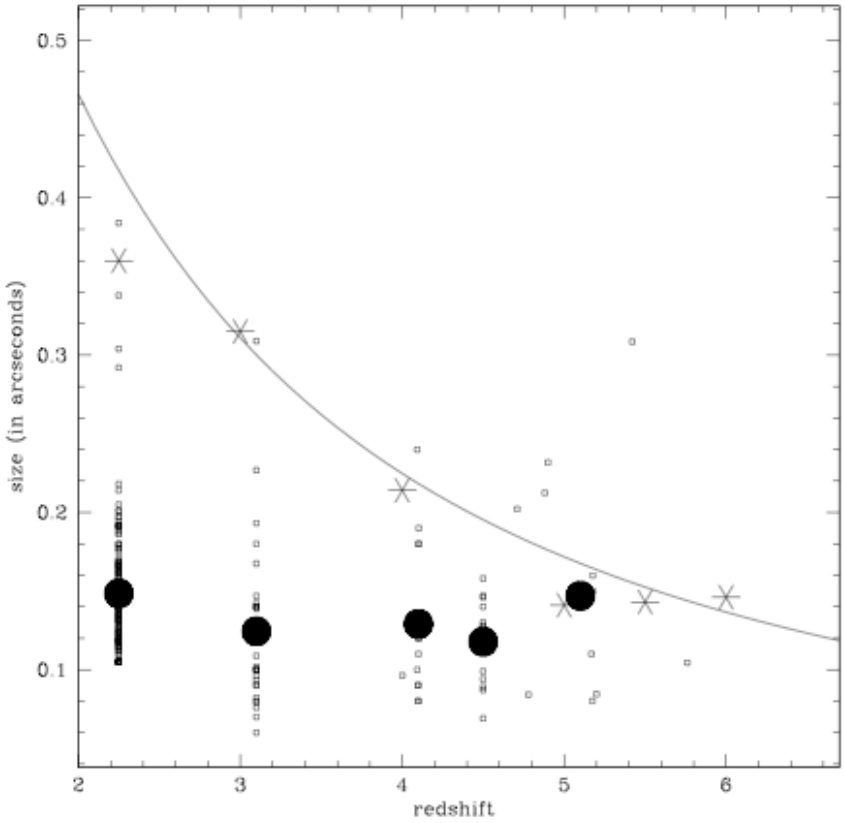
What about Lyman-alphas?

(Malhotra et al. 2009)



Can explain lack of (discernable) evolution of Lya galaxies between z=3-6 (Dawson et al. 2007, Ouchi et al. 2008, Wang et al. 2009)

(compare with LBGs: Bouwens et al. 2005-2009)

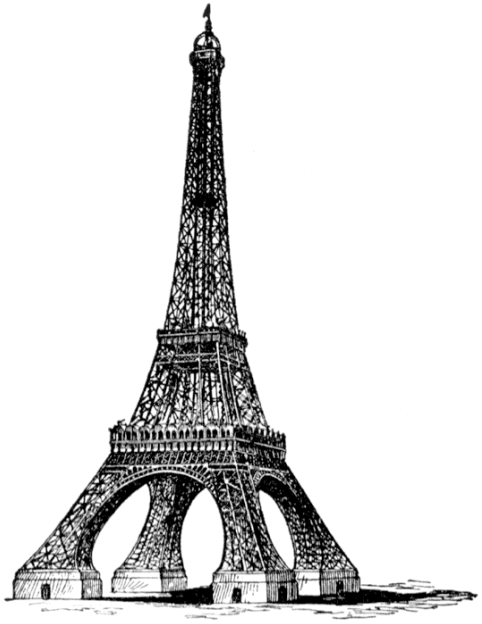


- Z=2.25 Nilsson et al. 2009
- z=3.1 McLinden et al. 2009, Venemans et al.
- z=4.5 Finkelstein et al.
- z=4.1 Overzier et al.
- z=5.2 Overzier et al.
- Z=4.5-6 Pirzkal et al
- Z=5.7 Taniguchi et al.

(politically incorrect)

Conclusion:

- Size Matters!



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Norbert Pirzkal, JunXian Wang, Chun Xu, Seth Cohen, Zhenya Zheng

Katarina Kovac, Steve Dawson, Steve Finkelstein, Nimish Hathi, Vithal Tilvi, Emily McLinden, Lifang Xia.

Unanswered questions:

1. Is there some physical mechanism that prevents Lyman alpha escape from physically larger galaxies?

- optical depth?

- shell/wind geometry?

2. Lyman-alpha building blocks….At present times we have run out of legos (P. Moller)