GRBs as Cosmological Probes: Cosmic Chemical Evolution

Sandra Savaglio
MPE - Garching

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Bob Abraham *(U. of Toronto)*
Hsiao-Wen Chen *(U. of Chicago)*
David Crampton *(NRC, Victoria)*
Mike Fall *(STScI)*
Karl Glazebrook *(Hopkins University)*
Stéphanie Juneau *(Steward Observatory)*
Damien Le Borgne *(Saclay, Paris)*
Pat McCarthy *(Carnegie Observatories)*

Background

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❶ Light elements formed during Big Bang

→ 75% hydrogen, 25% deuterium, 0.01% helium, <0.01% lithium

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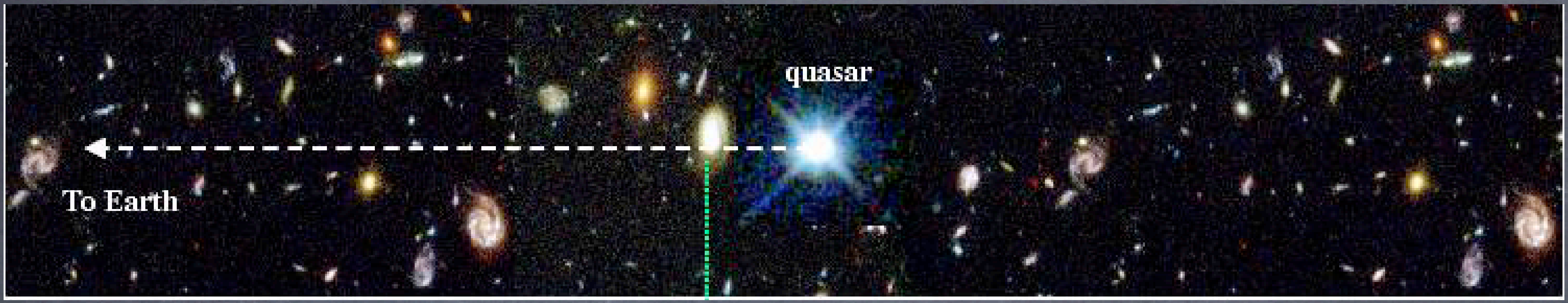
❸ Today in the solar neighborhood (13.5 billions years later):

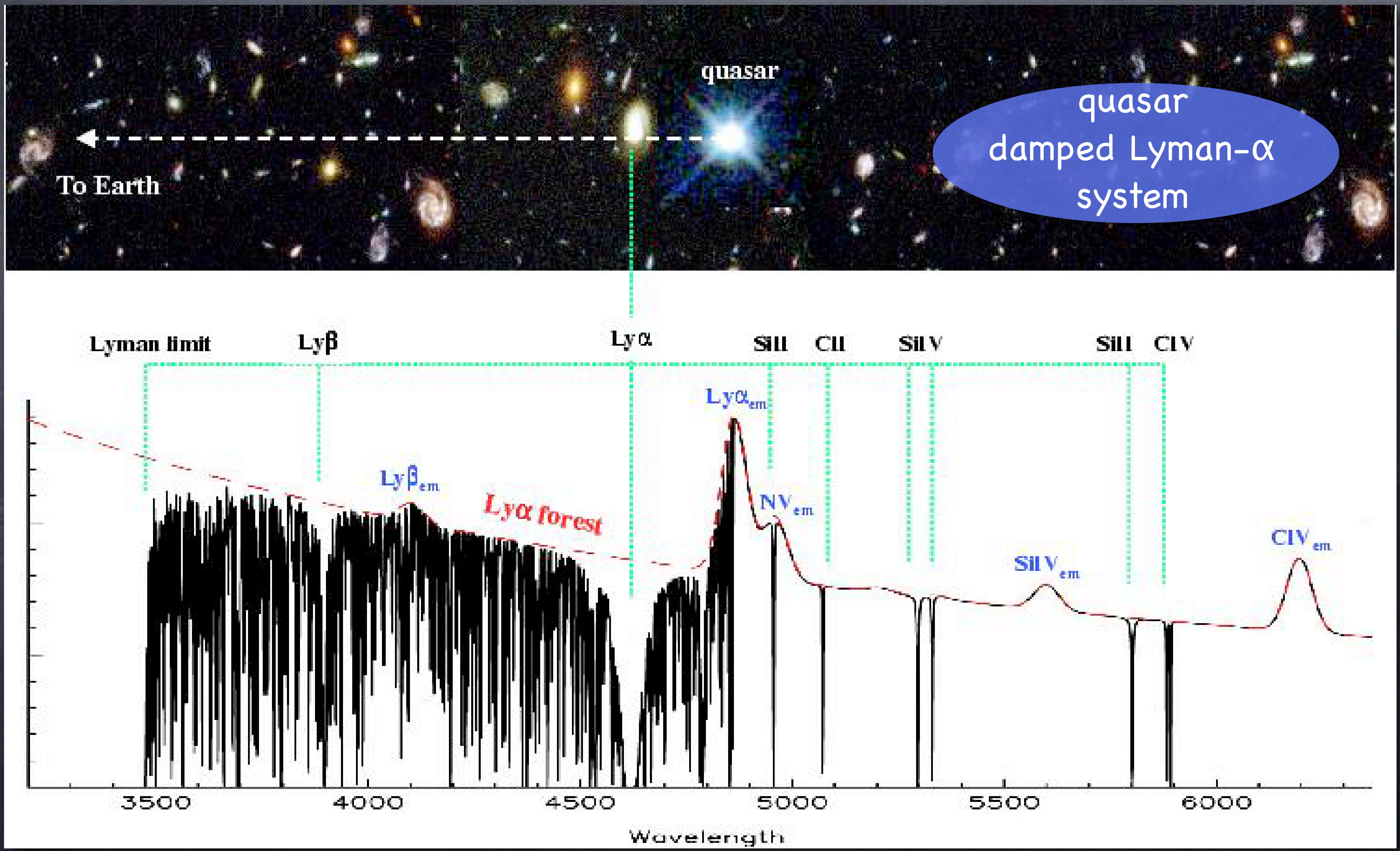
→ 71% hydrogen, 27% helium + 2% all other elements

Chemical enrichment of the interstellar medium



(Courtesy of John Webb)

Chemical enrichment of the interstellar medium



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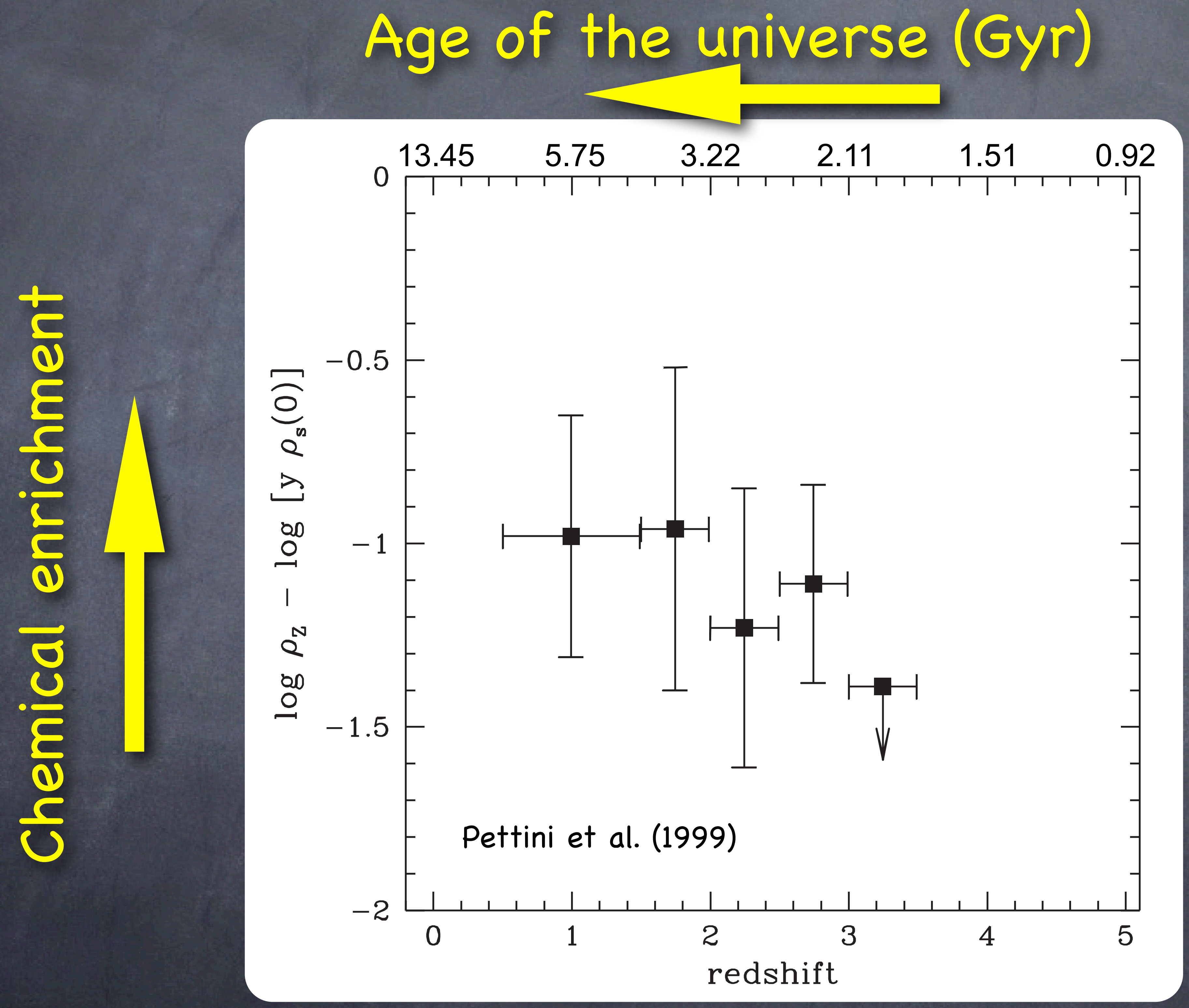
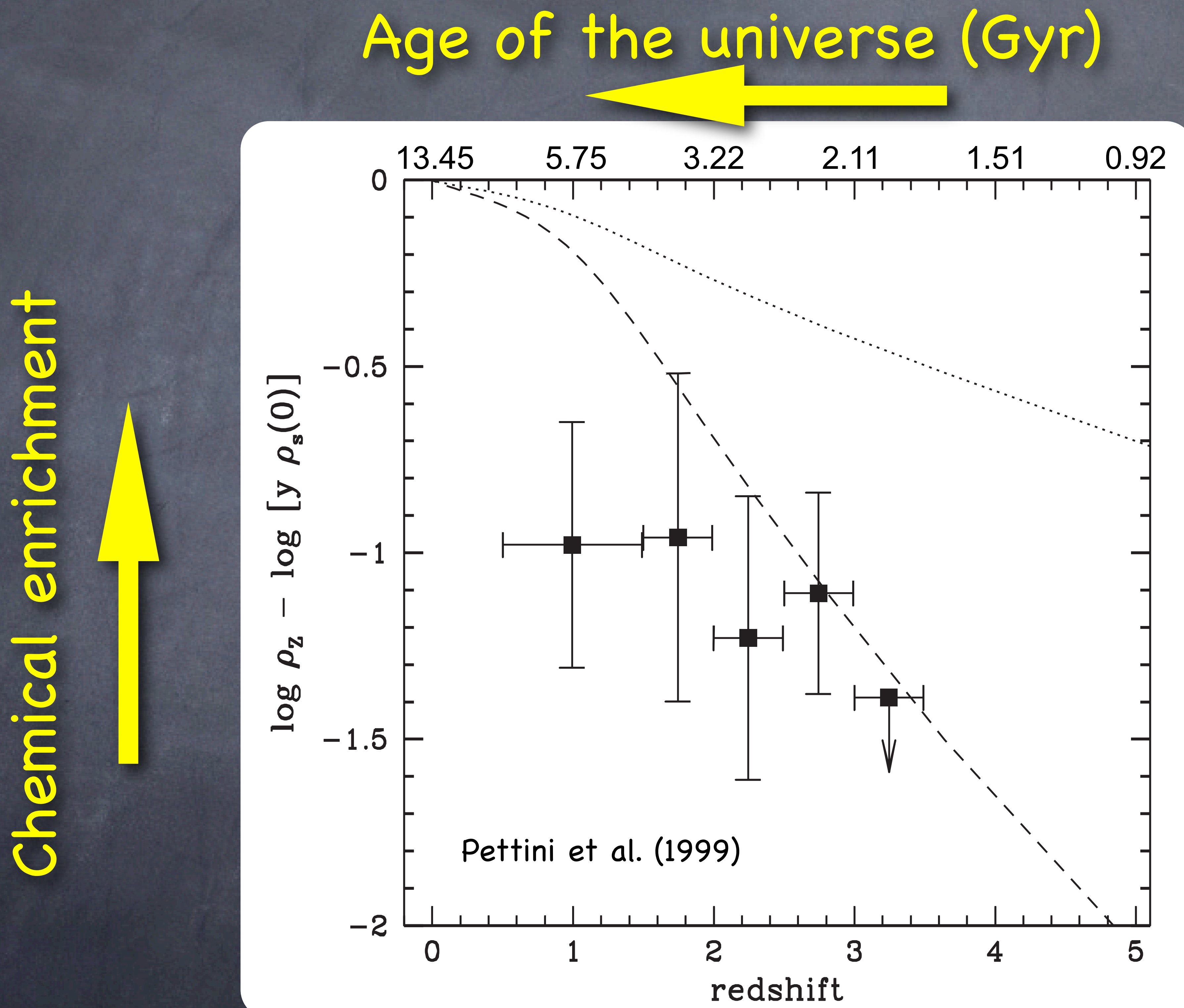

Age of the universe (Gyr)
13.45
5.75
3.22
2.11
1.51
0.92
Chemical enrichment
0
−0.5
−1
−1.5
−2
log ρZ − log [y ρs(0)]
Pettini et al. (1999)
0
1
2
3
4
5
redshift

Background

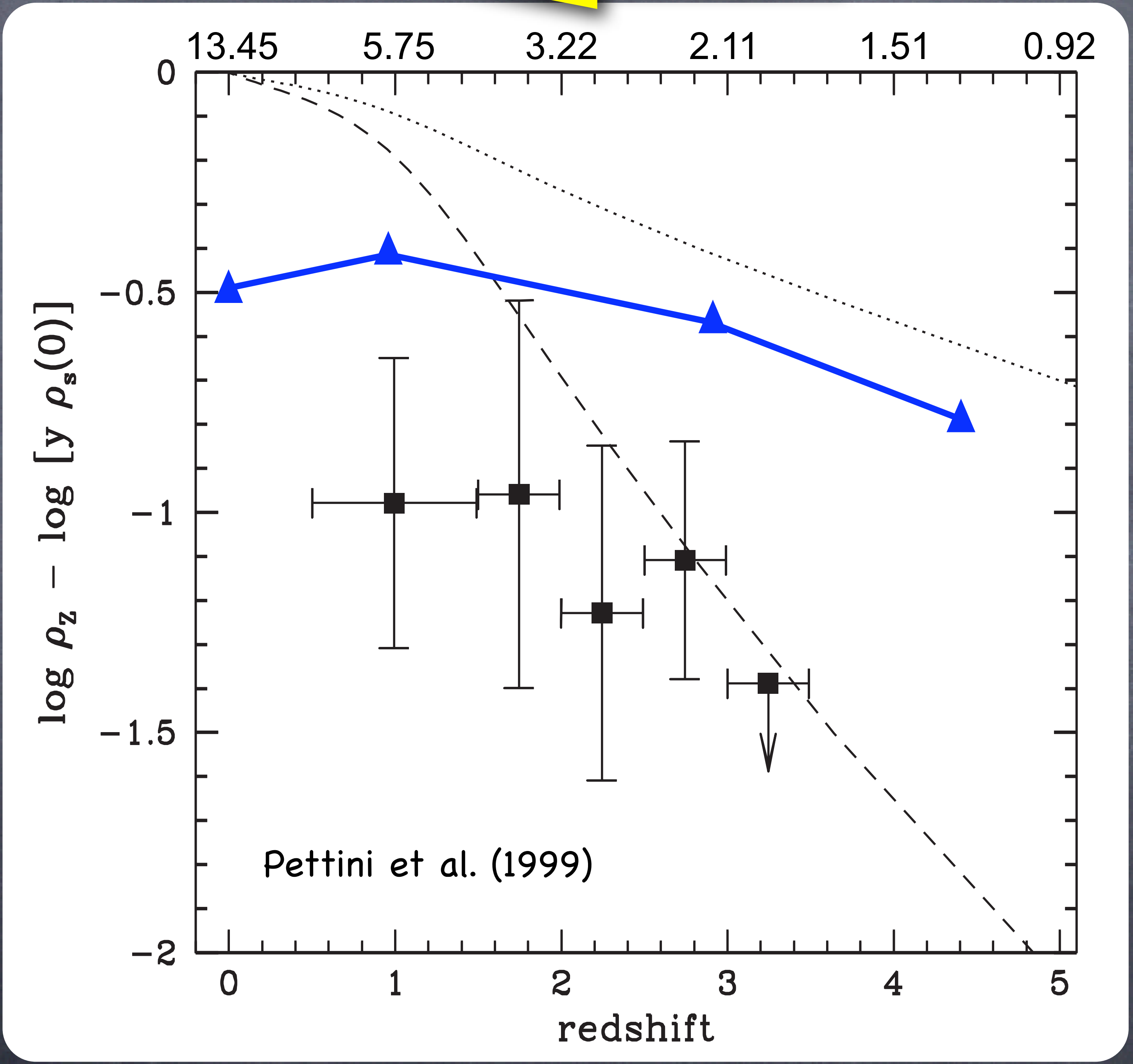


From the Madau plot (Madau, Pozzetti & Dickinson 1998)

Background

Age of the universe (Gyr)

Chemical enrichment



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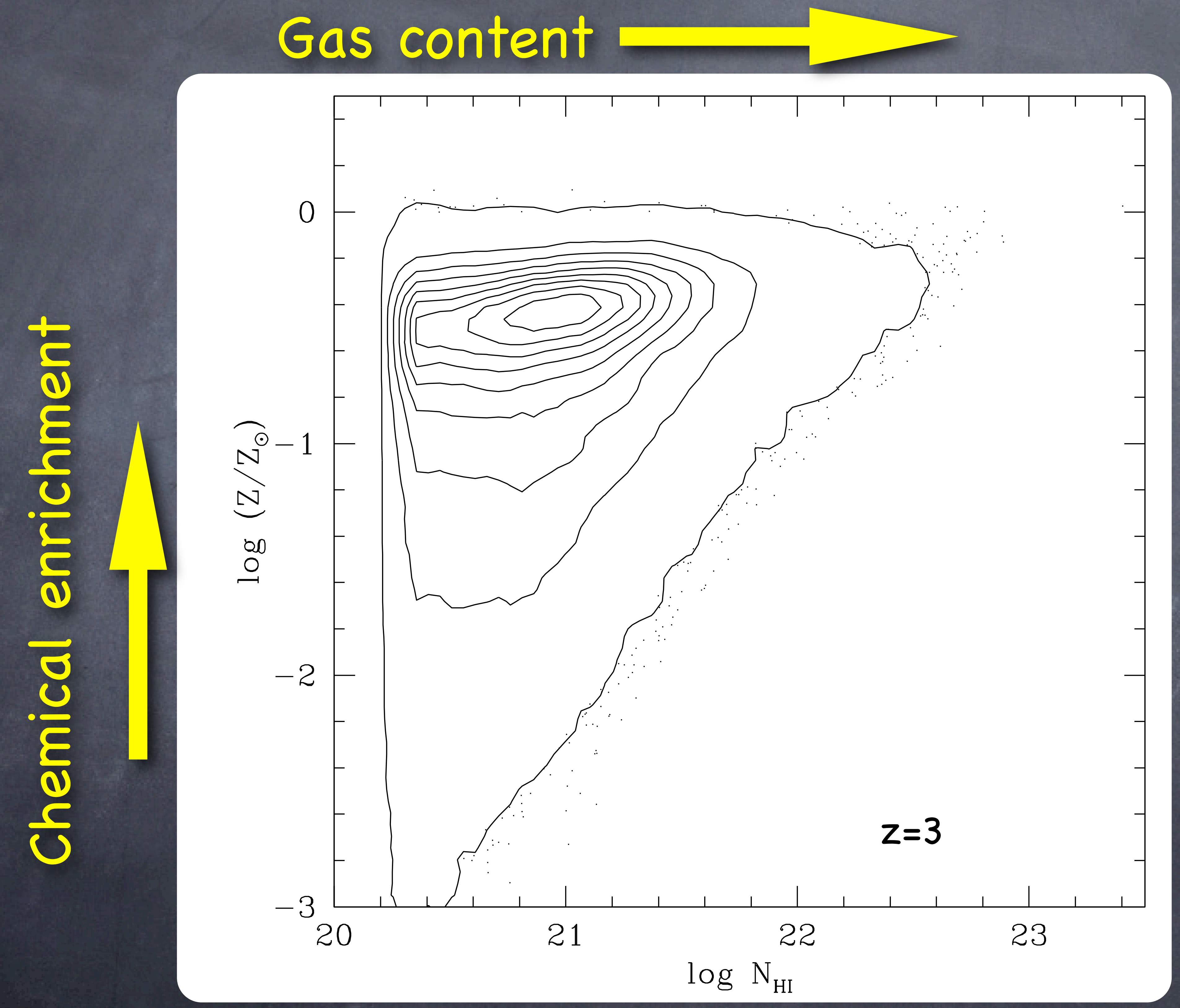
Cosmological Simulations (Nagamine, Springel & Hernquist 2004)

Background



Cosmological Simulations z=3 (Nagamine, Springel & Hernquist 2004)

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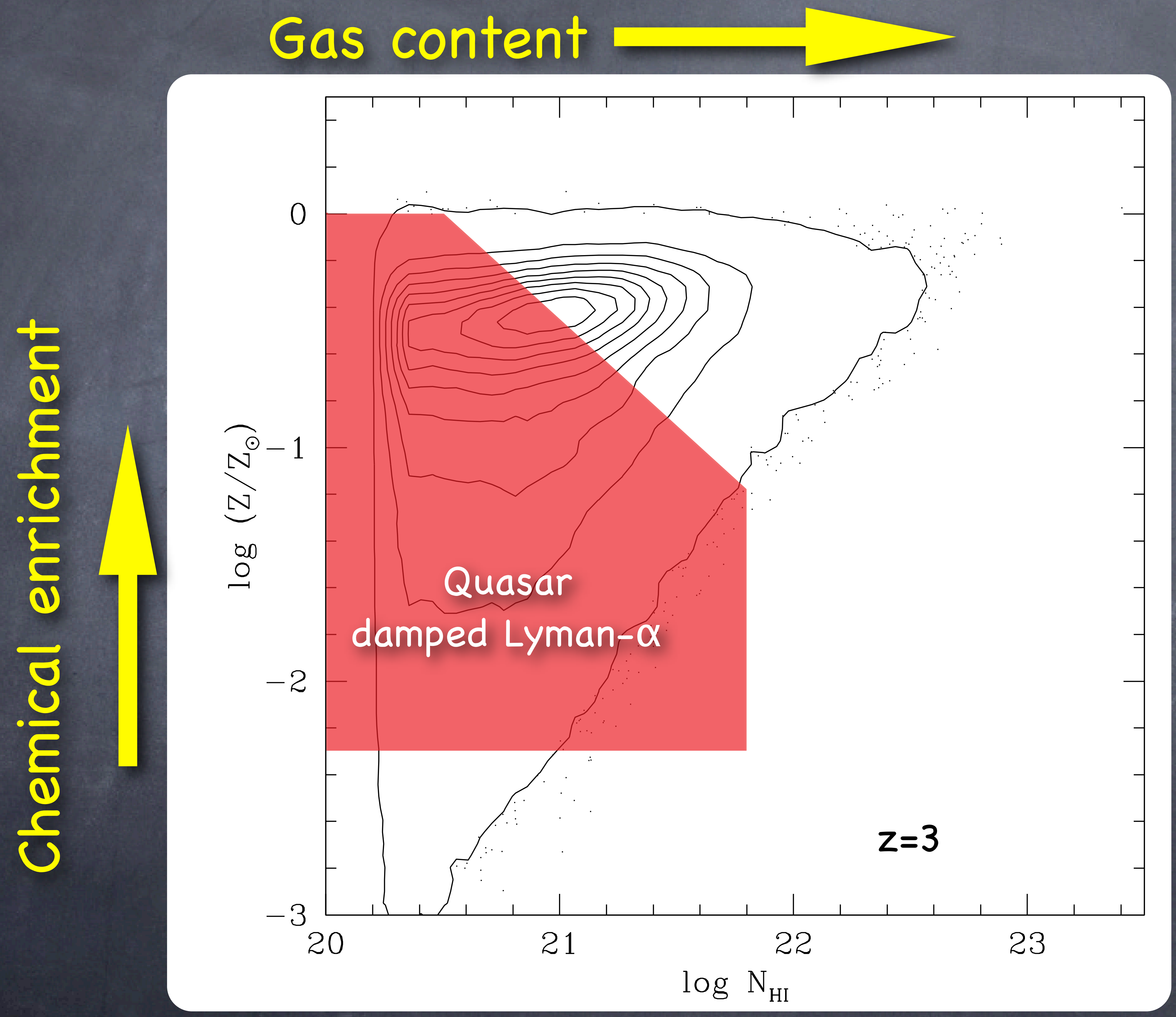

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Outline

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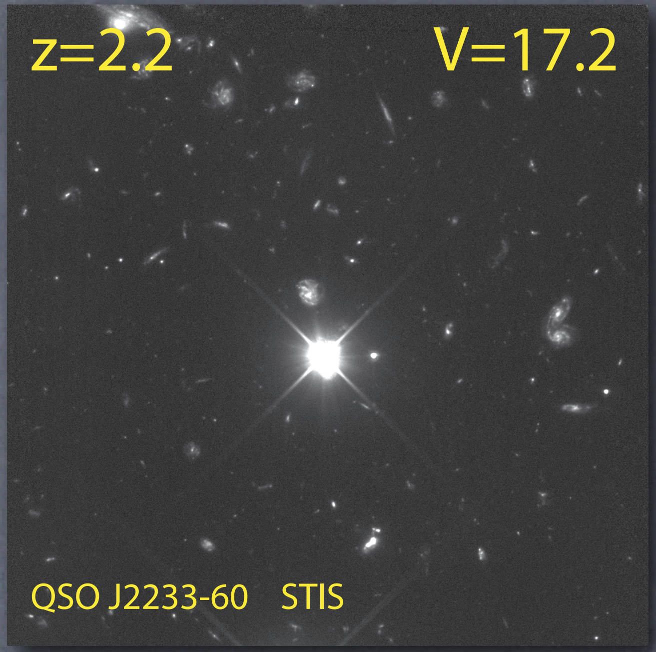
❶ Better understanding of QSO-DLA selection

→ Dust effects



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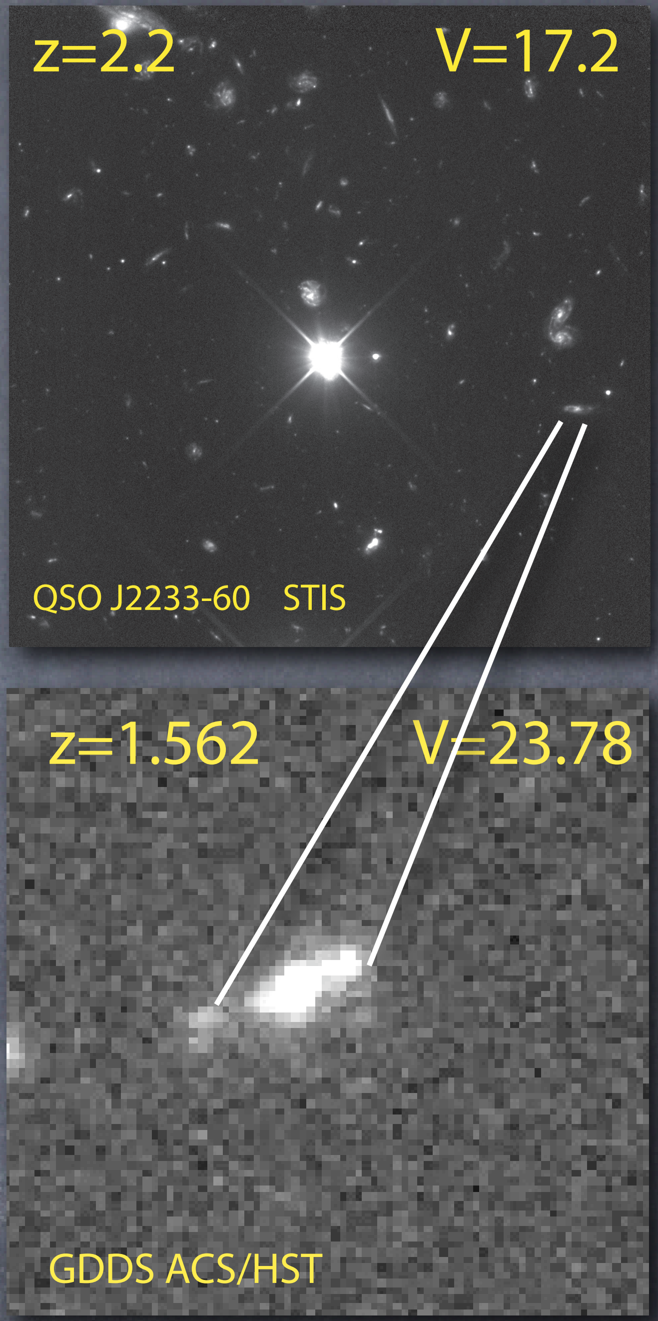
❷ Directly observe high redshift galaxies

→ Deep NIR galaxy surveys



Outline

❶ Better understanding of QSO-DLA selection

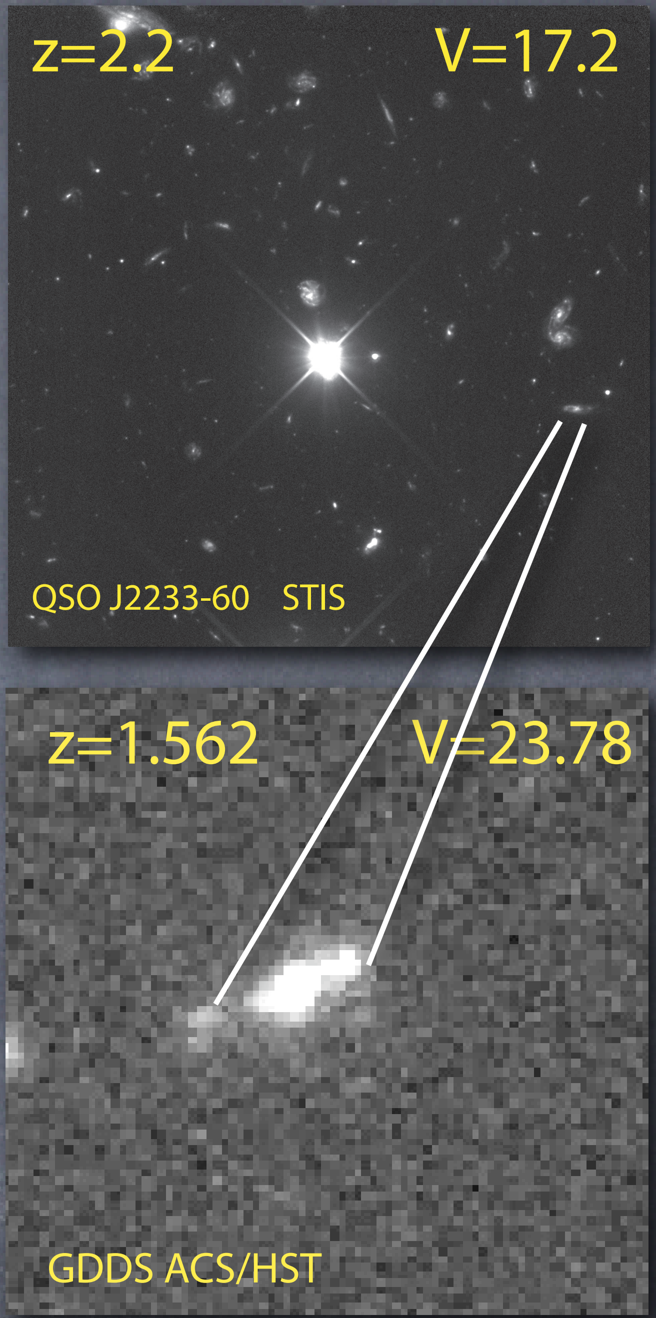
→ Dust effects

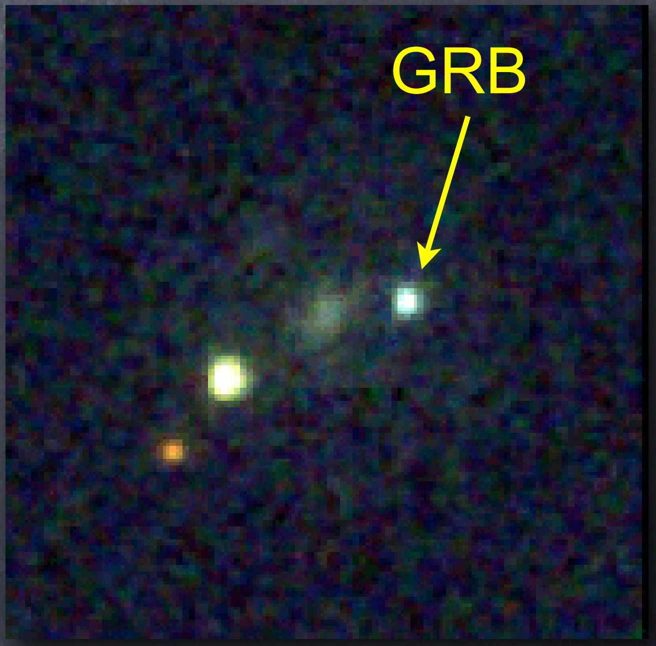
❷ Directly observe high redshift galaxies

→ Deep NIR galaxy surveys

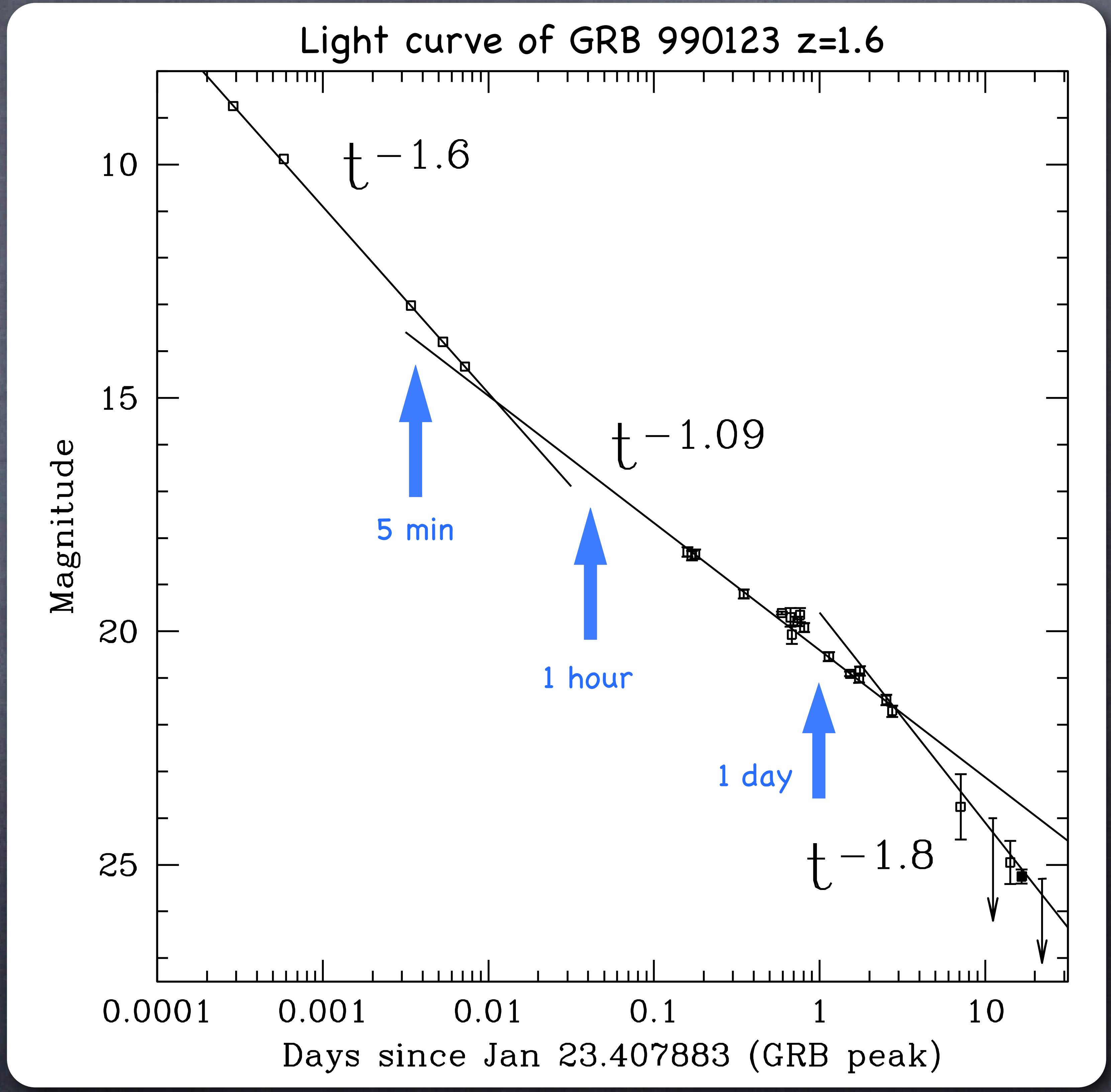
❸ New probes for cosmology: gamma-ray bursts

→ Very steep light curve !



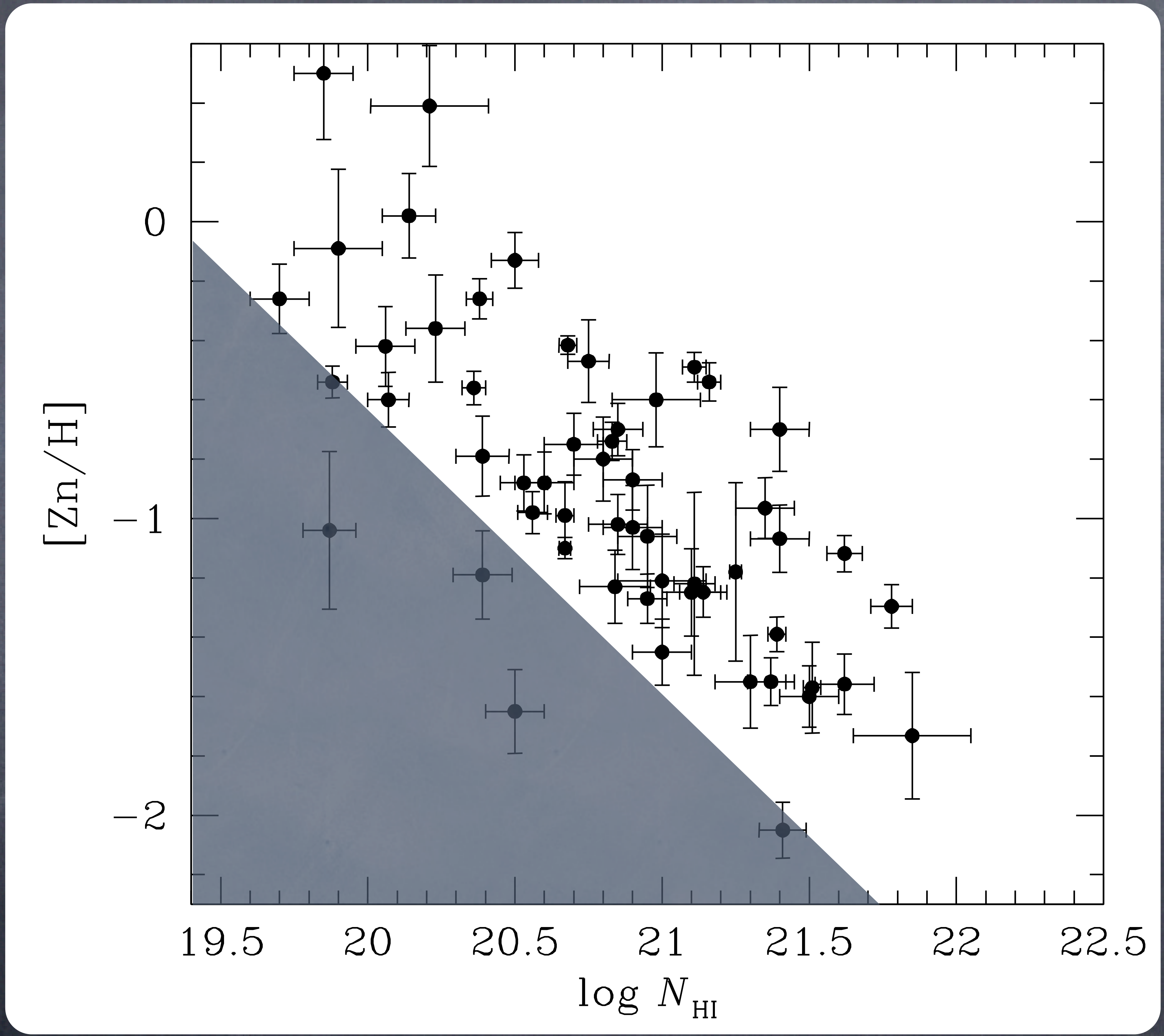


GRB afterglows to study the high-z ISM



Fruchter et al. (1999)

Dust extinction in QSO-DLAs



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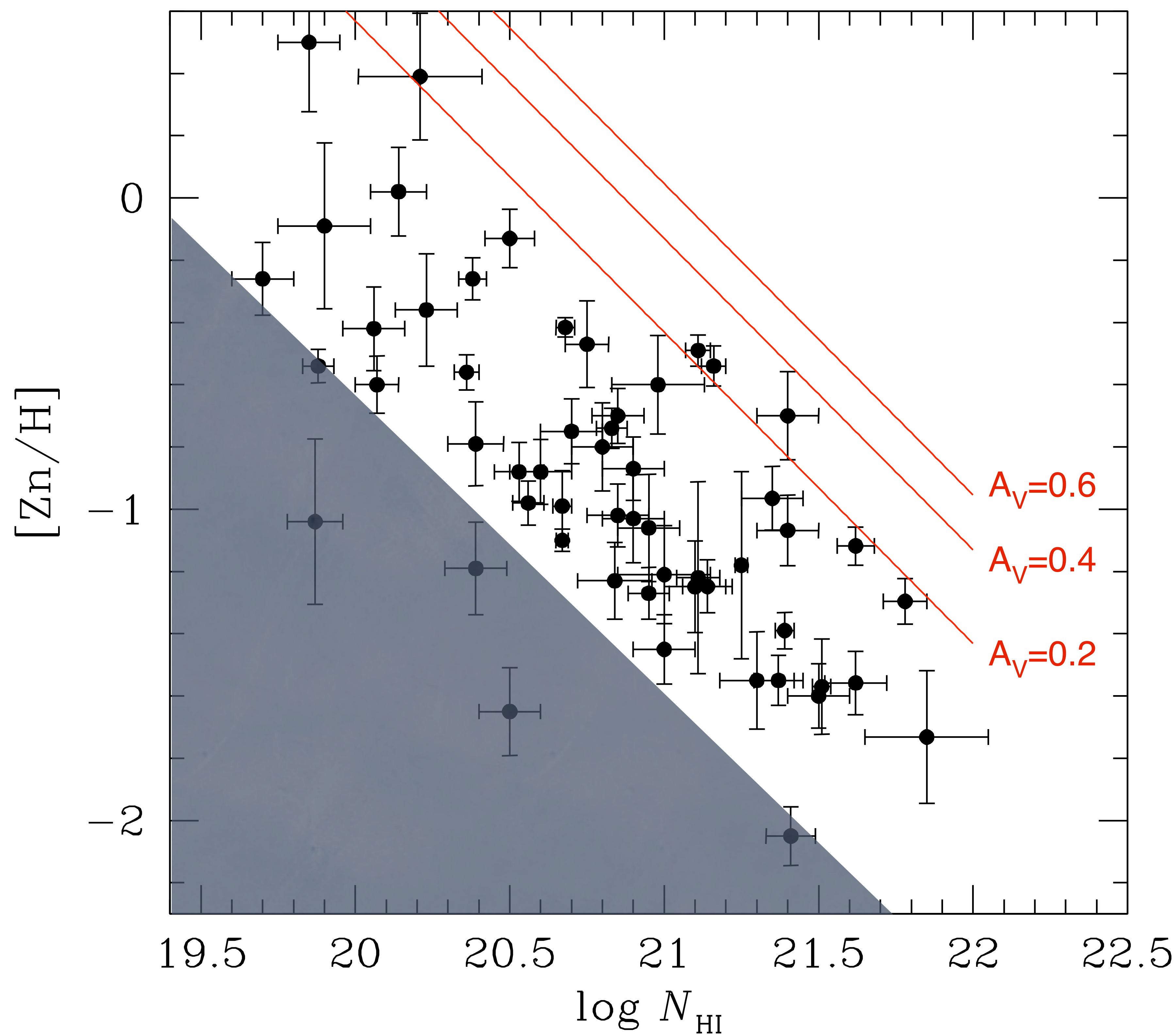

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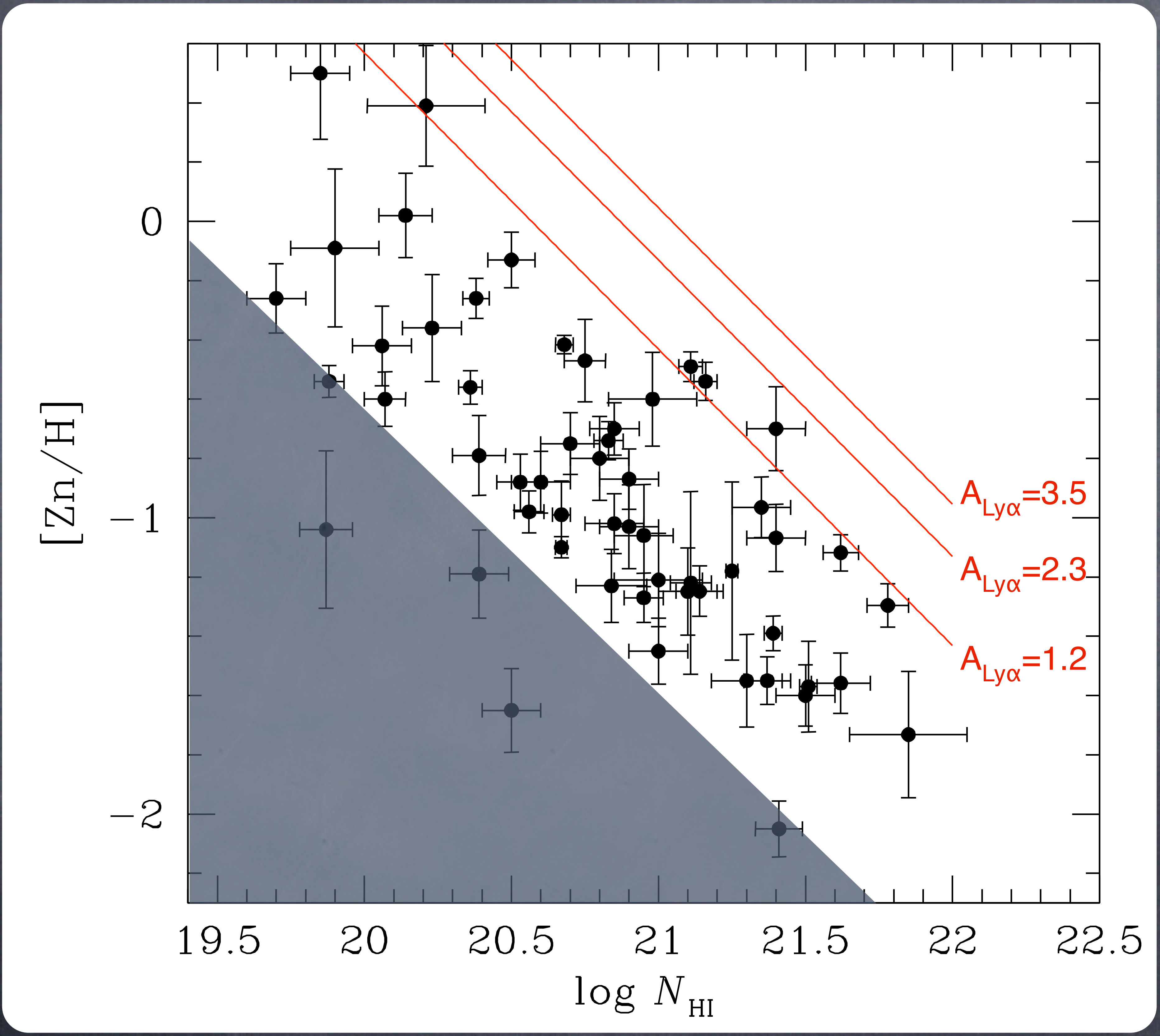
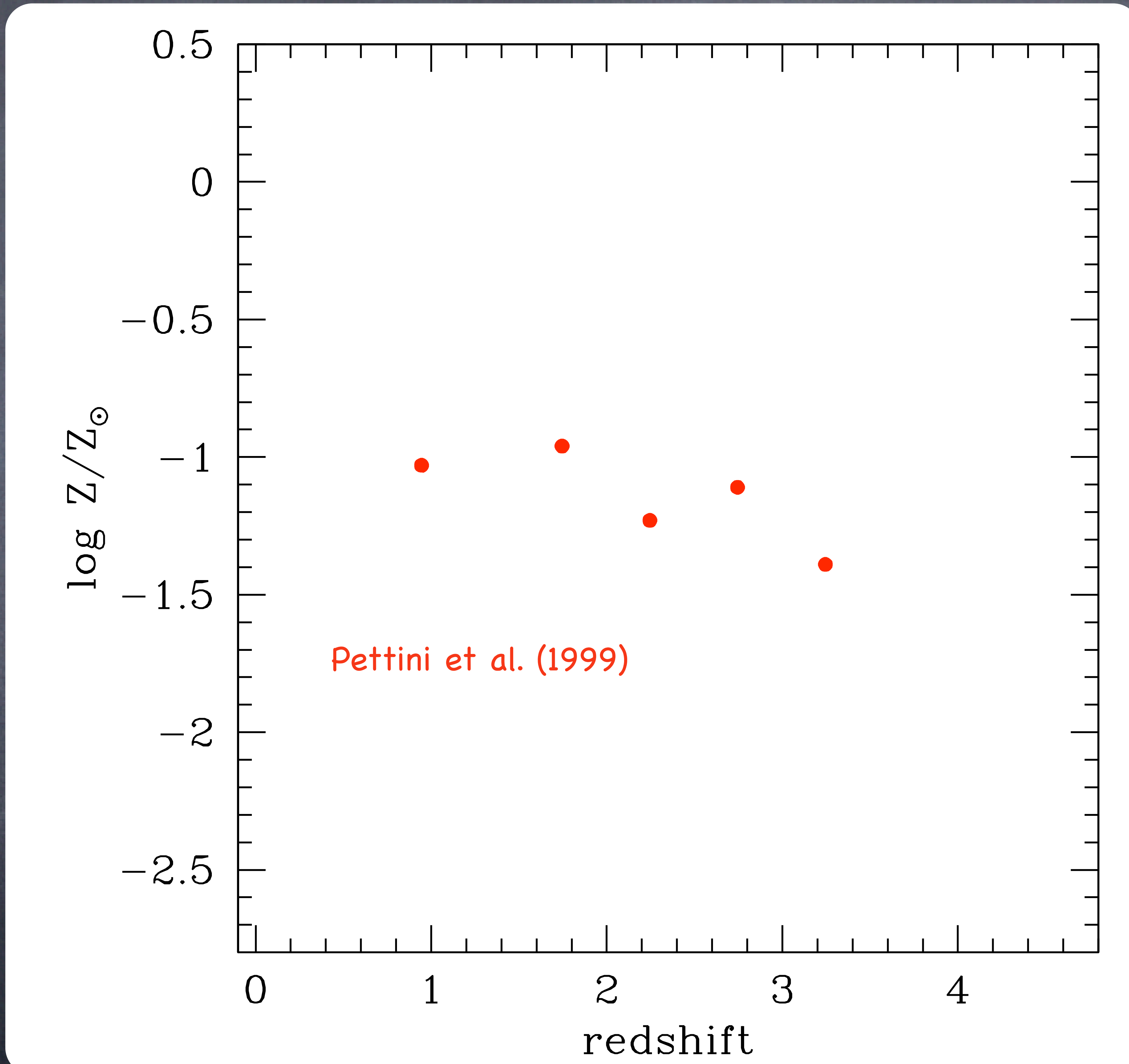


Metallicity evolution of QSO-DLAs



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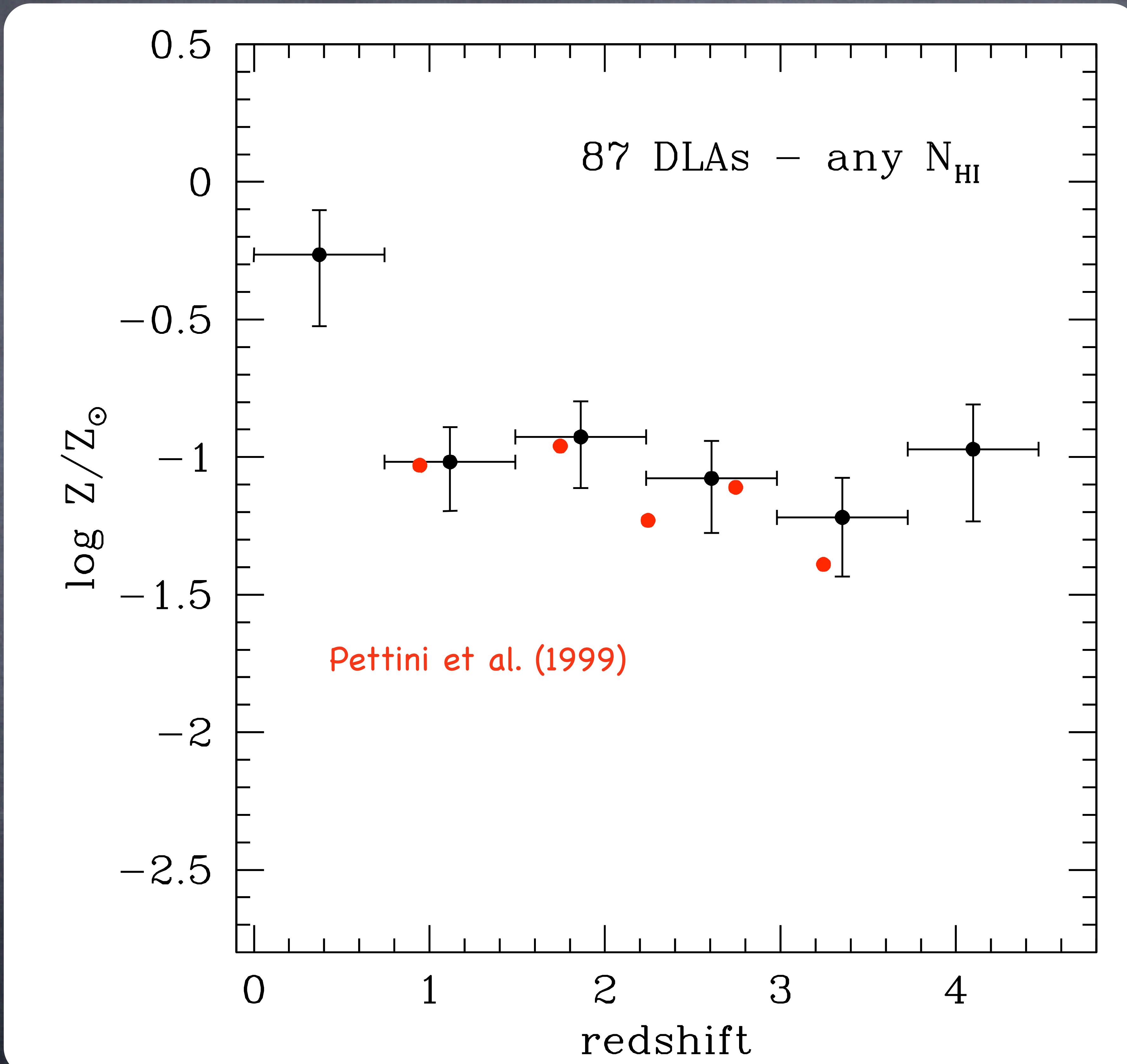

Savaglio (2000)

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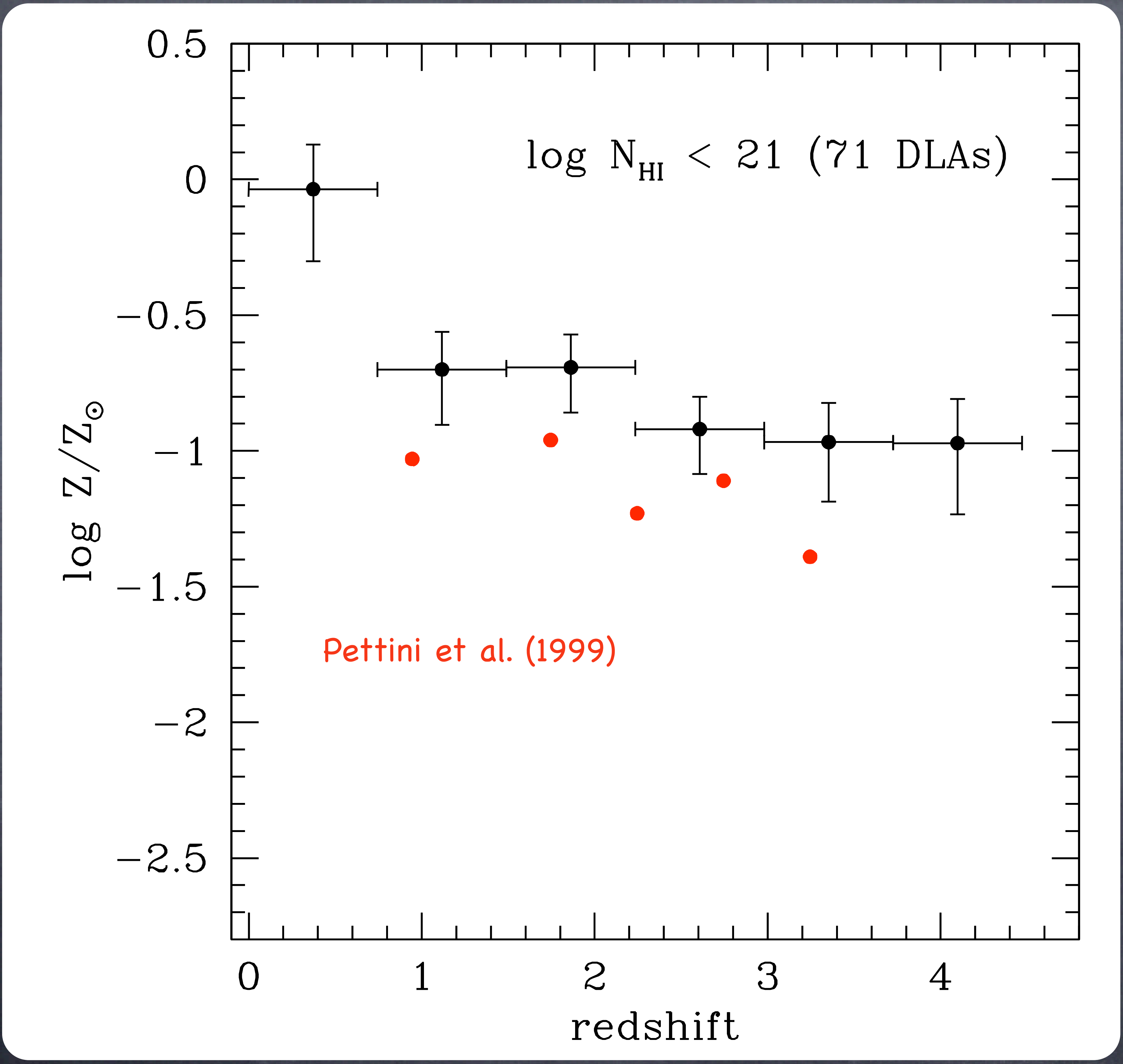

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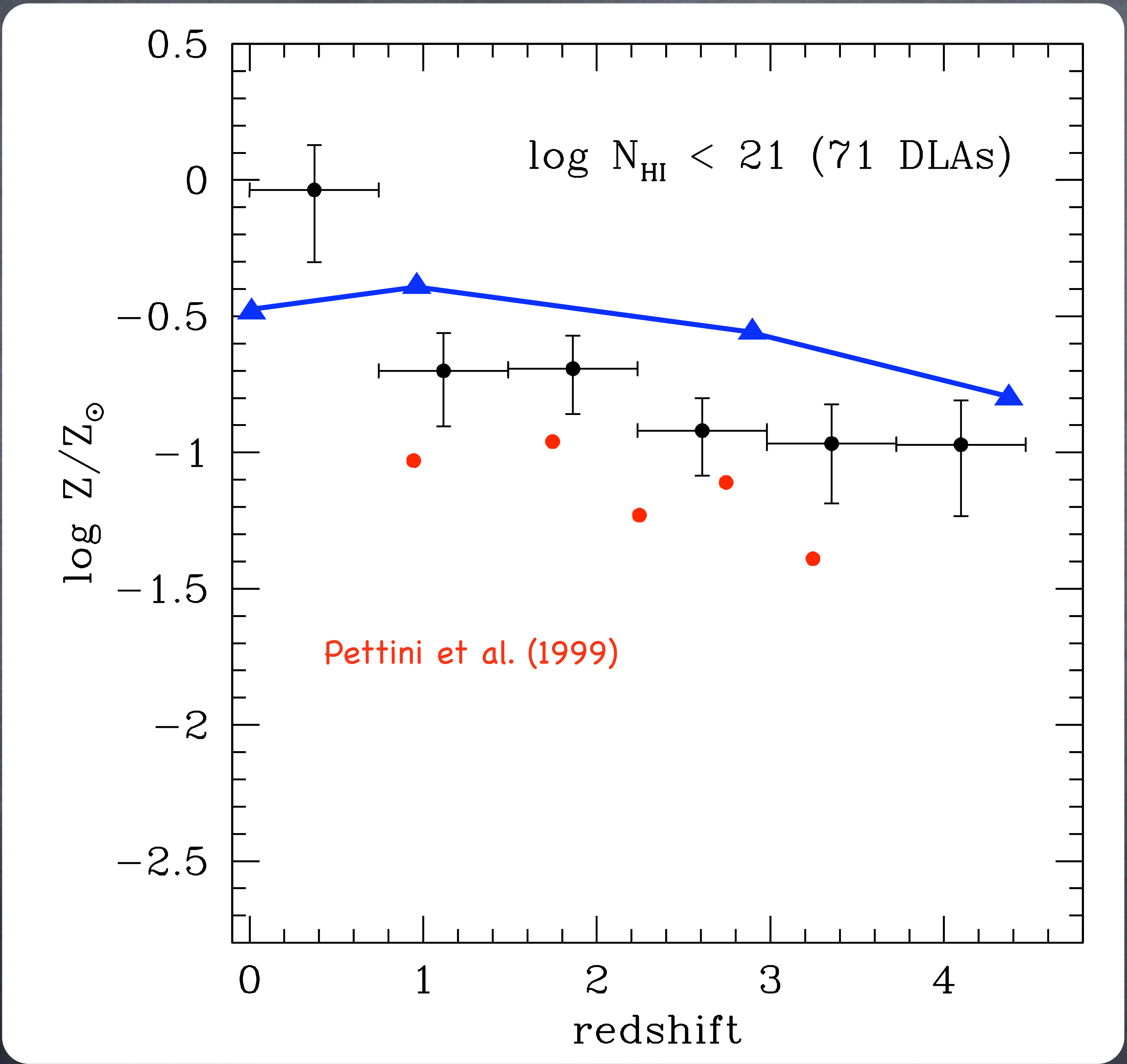

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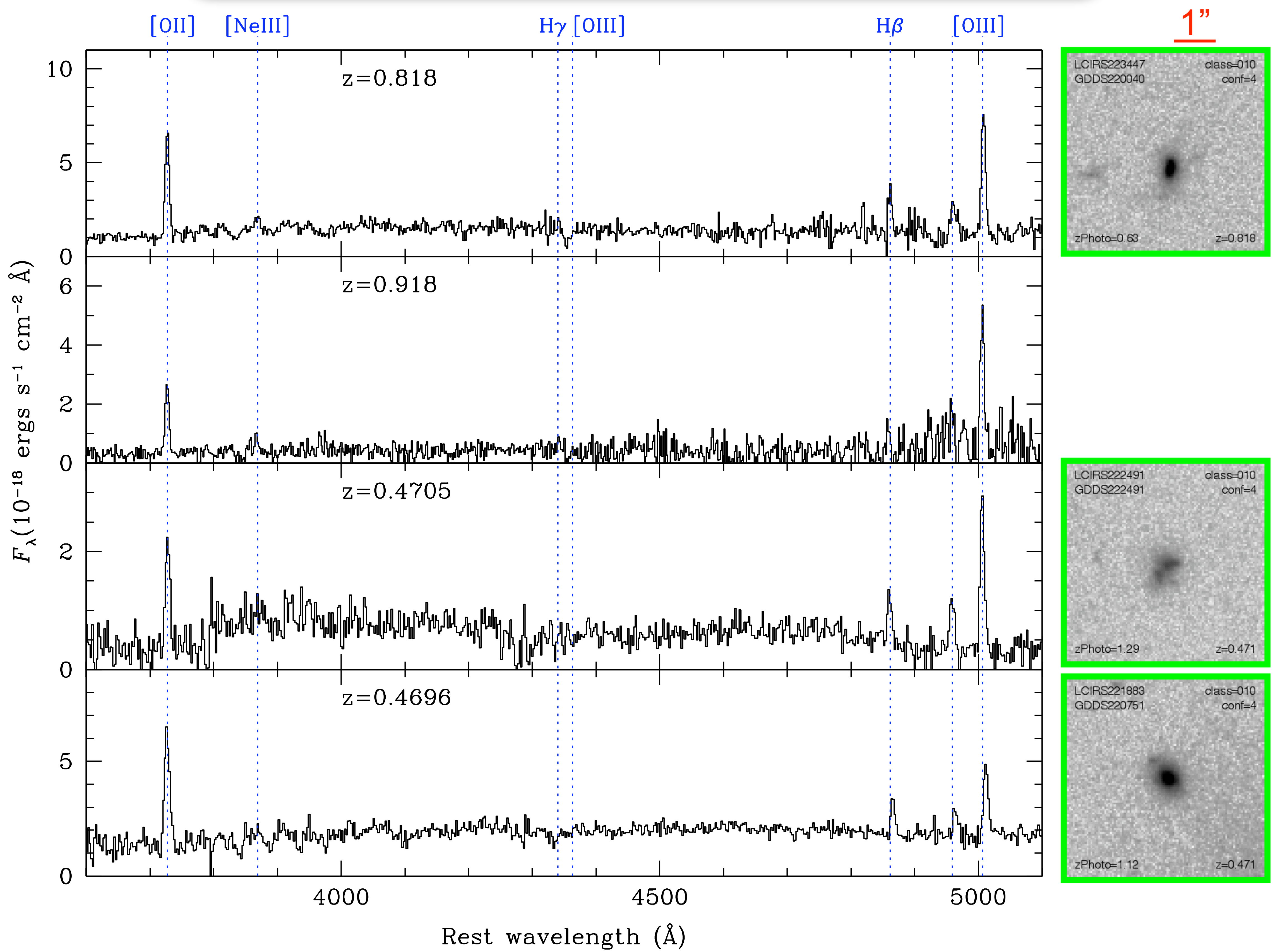
ISM in starforming galaxies



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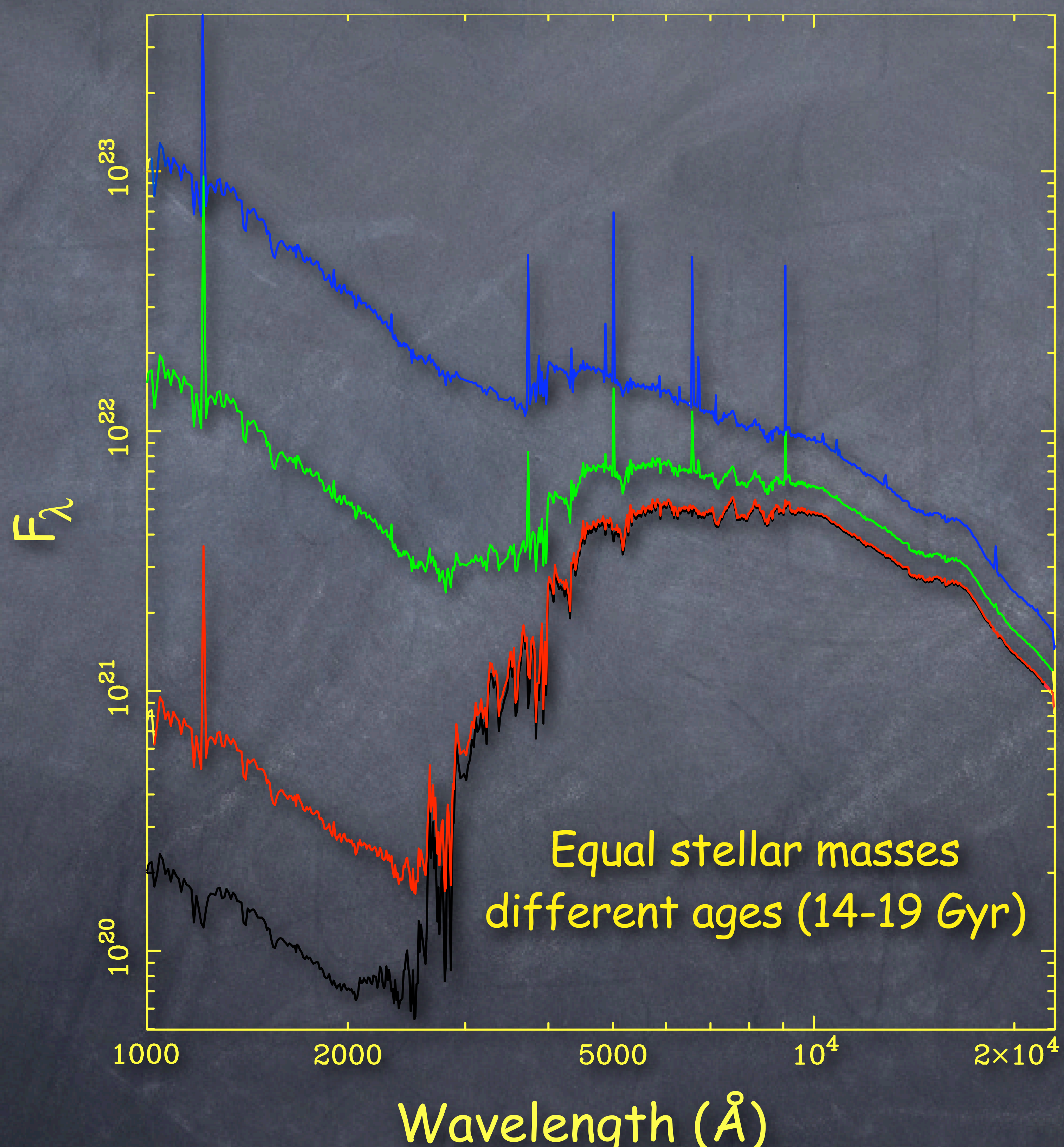
Total stellar mass for 56 galaxies $\langle z \rangle = 0.7$

$$M_\star = 10^{8.1} - 10^{10.8}\ M_\odot$$

Stellar masses from SEDs



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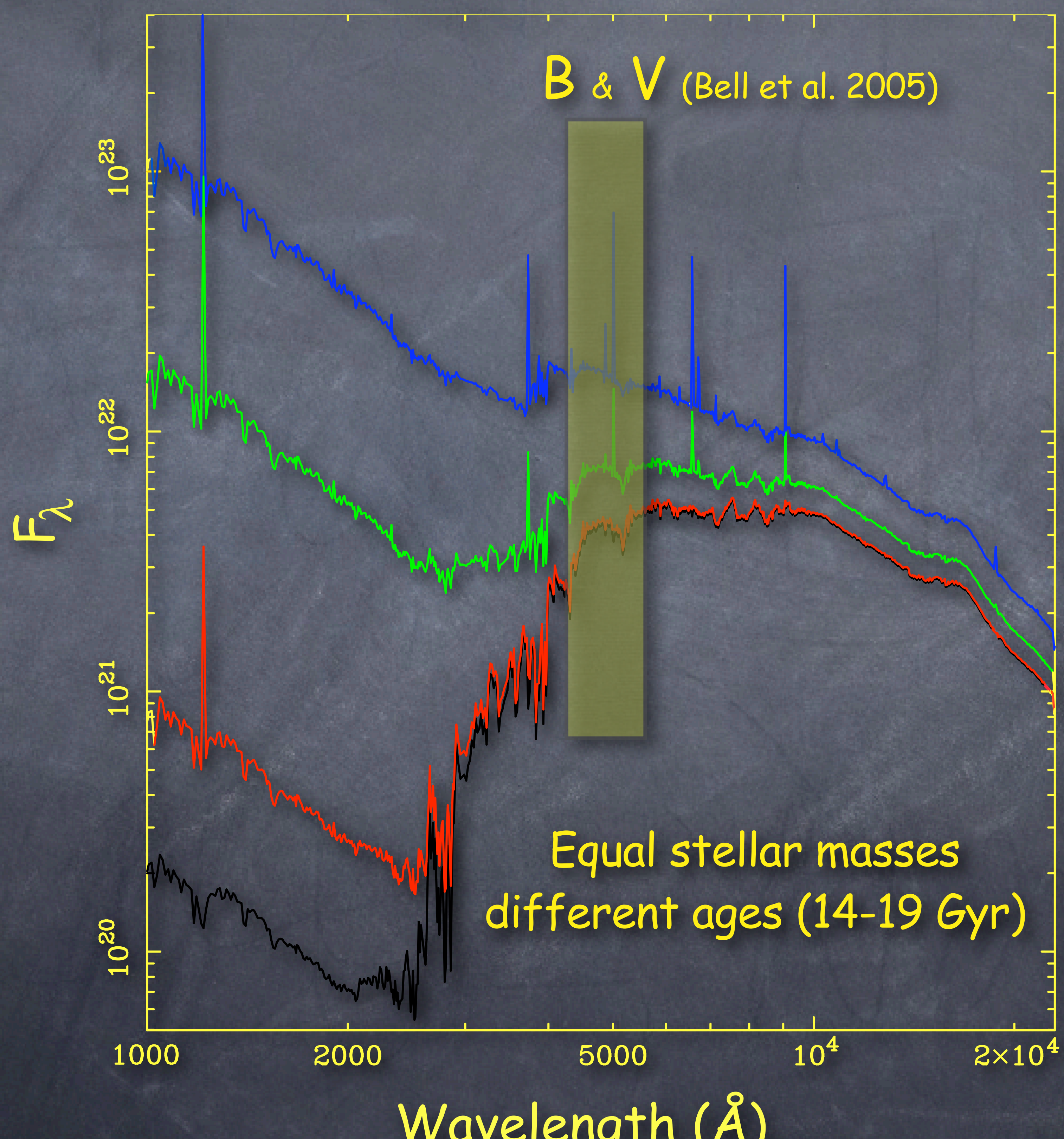
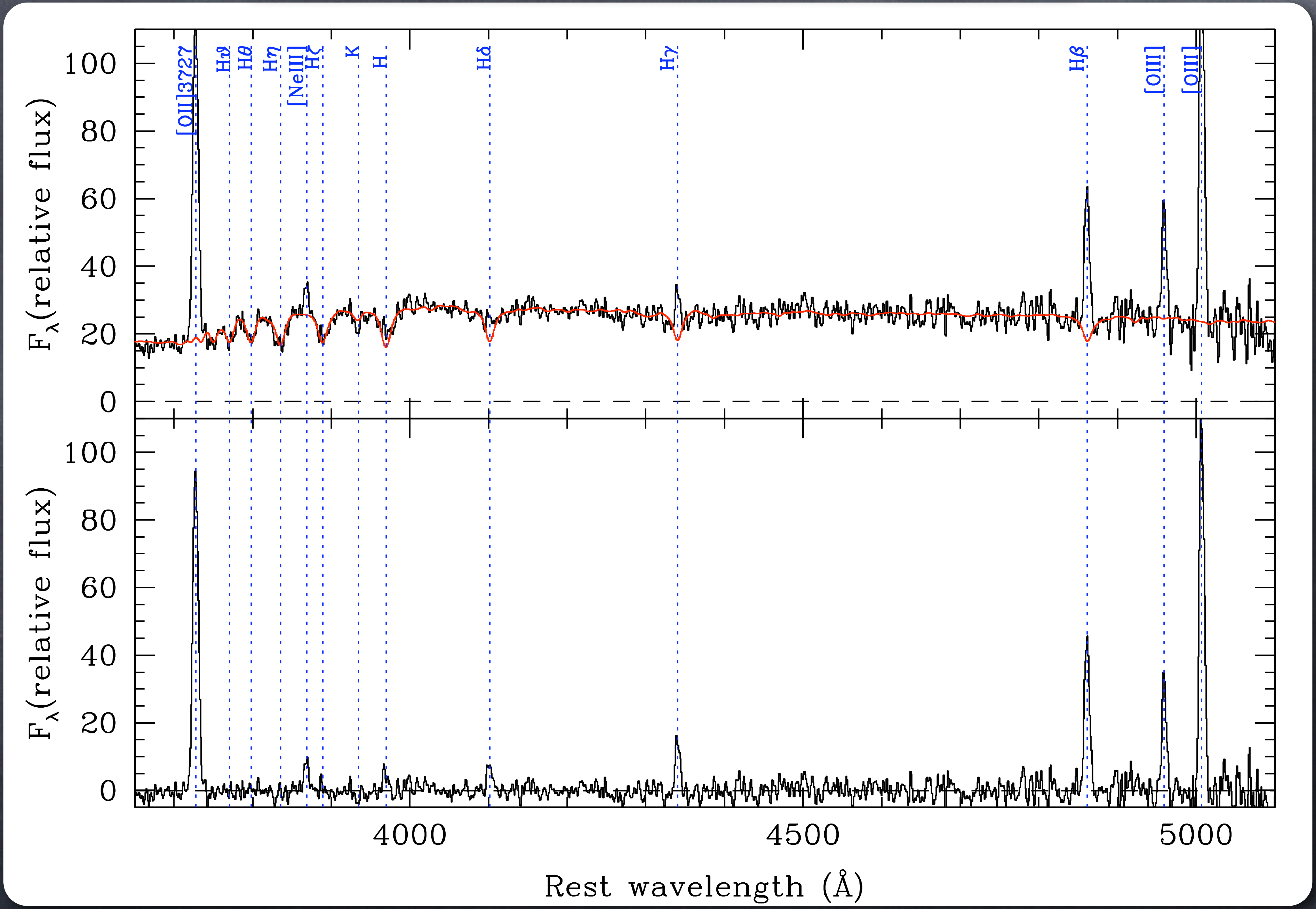


GDDS composite spectrum



Savaglio, Glazebrook, Le Borgne et al. (2005)

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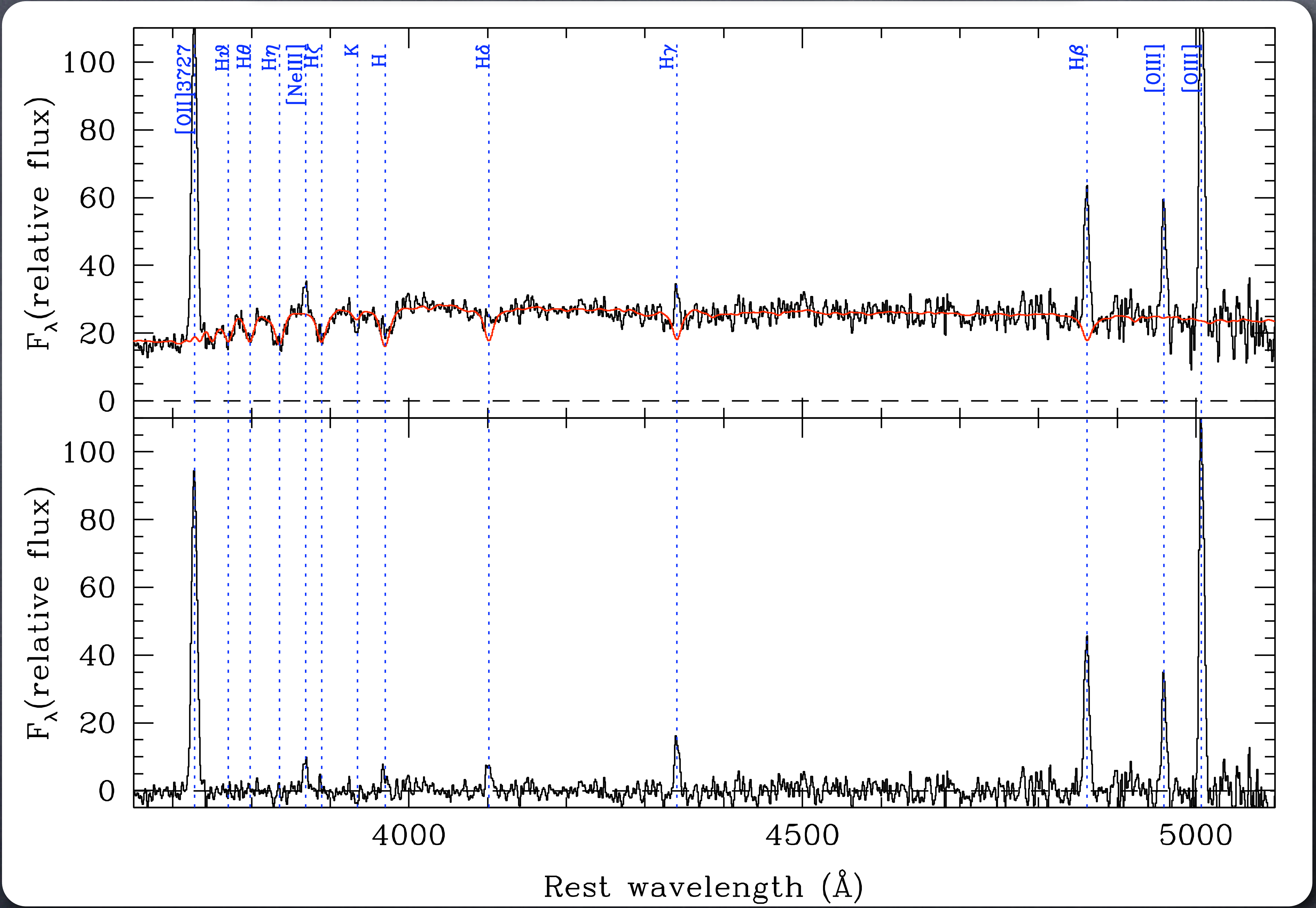
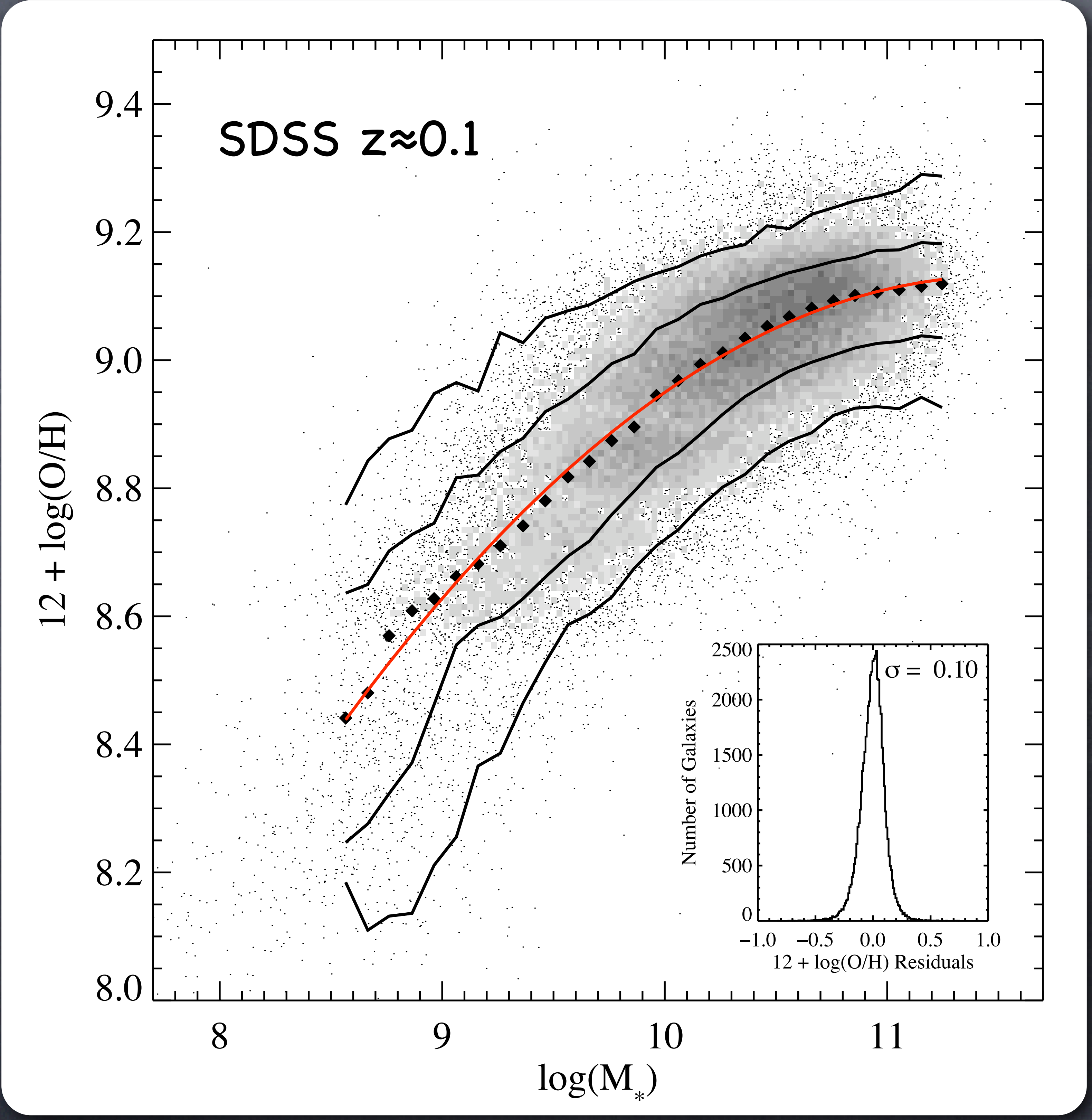


➤ Mean optical extinction $A_V = 2.20 \pm 0.34$

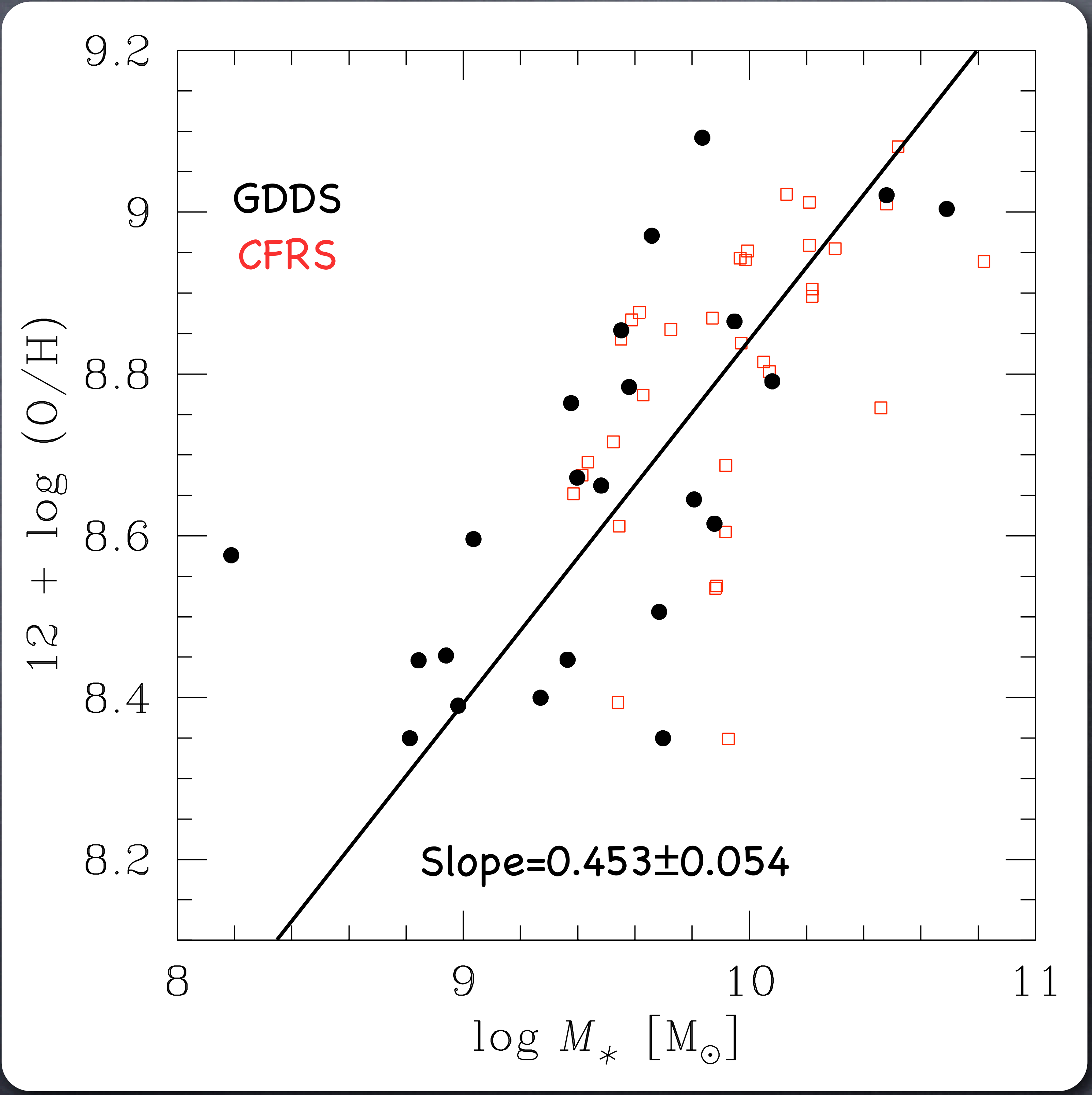
Savaglio, Glazebrook, Le Borgne et al. (2005)

Mass-metallicity relation



Tremonti et al. (2004)

Mass-metallicity relation at z ~ 0.7



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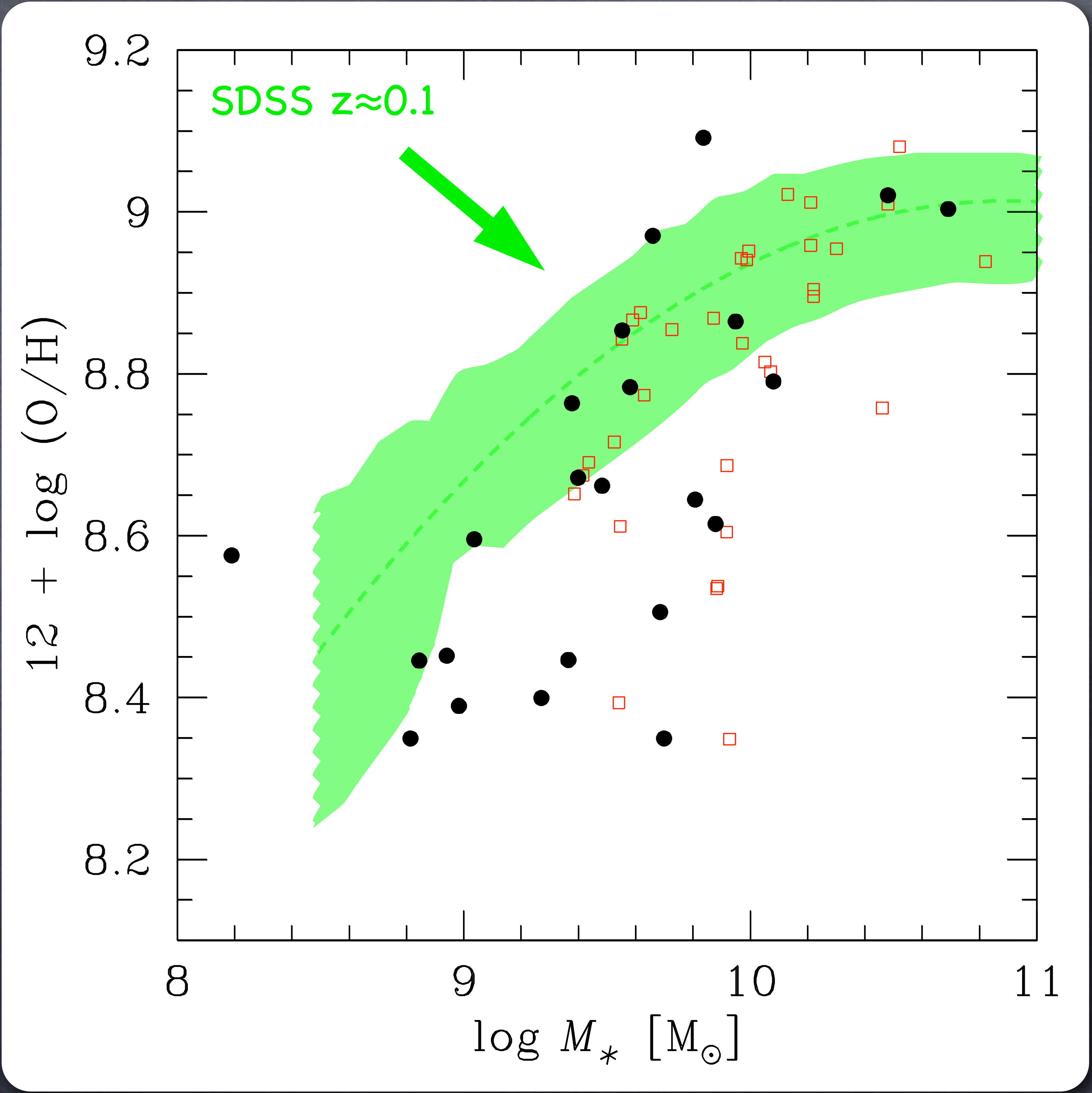

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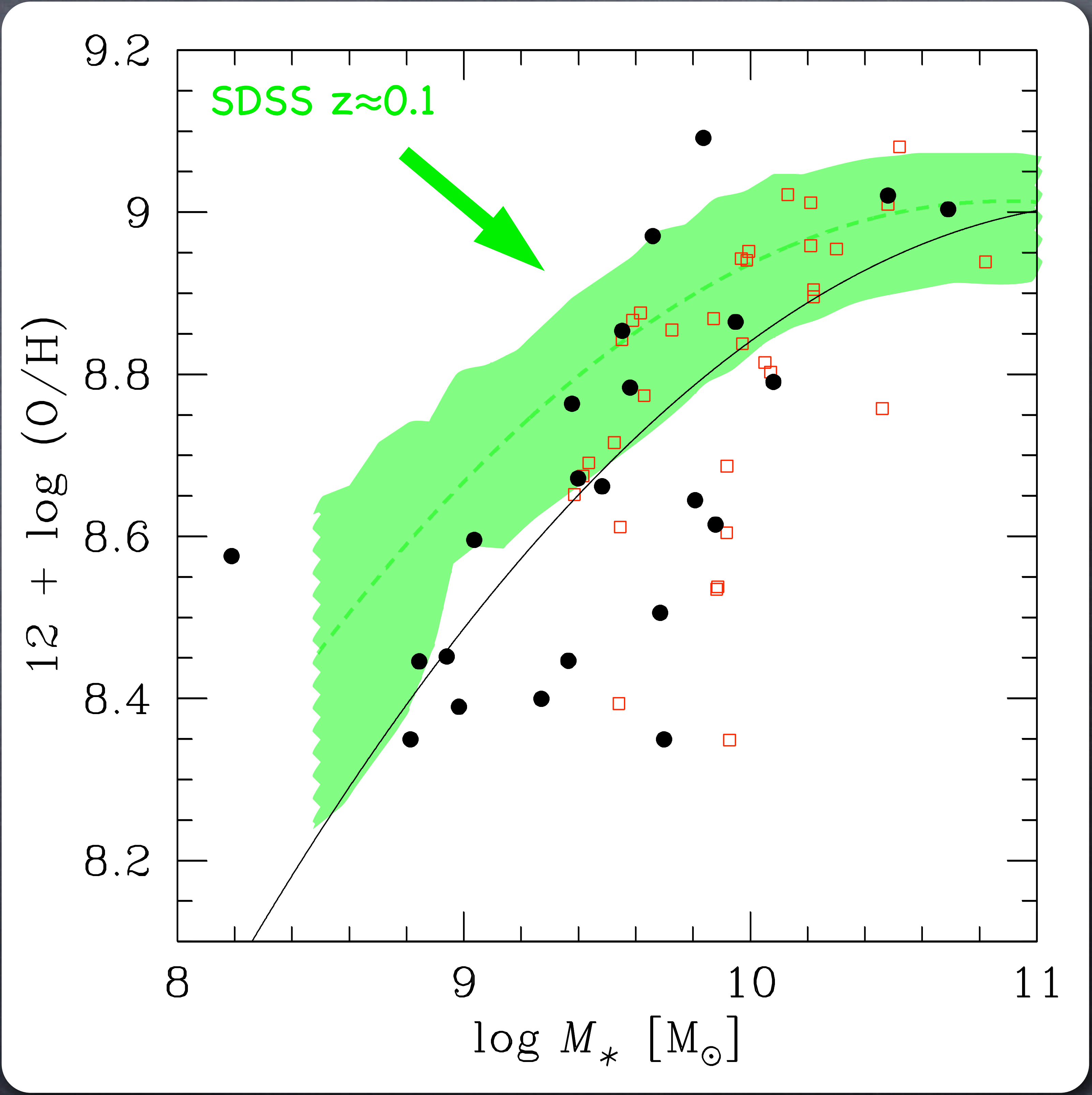

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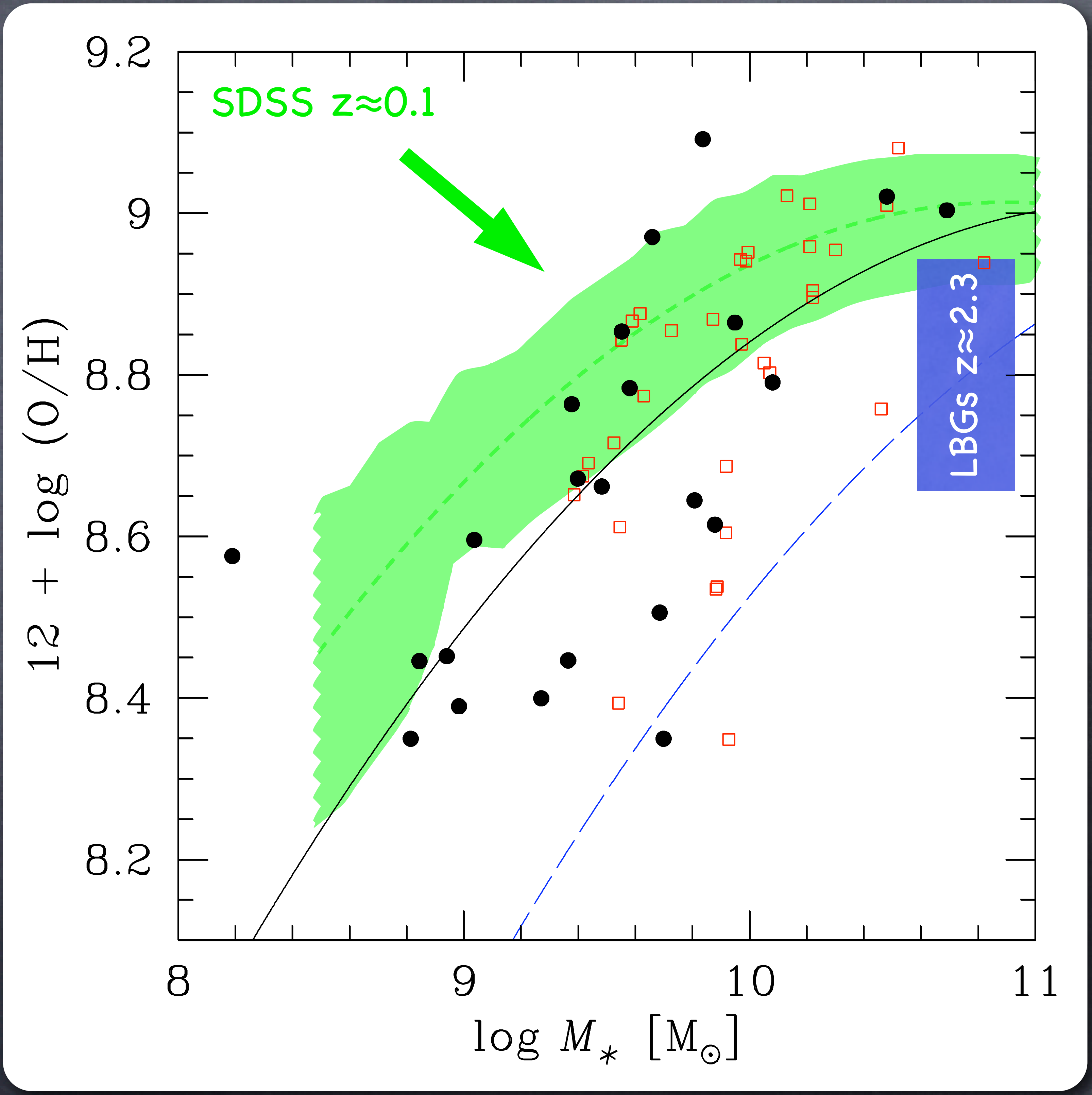

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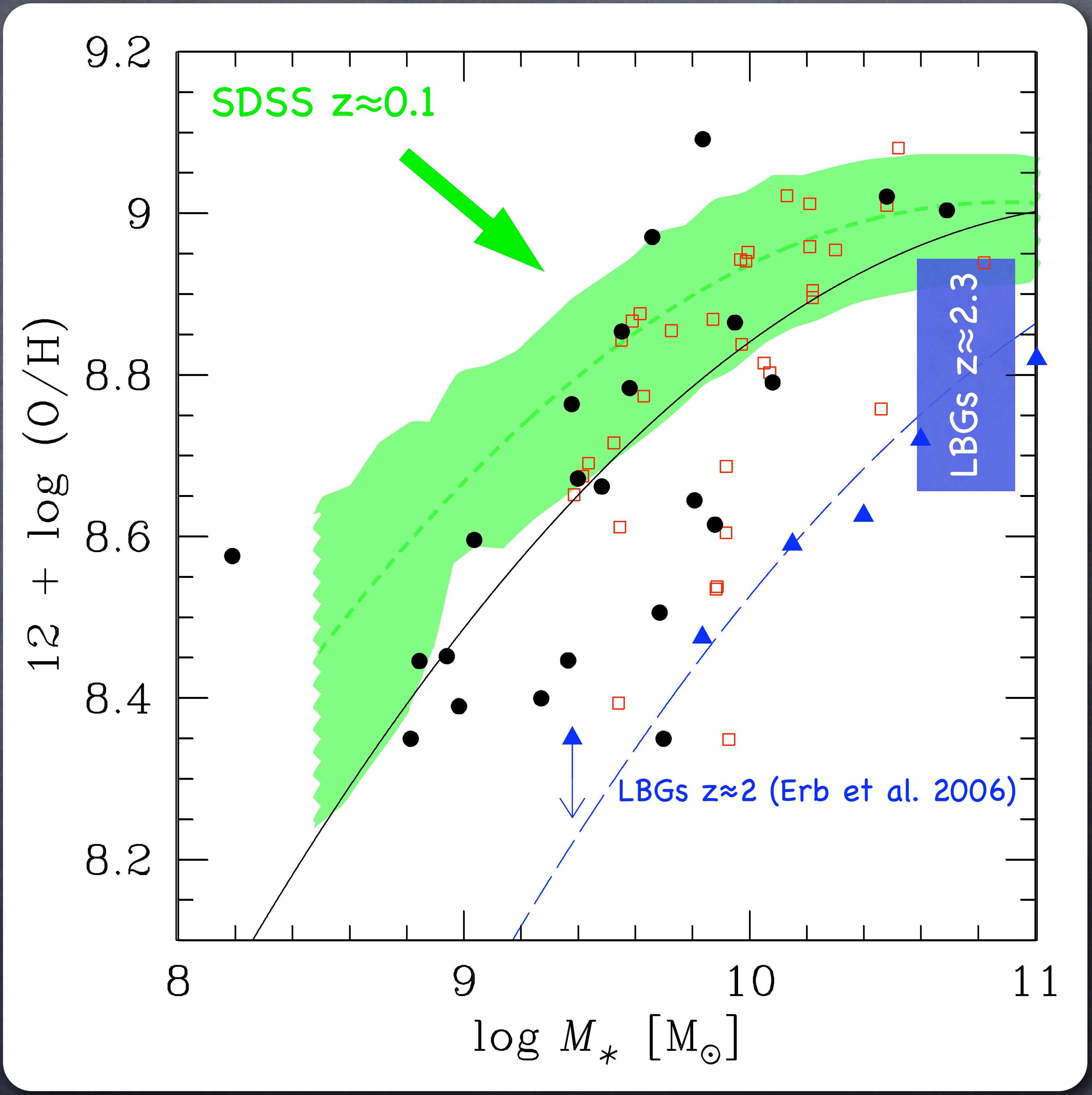
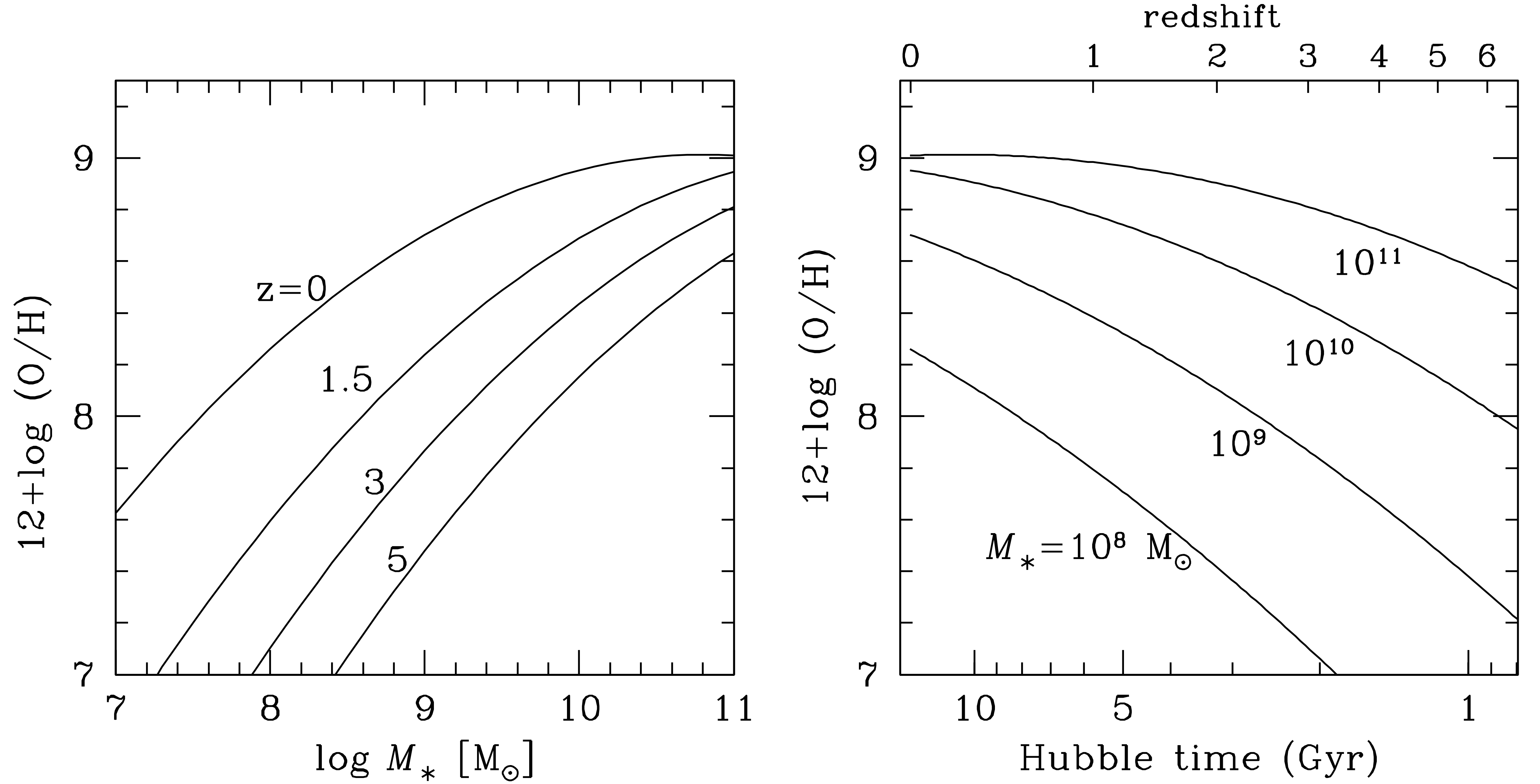


Savaglio et al. (2005)

Redshift evolution of mass-metallicity relation



$$12+\log\,(O/H) = -7.58+2.53\log M_* - 0.096\log^2 M_* + $$

$$+5.20\log t_H - 0.41\log^2 t_H - 0.40\log t_H \log M_*$$

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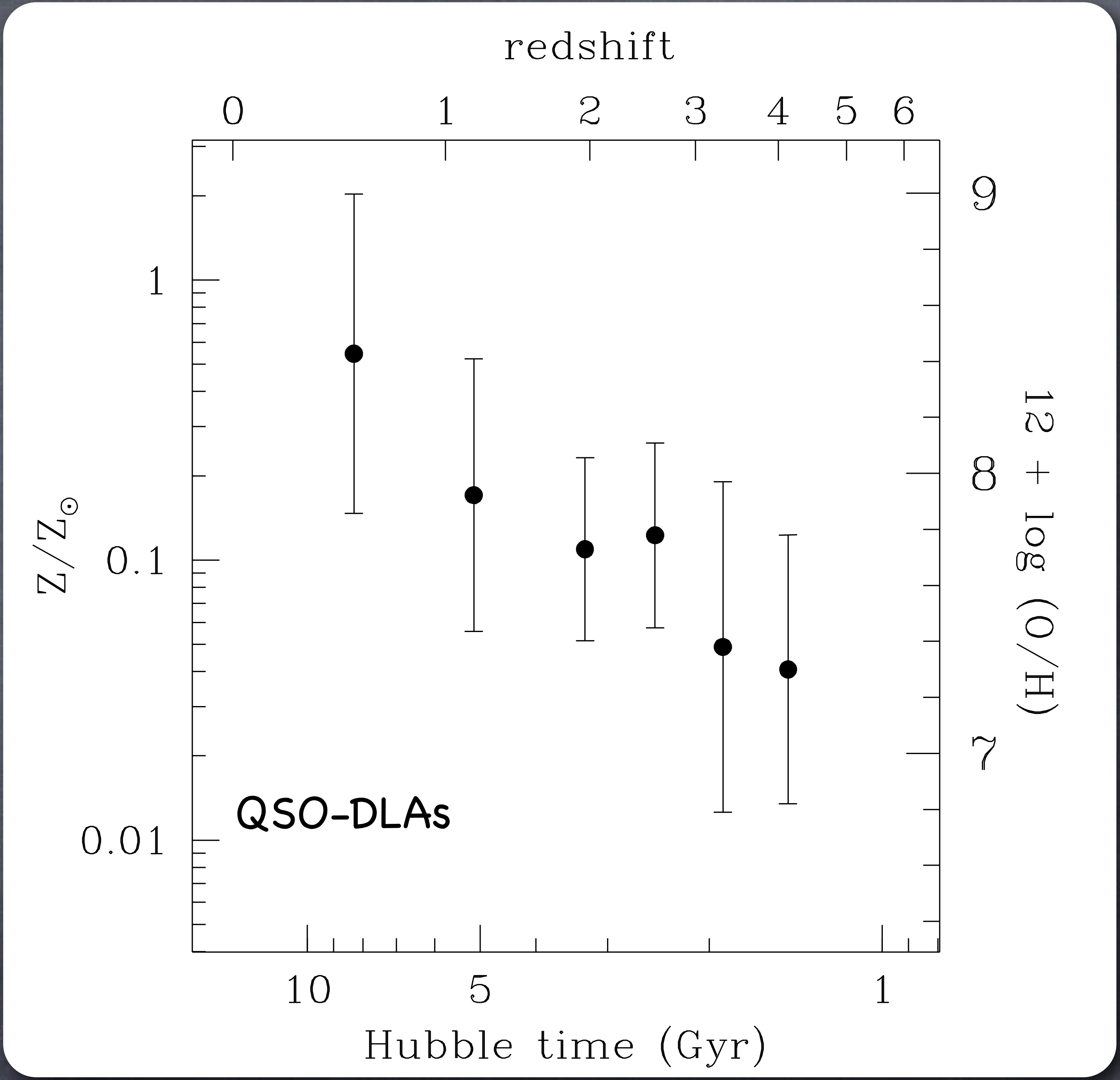

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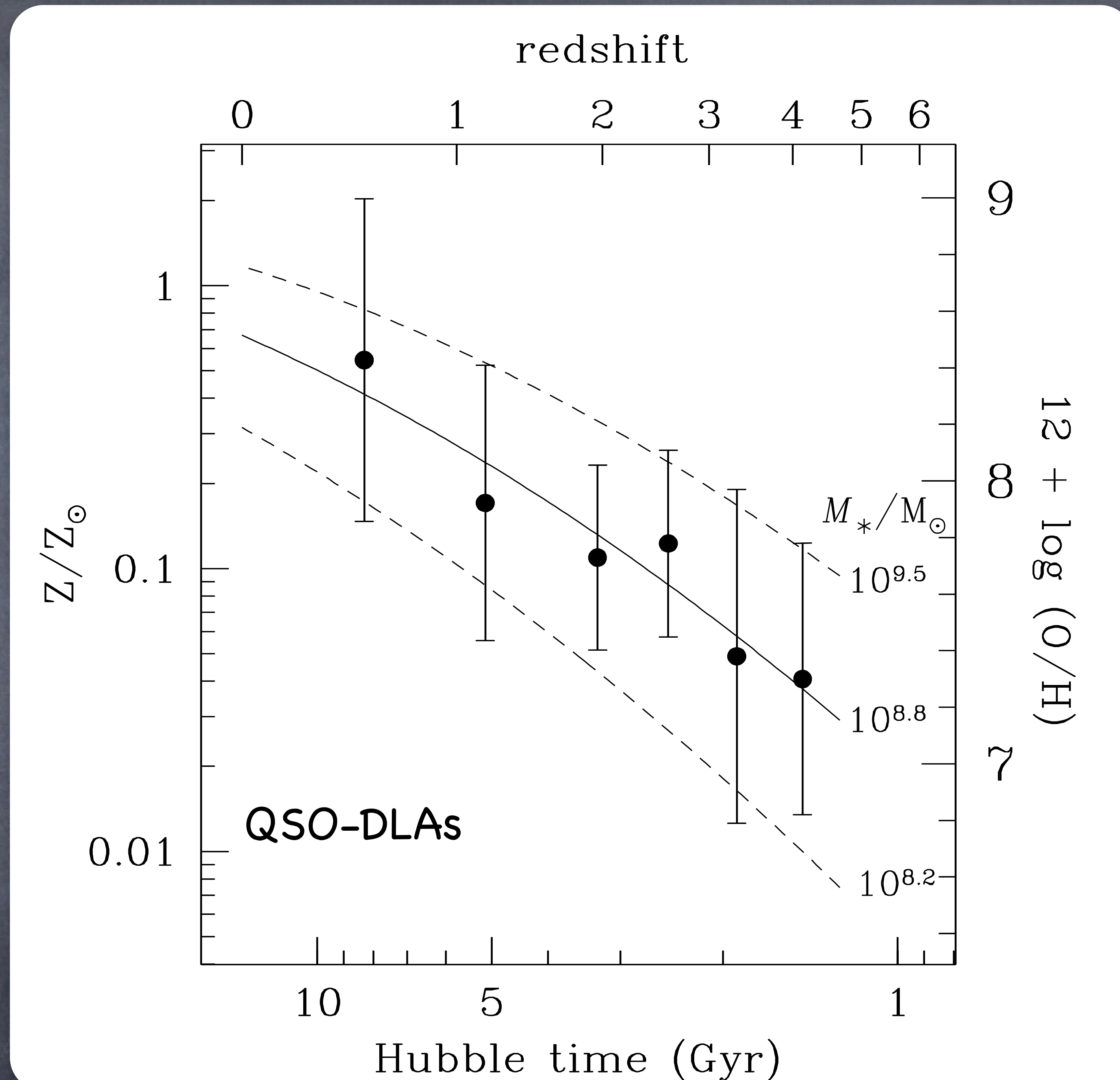

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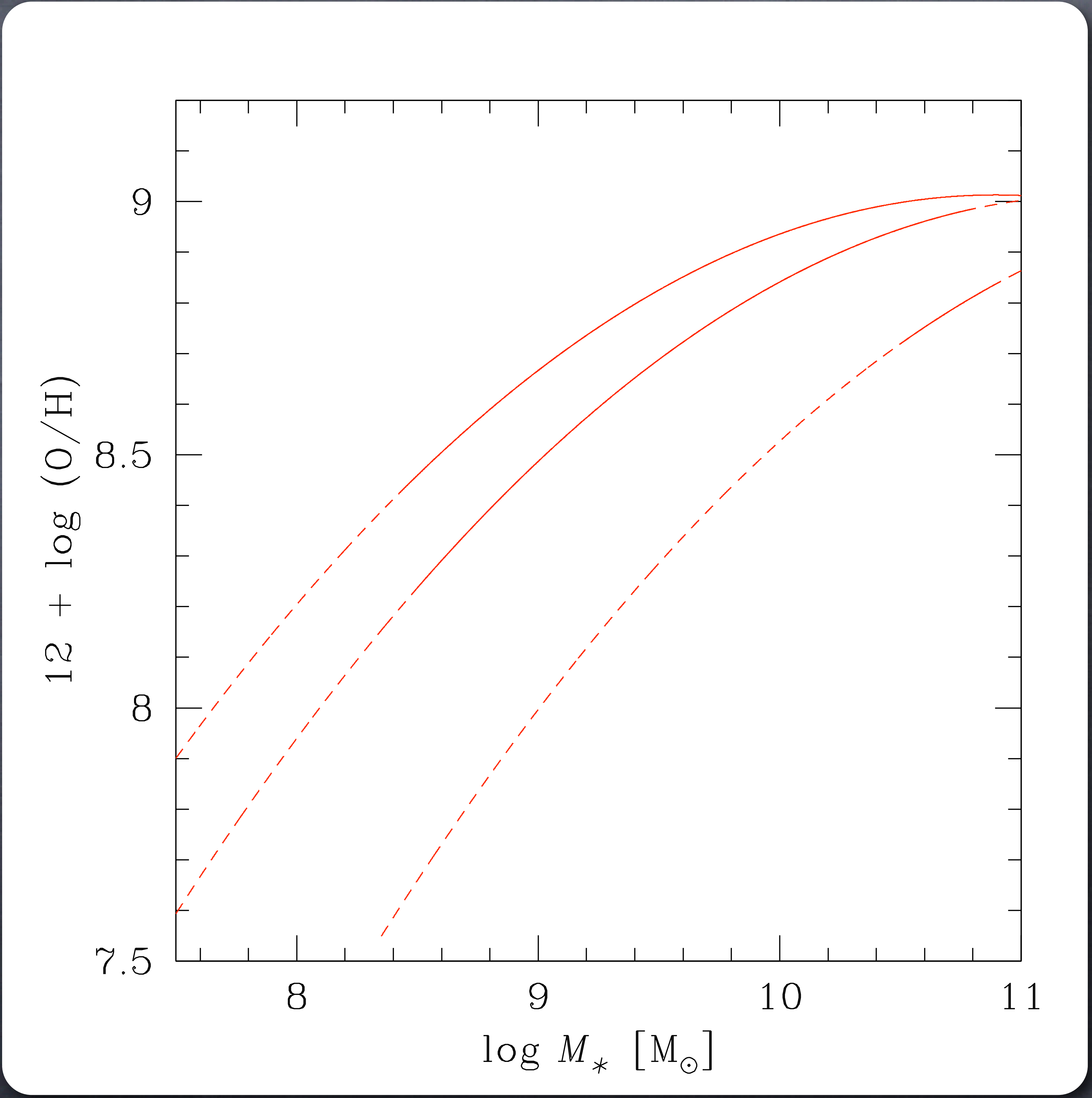

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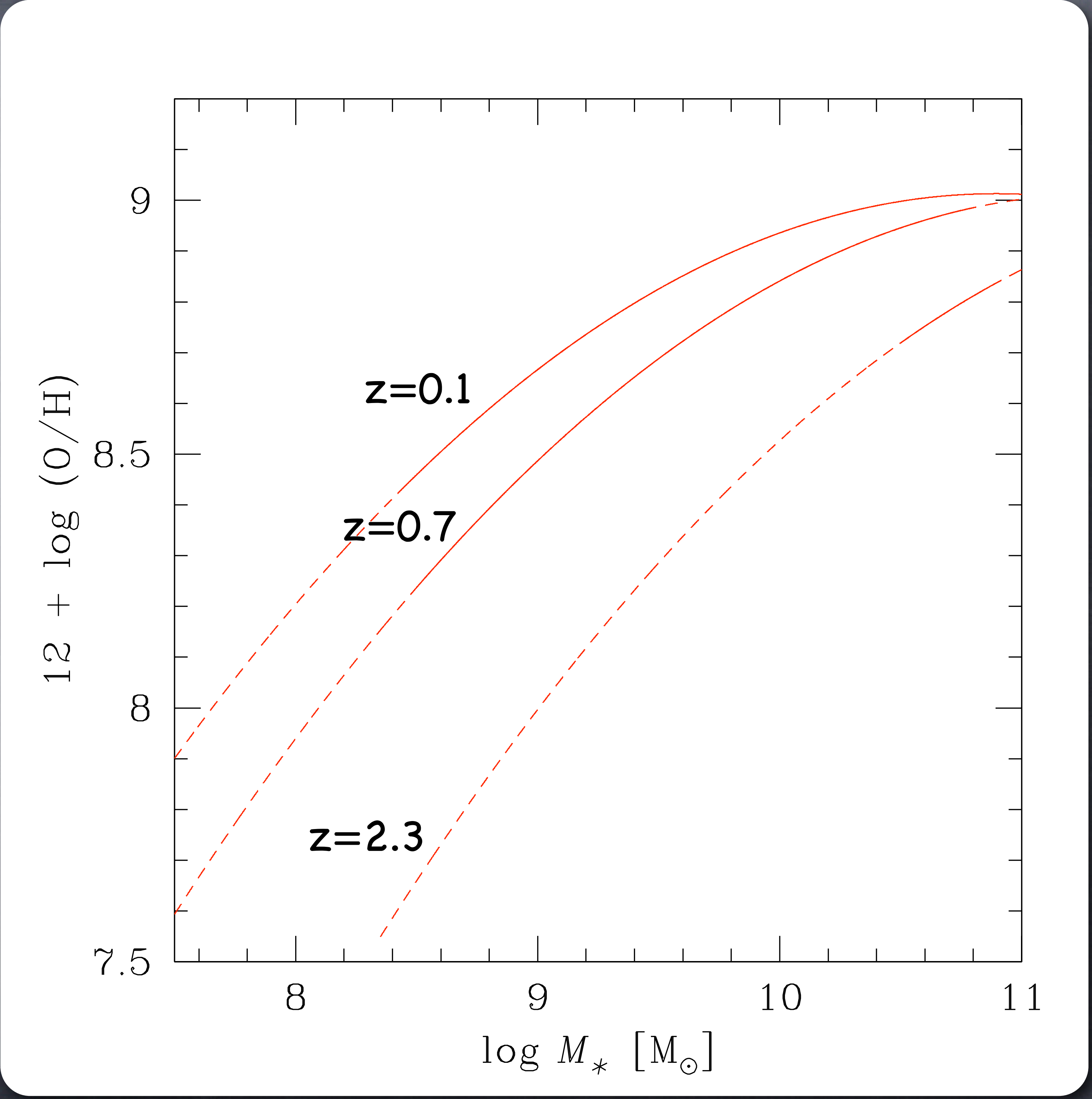

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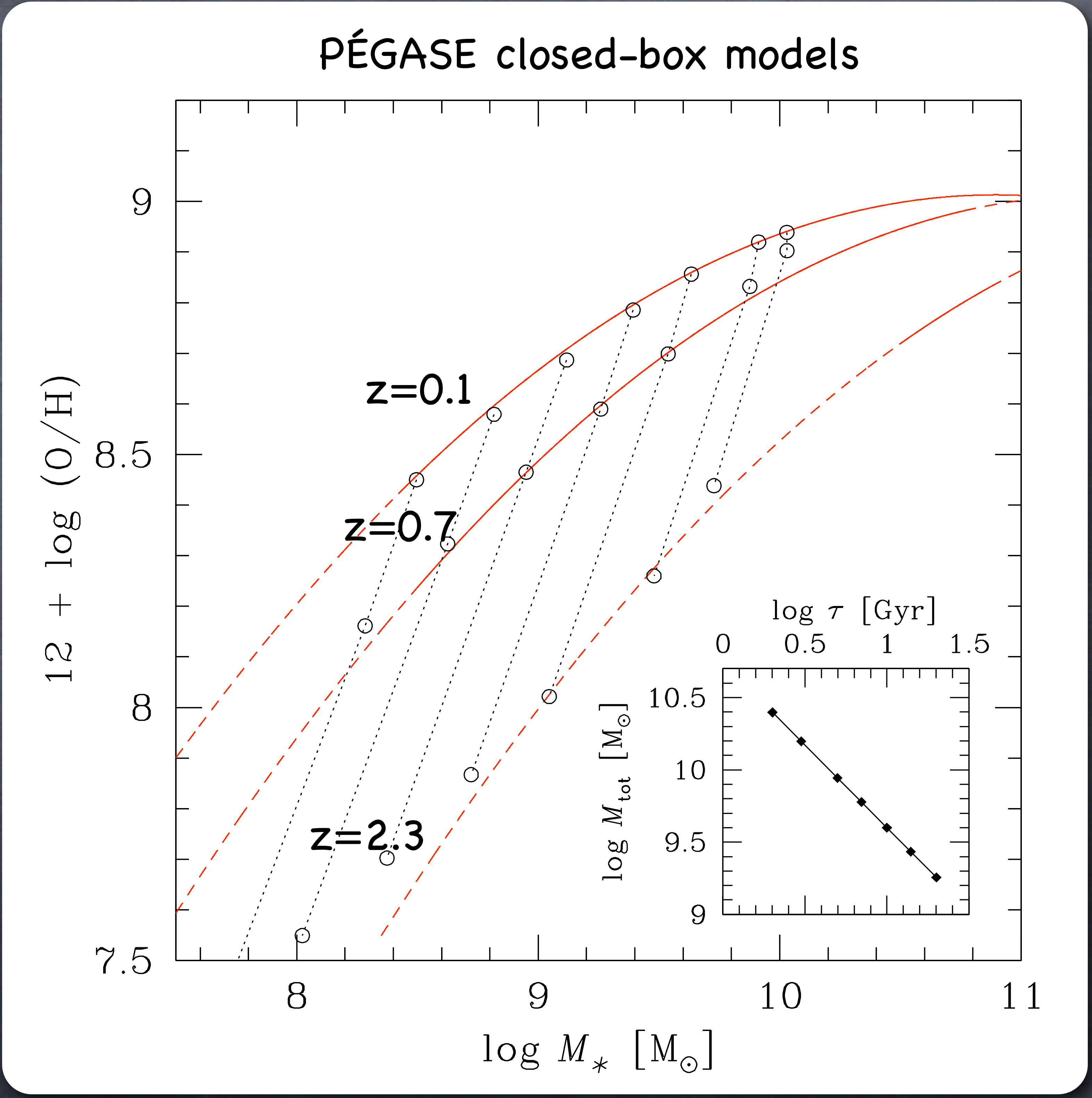
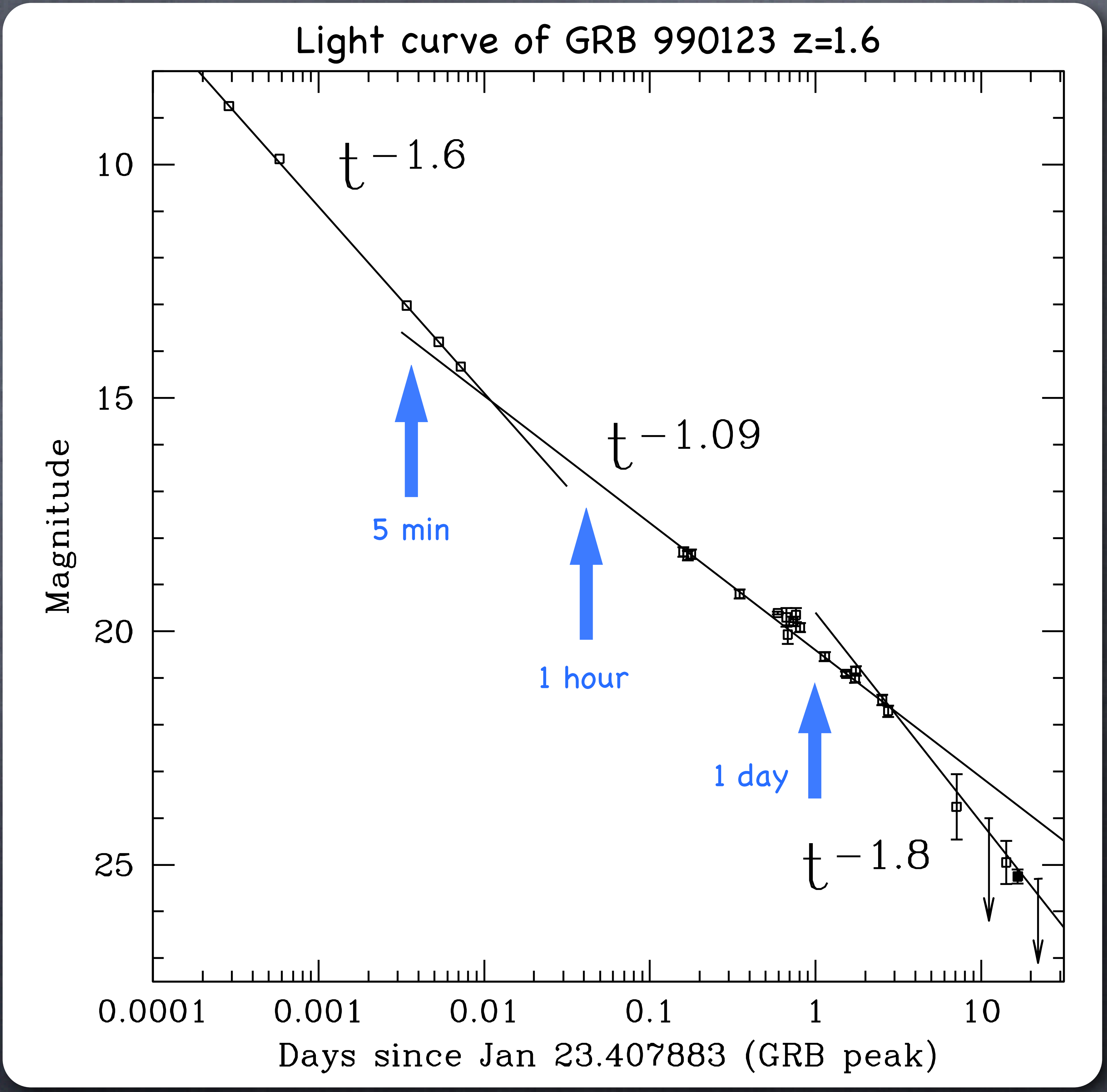


GRB afterglows to study the high-z ISM



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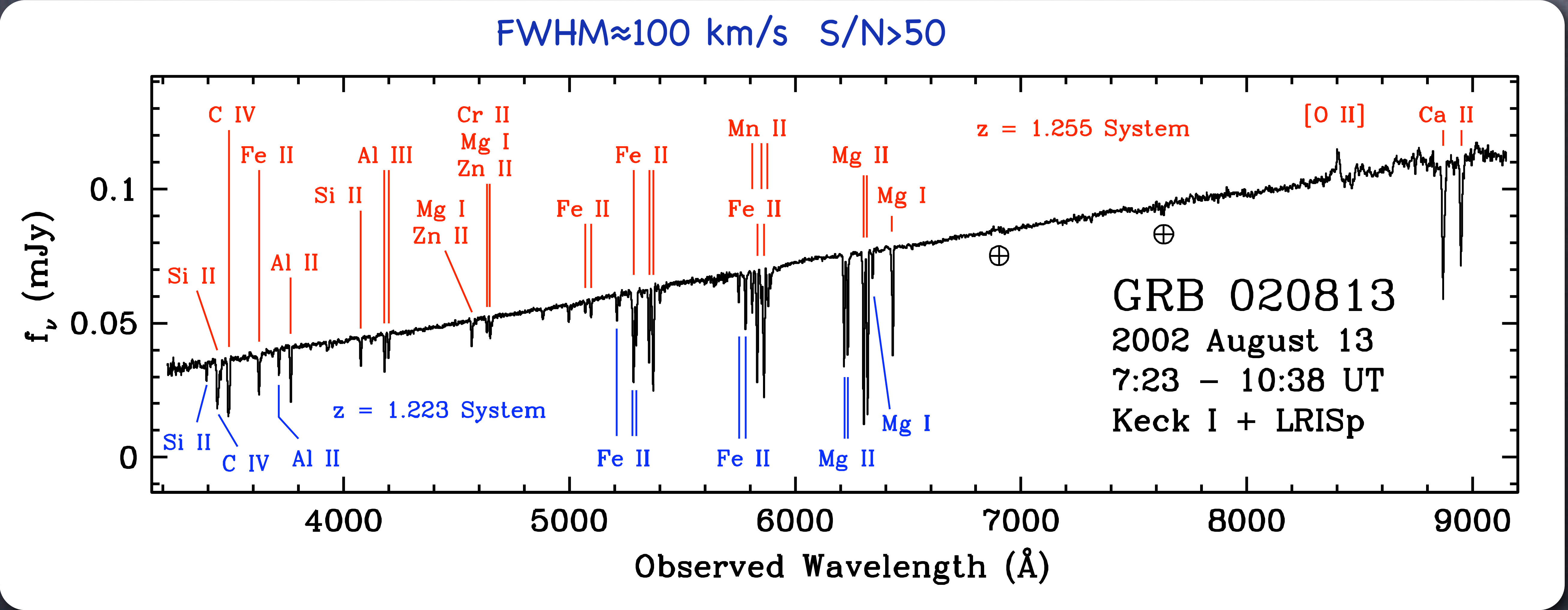

GRB 020813 z=1.255 (Barth et al. 2003)

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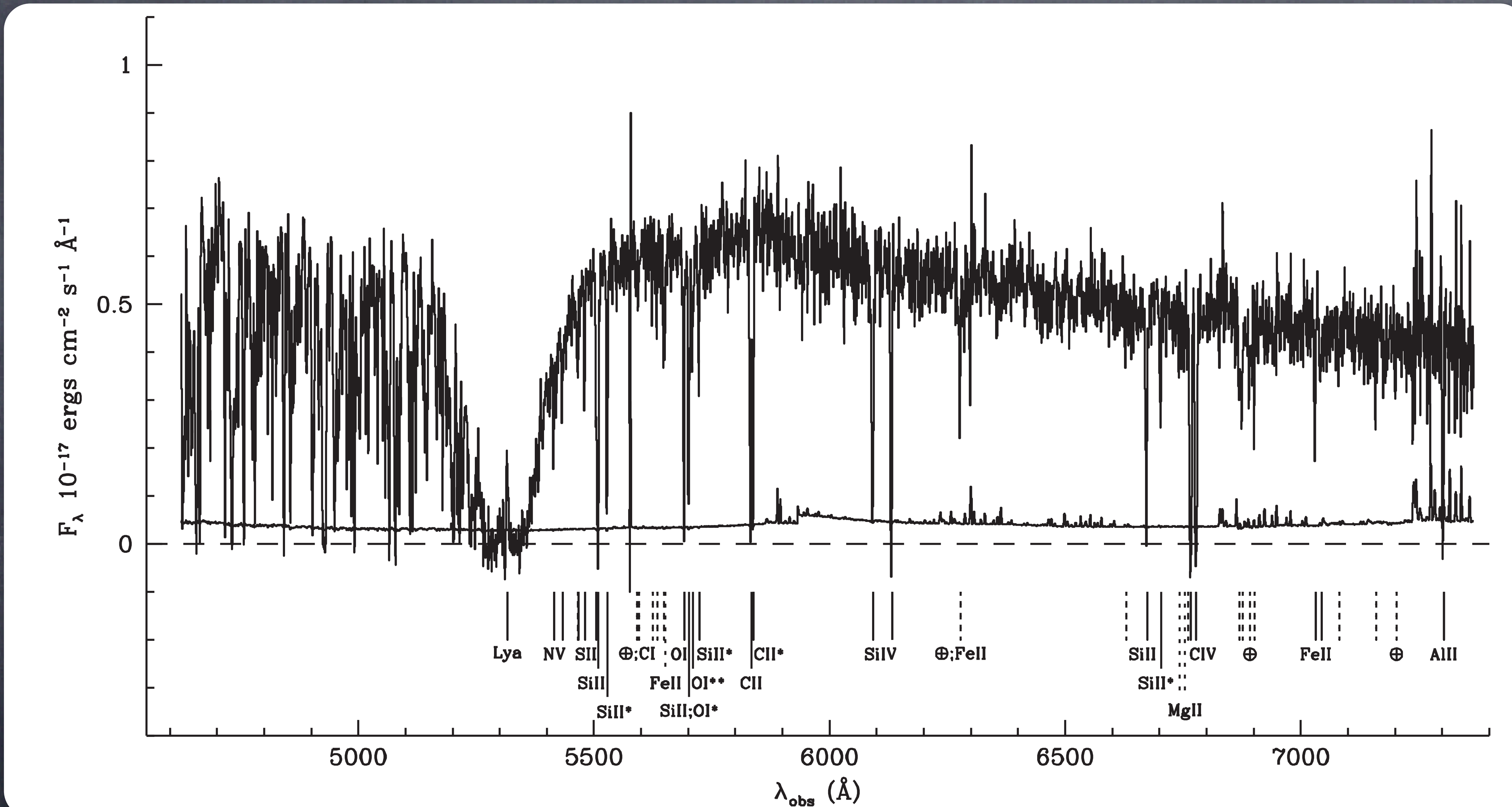

GRB 030323 z=3.372 :(Vreeswijk et al. 2004)

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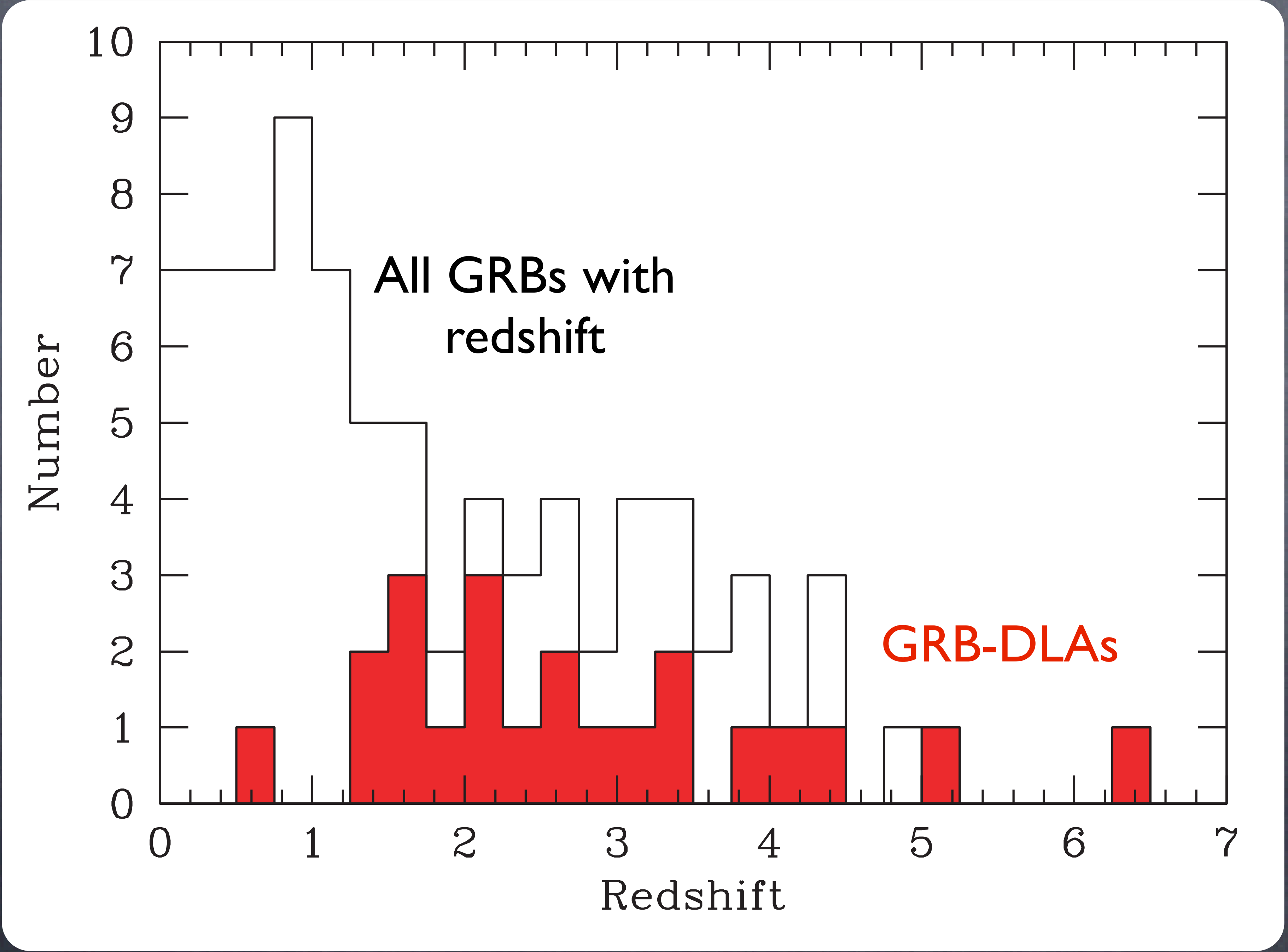

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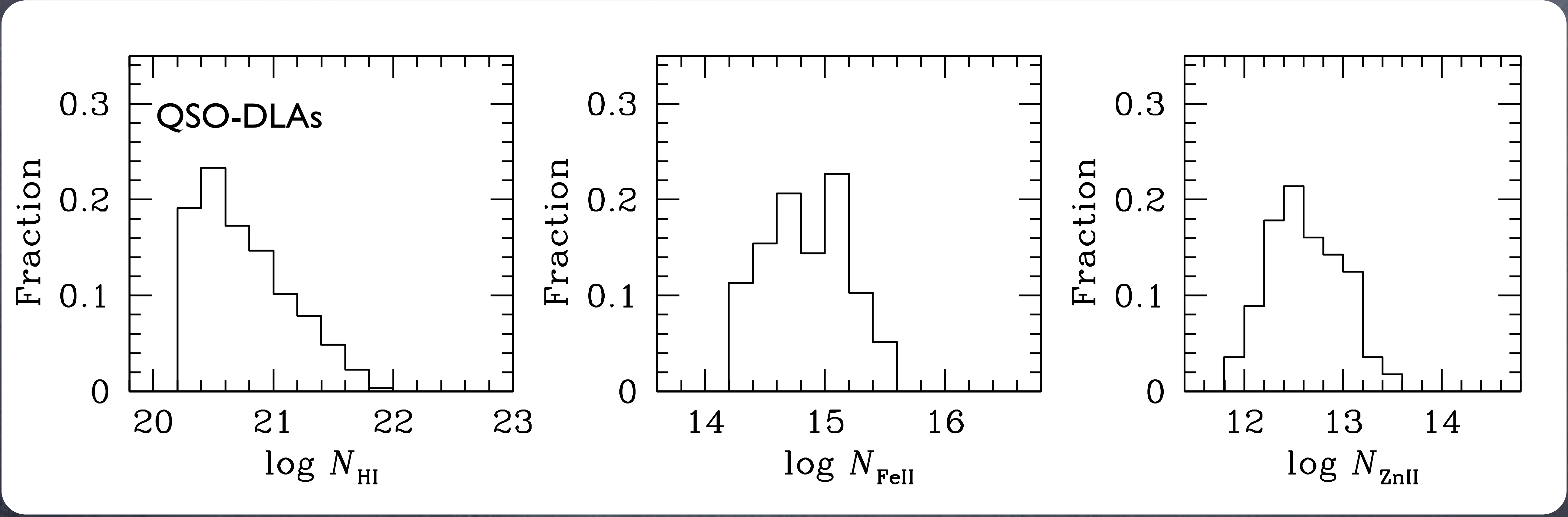

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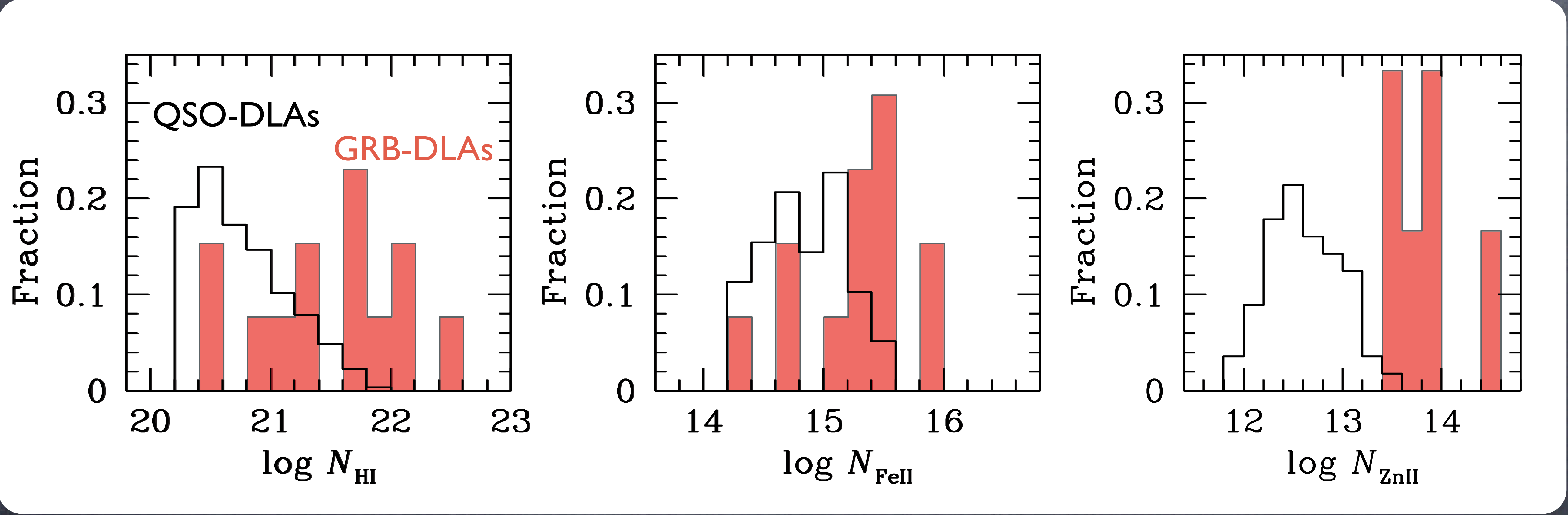
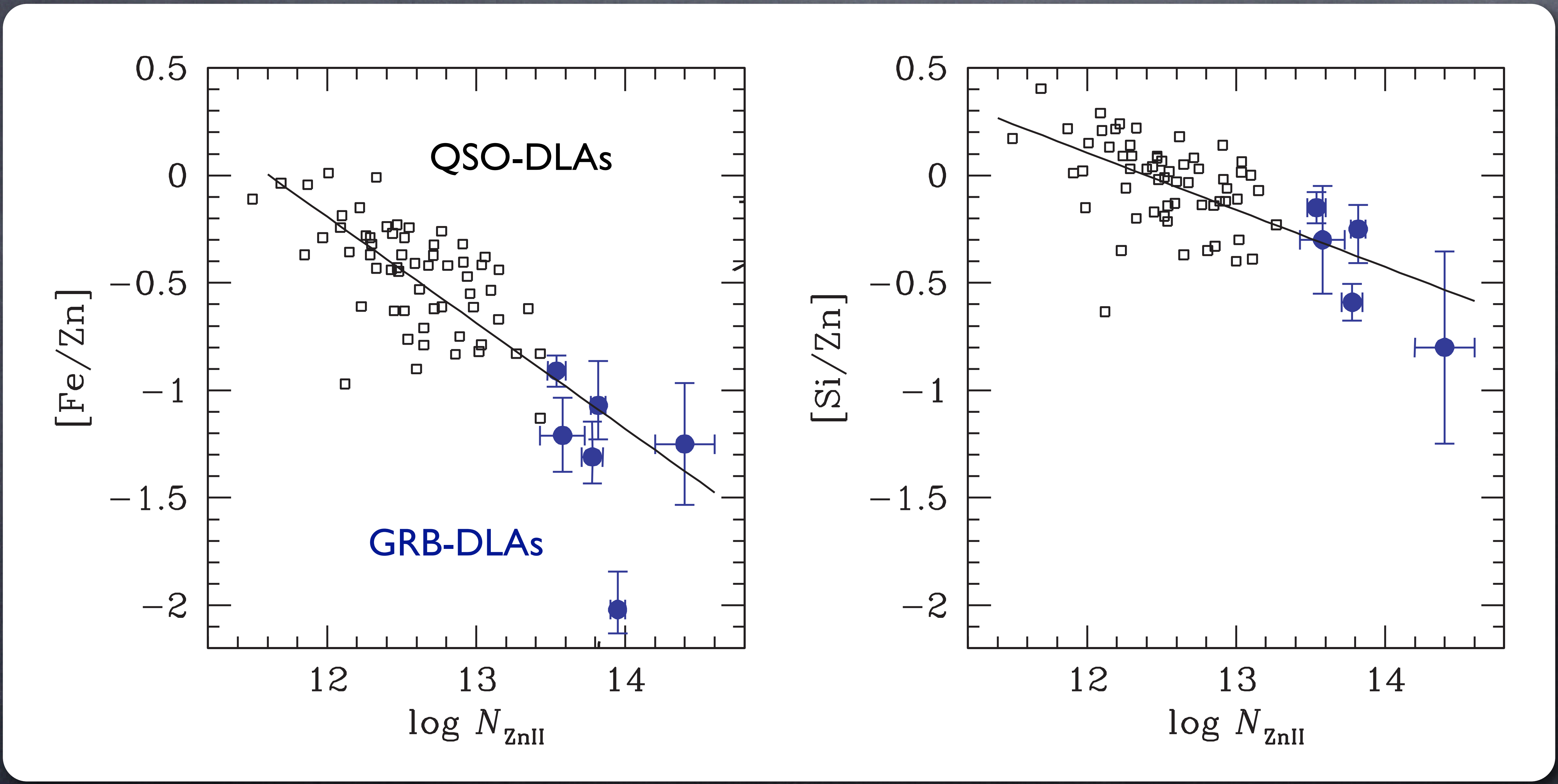


Dust depletion in GRB-DLAs



Savaglio, Fall & Fiore (2003)
Savaglio & Fall (2004)
Savaglio (2006)

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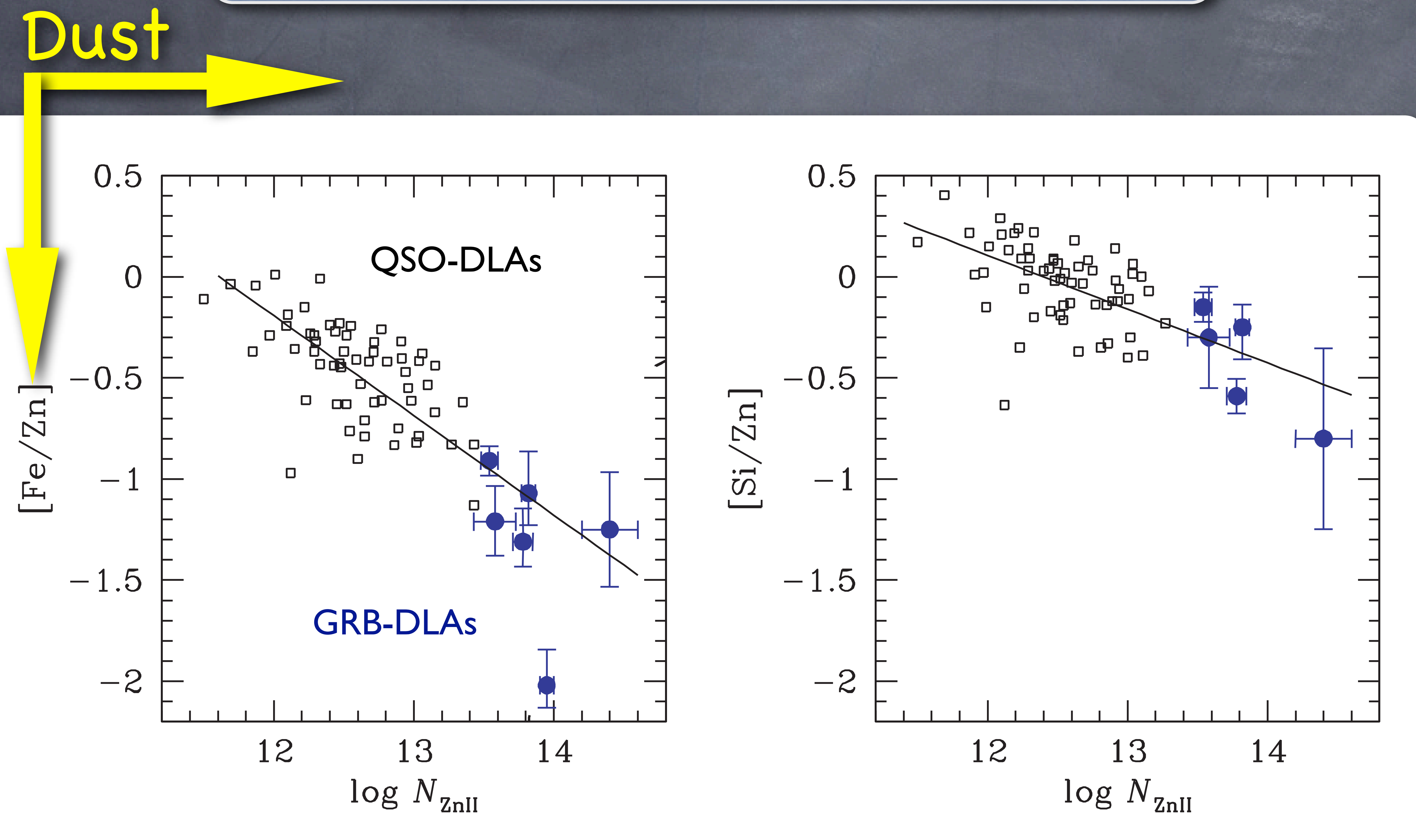

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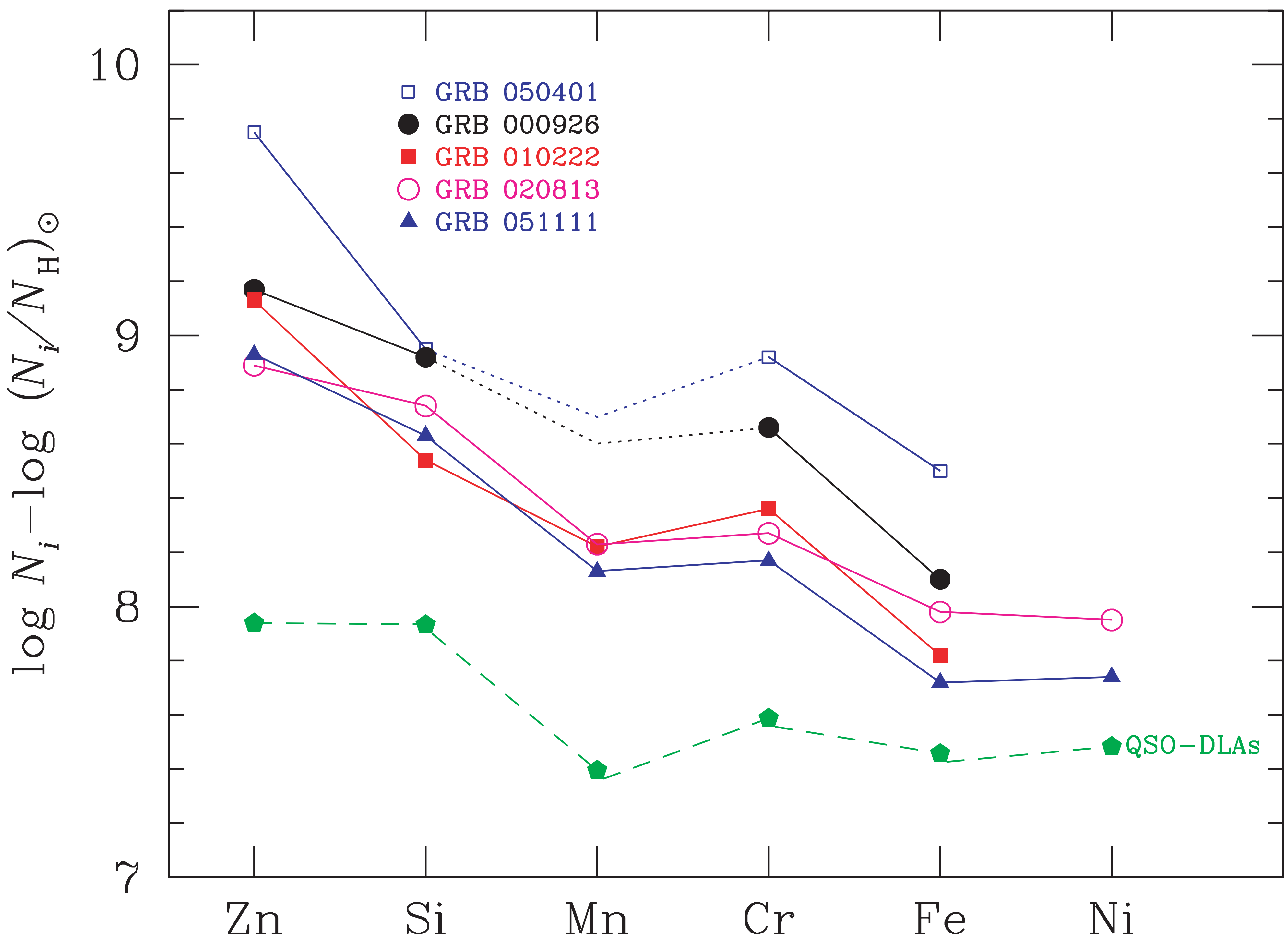

Savaglio (2006)

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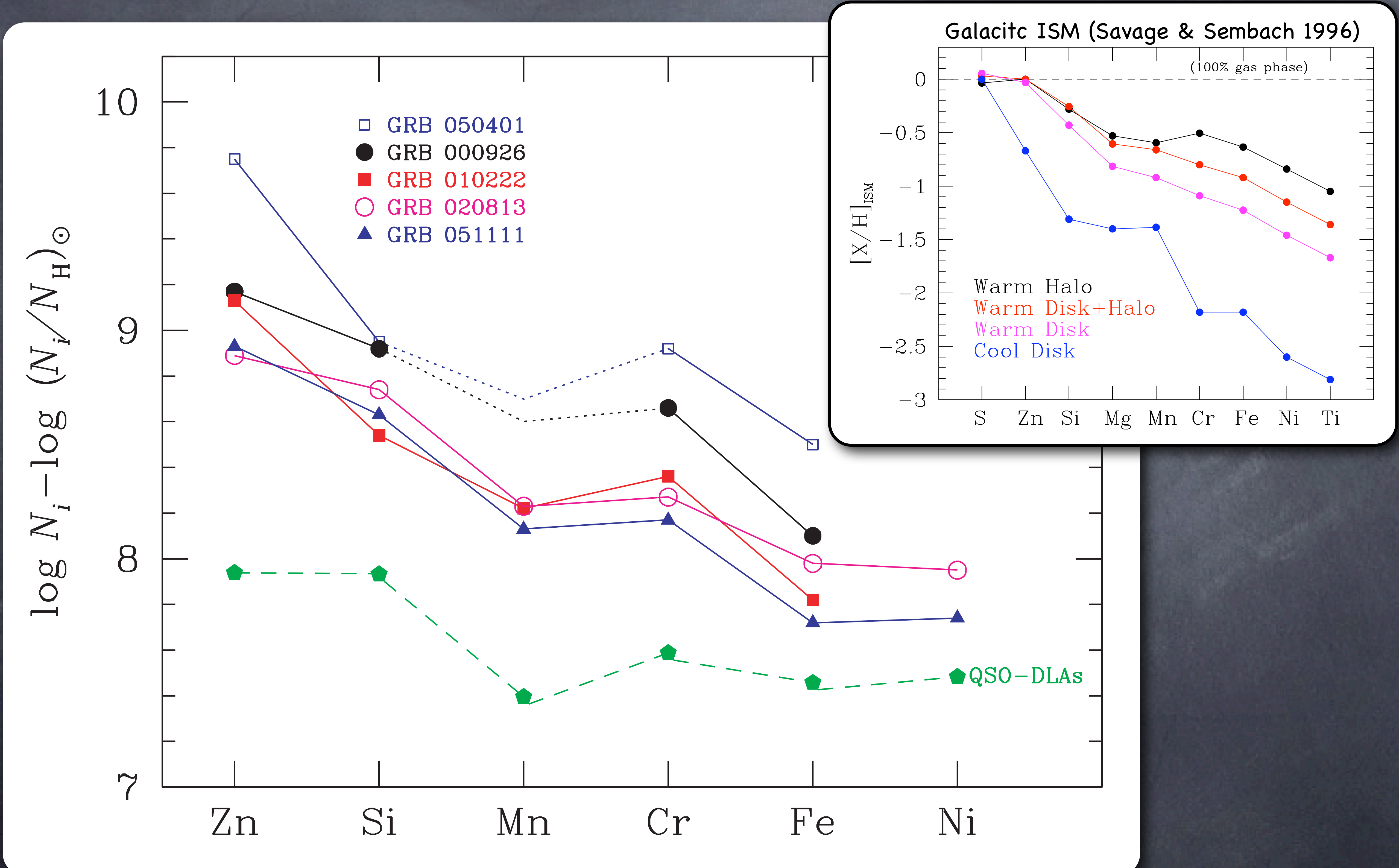
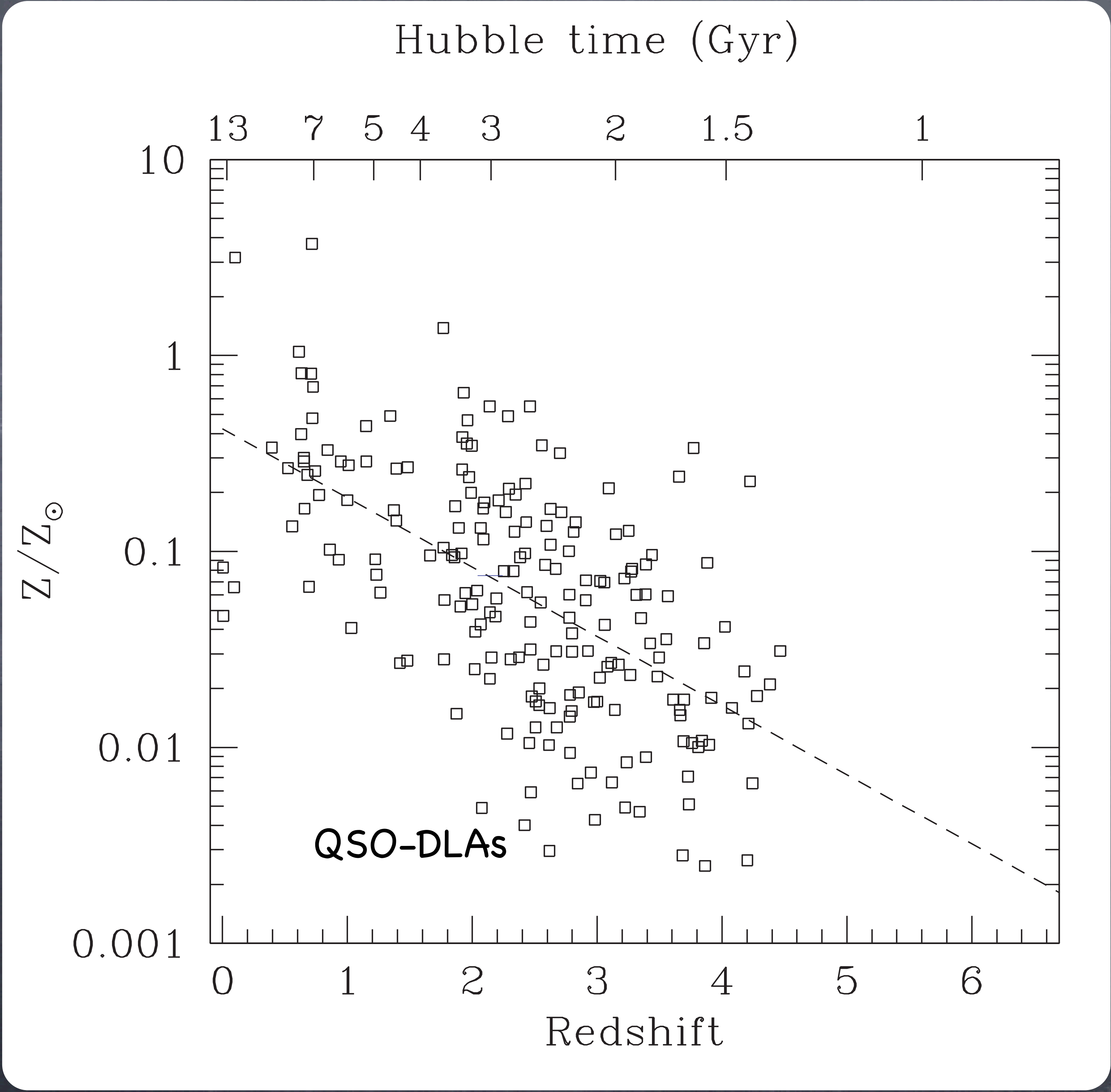


Savaglio (2006)

ISM metal enrichment in GRB-DLAs



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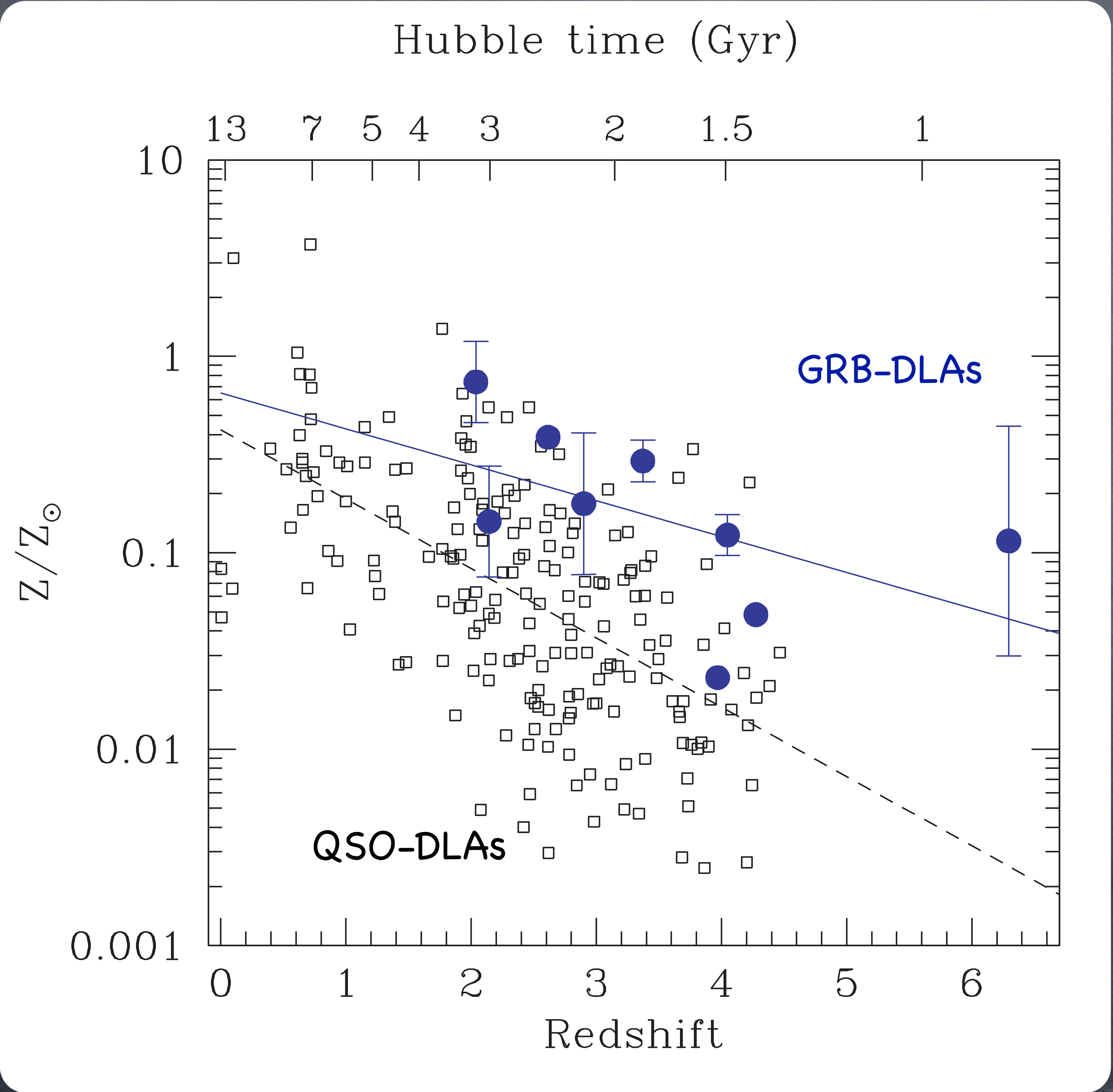

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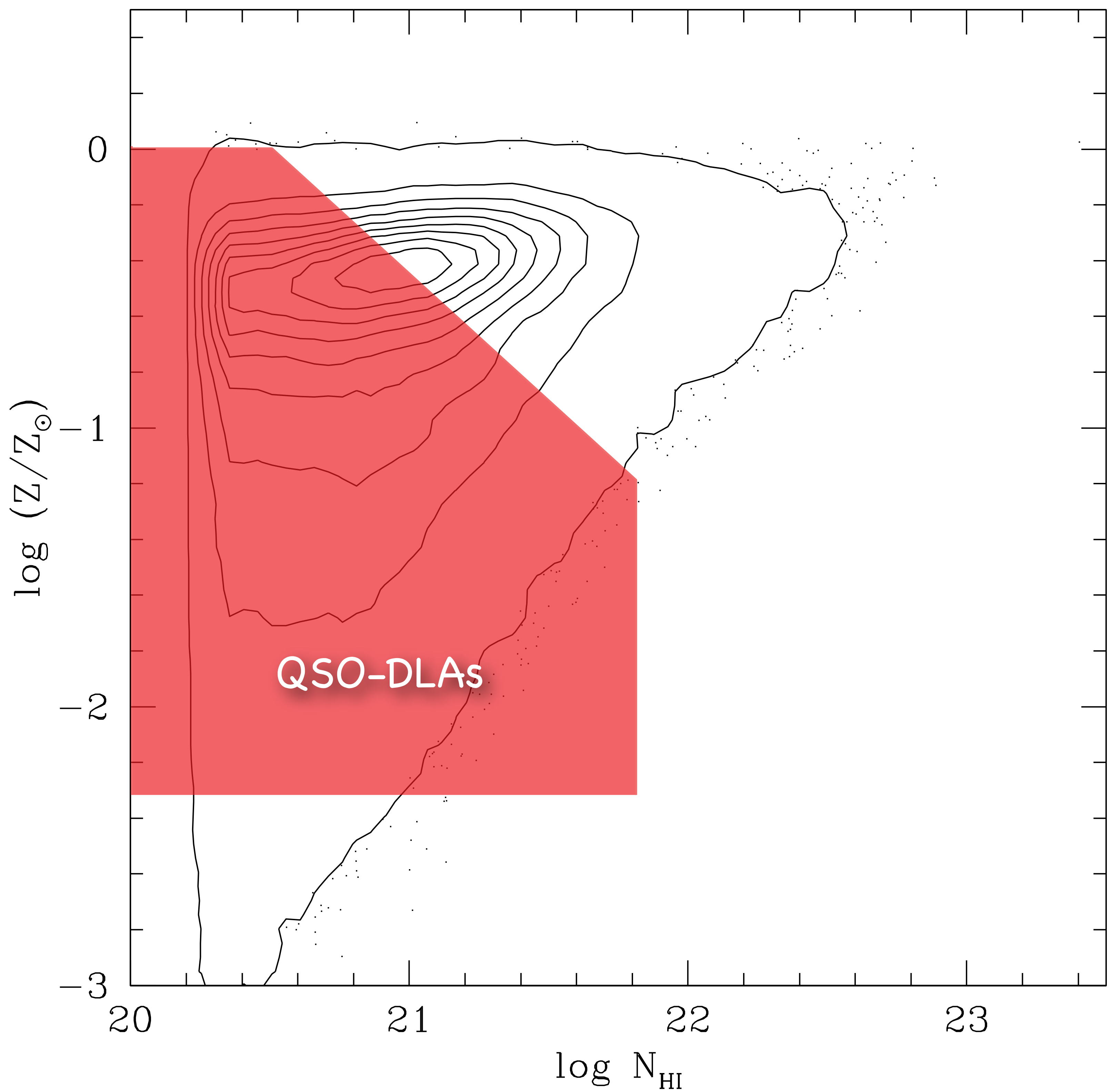

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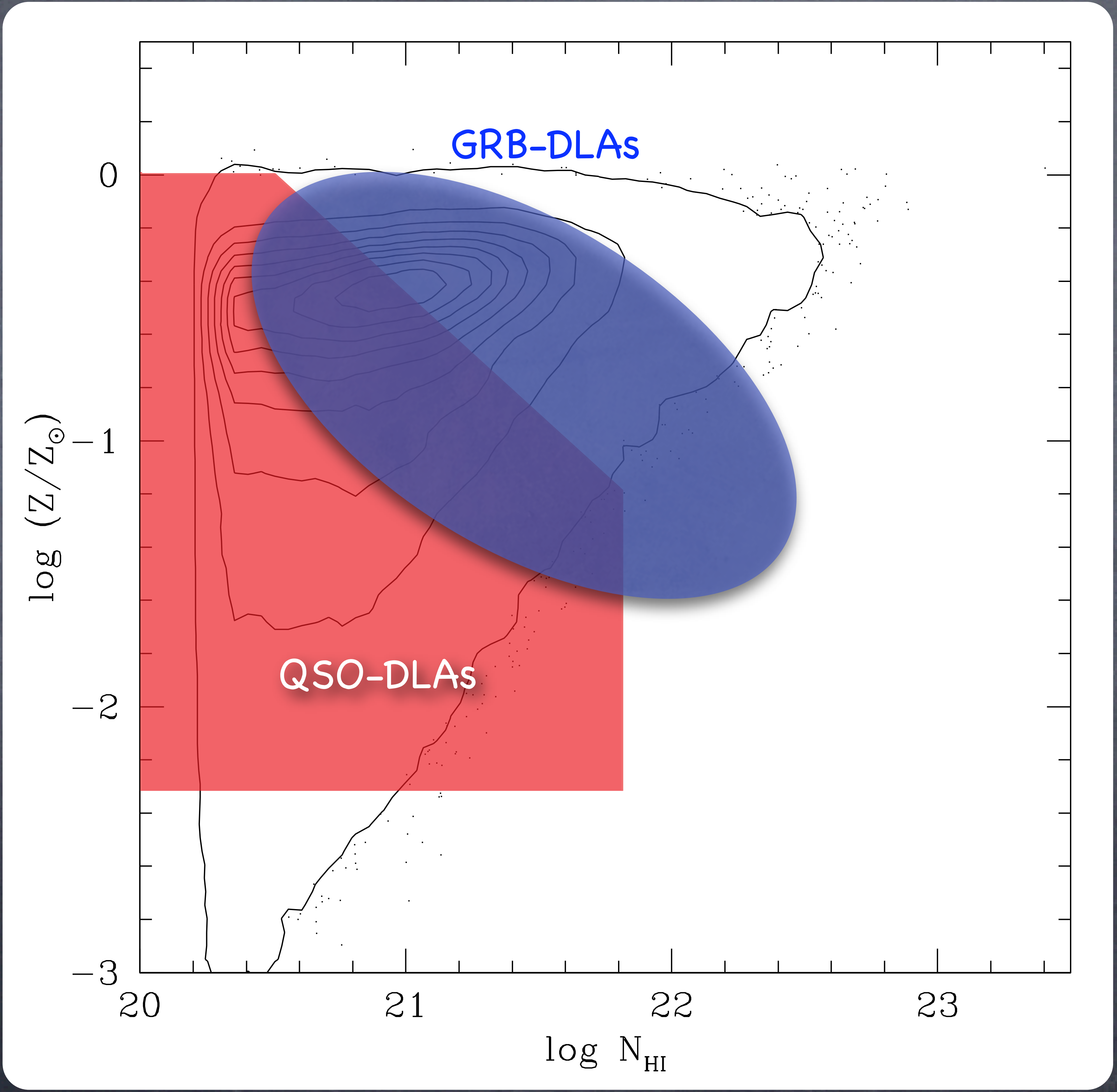
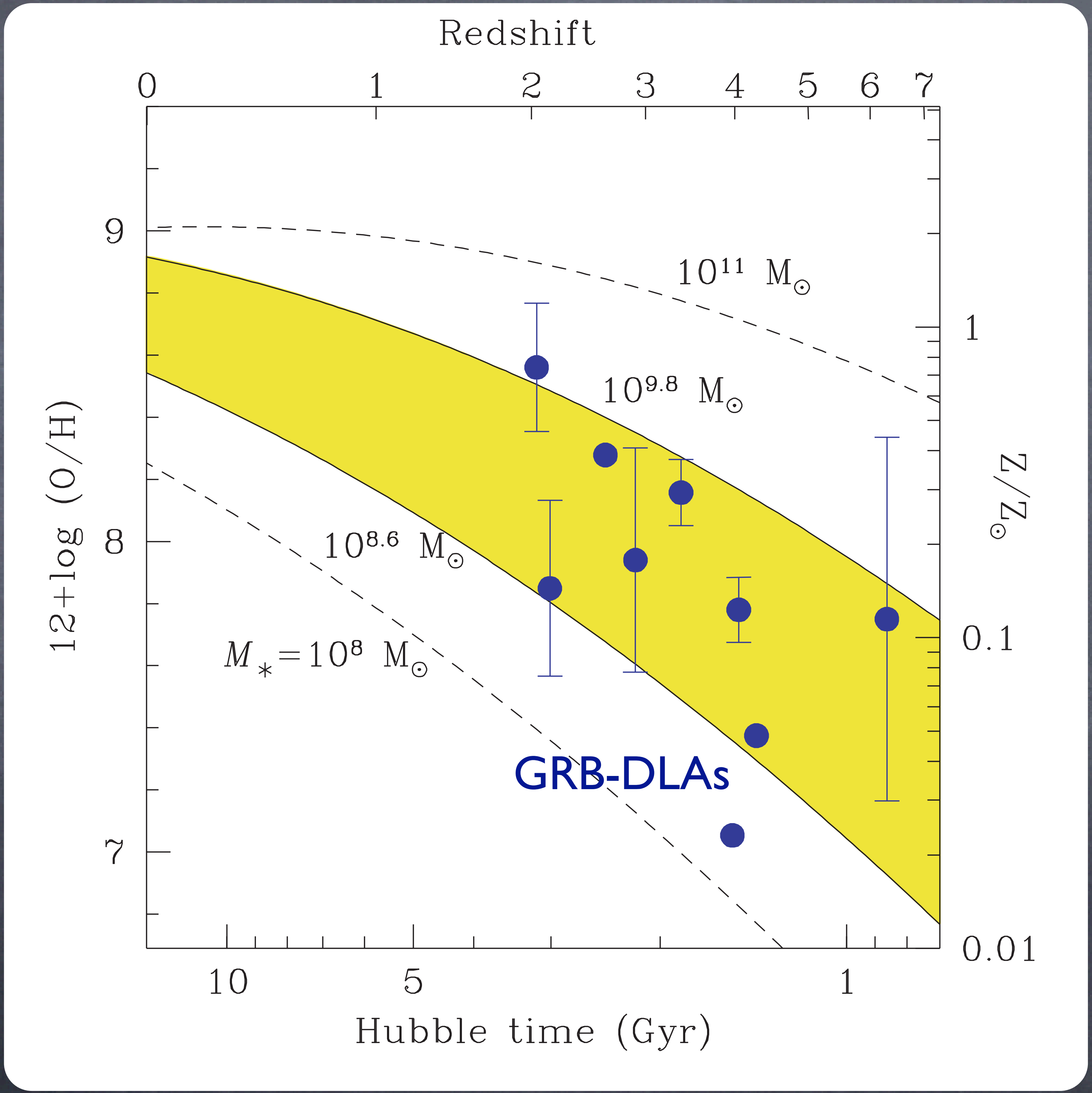


Redshift evolution of mass-metallicity relation



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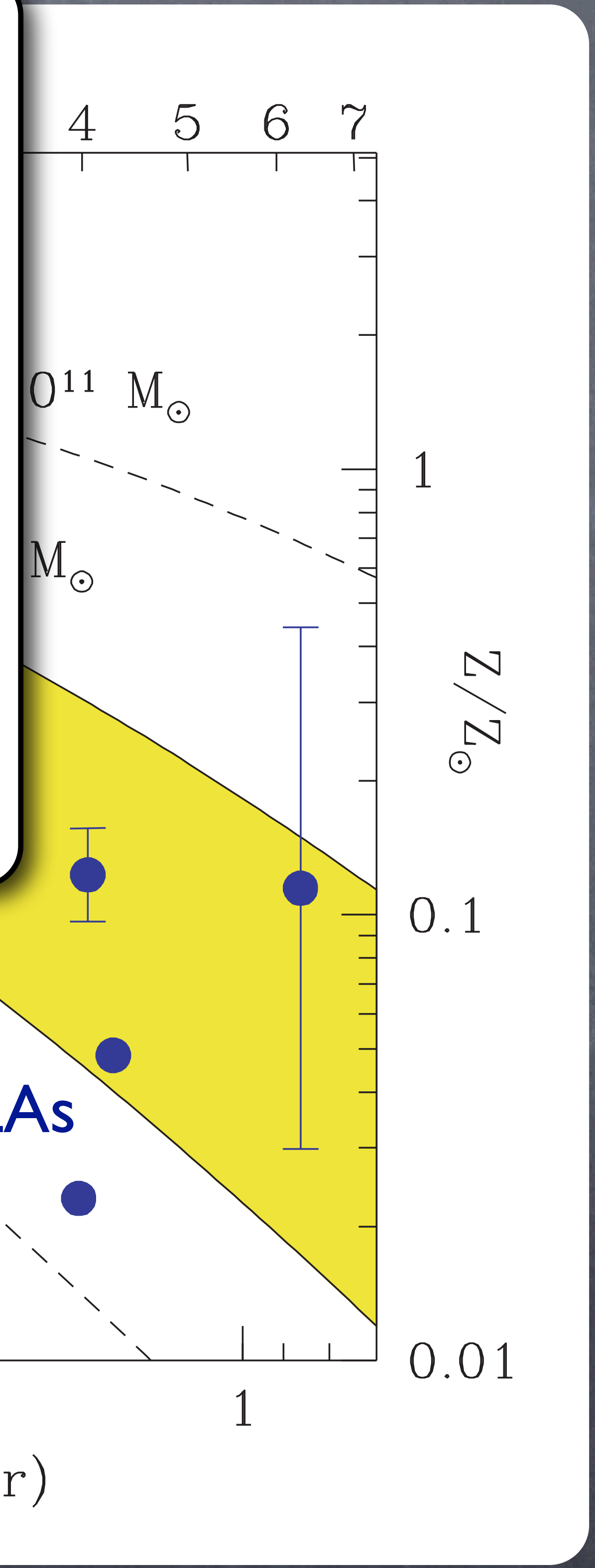

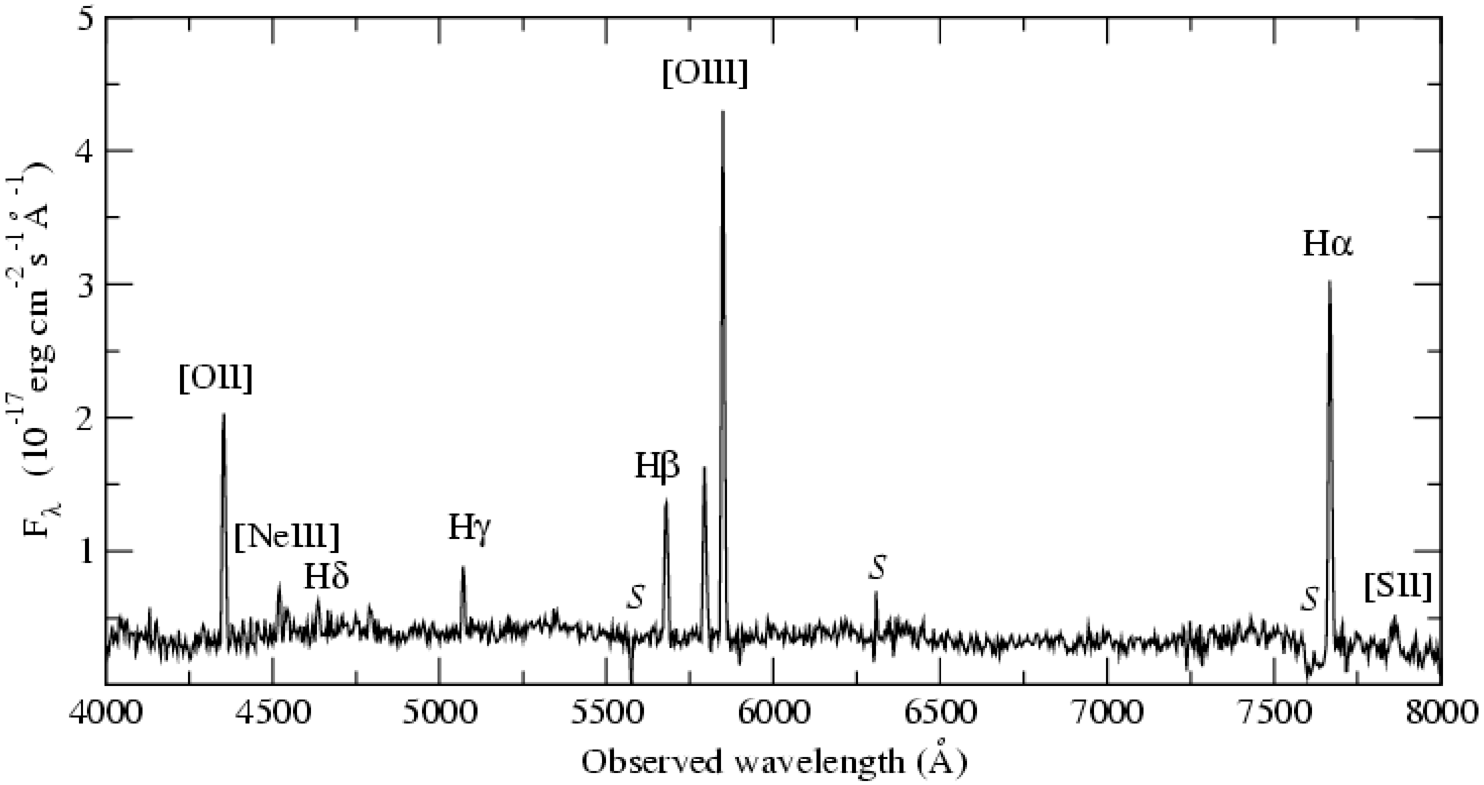

GRB 030328 z=0.168 (Gorosabel et al. 2005)

Savaglio (2006)

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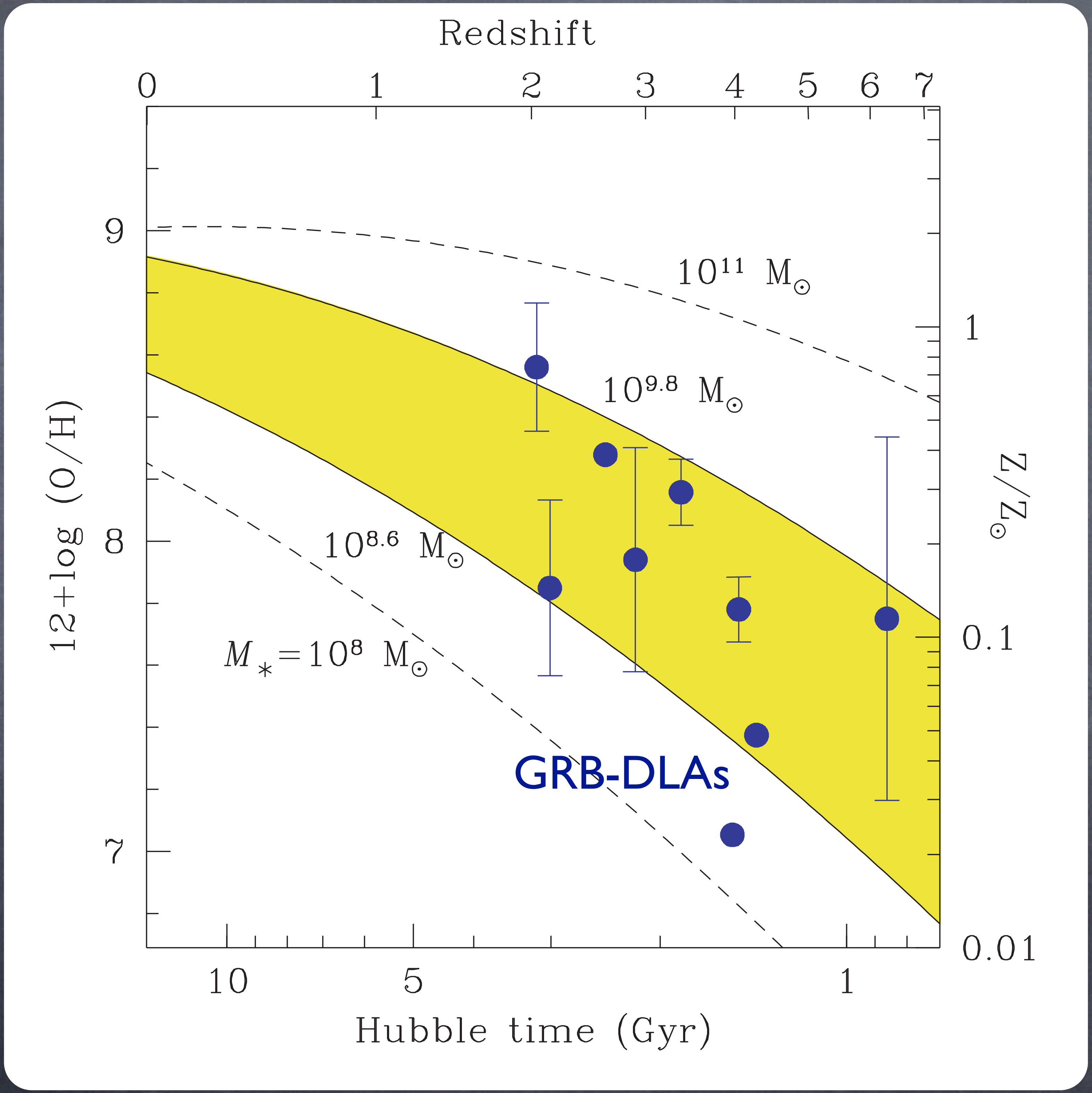
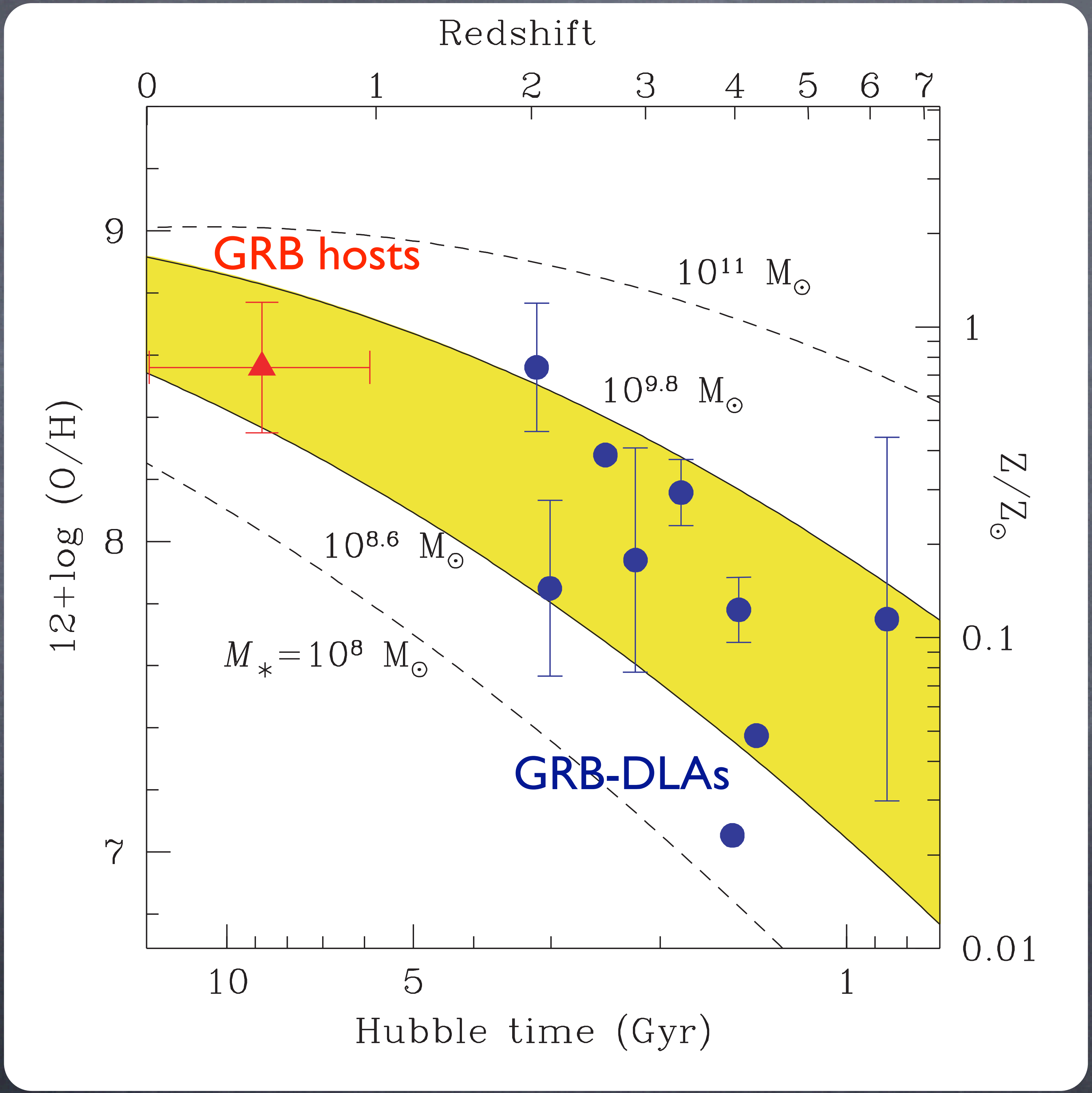


Savaglio (2006)

Redshift evolution of mass-metallicity relation



Savaglio (2006)

GHostS

Gamma-Ray Burst Host Studies

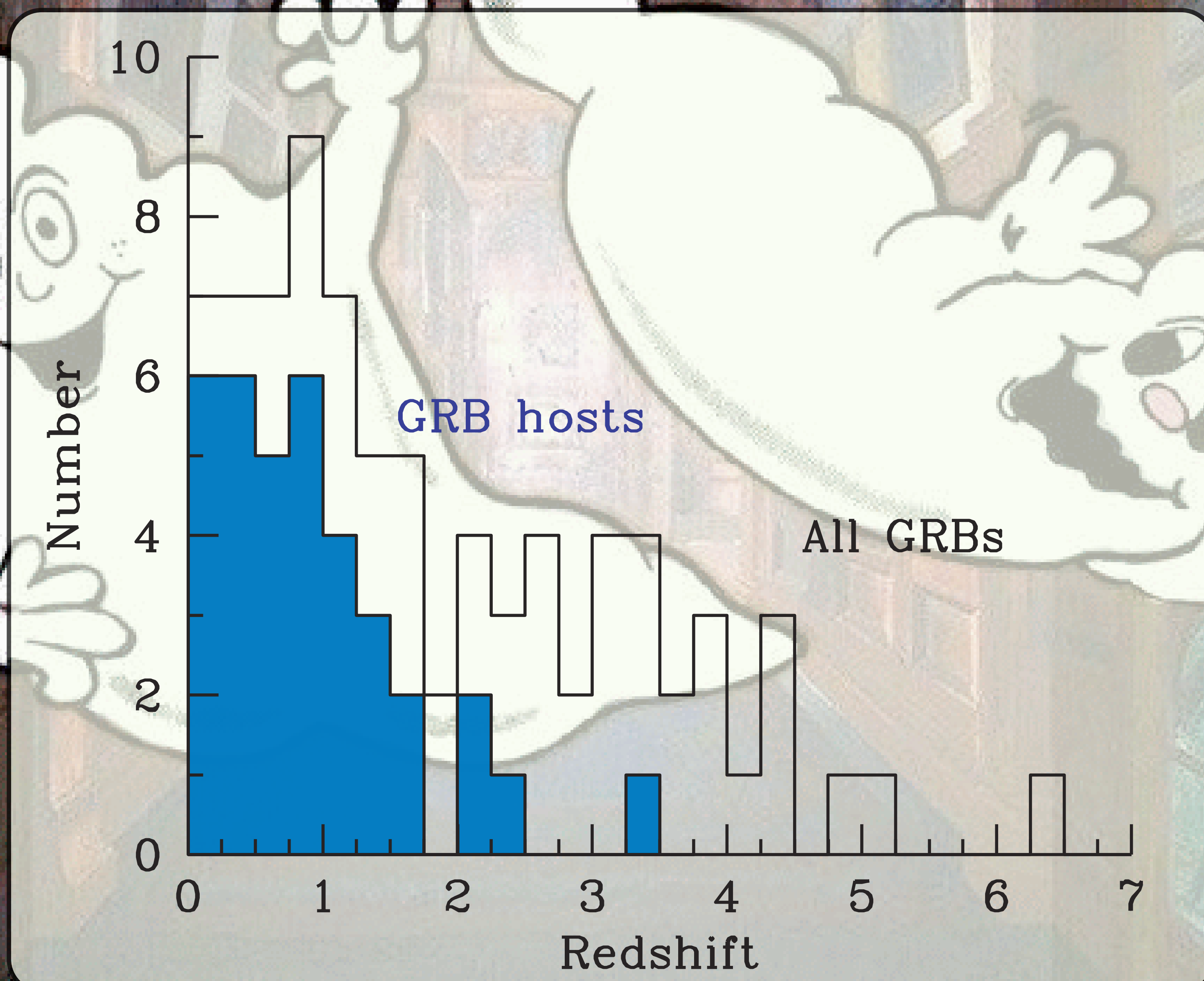
S. Savaglio (MPE) K. Glazebrook (JHU) D. Le Borgne (Saclay)

http://www.pha.jhu.edu/~savaglio/ghosts

GRB Host Studies (GHostS)

➜ The largest archive of gamma-ray burst host galaxies

➜ Multi-band opt-NIR photometry and spectroscopy



Savaglio, Glazebrook, Le Borgne (in preparation)

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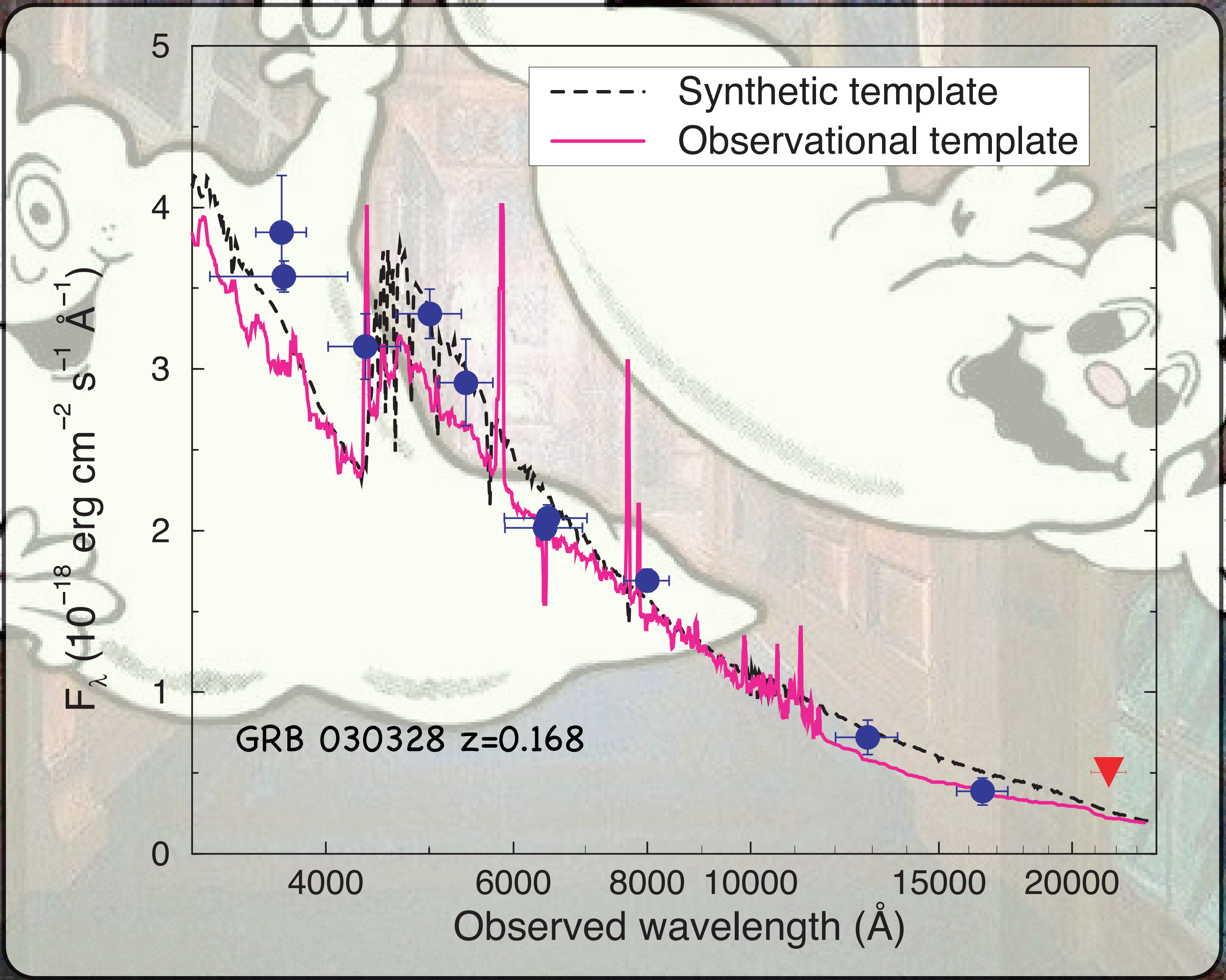
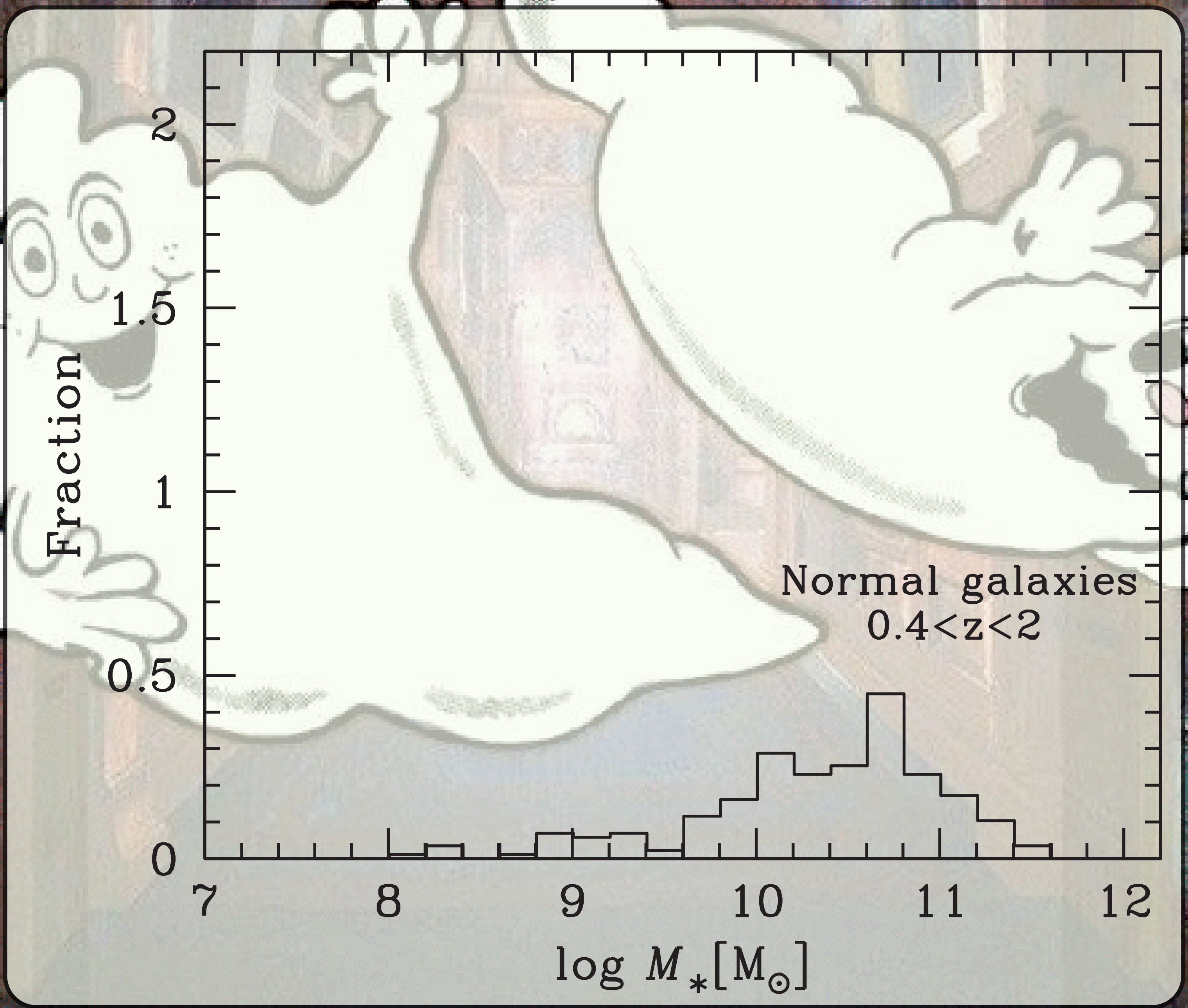


Gorosabel et al. (2005)

GRB Host Studies (GHostS)

Total stellar mass for the host galaxies



Savaglio, Glazebrook, Le Borgne (in preparation)

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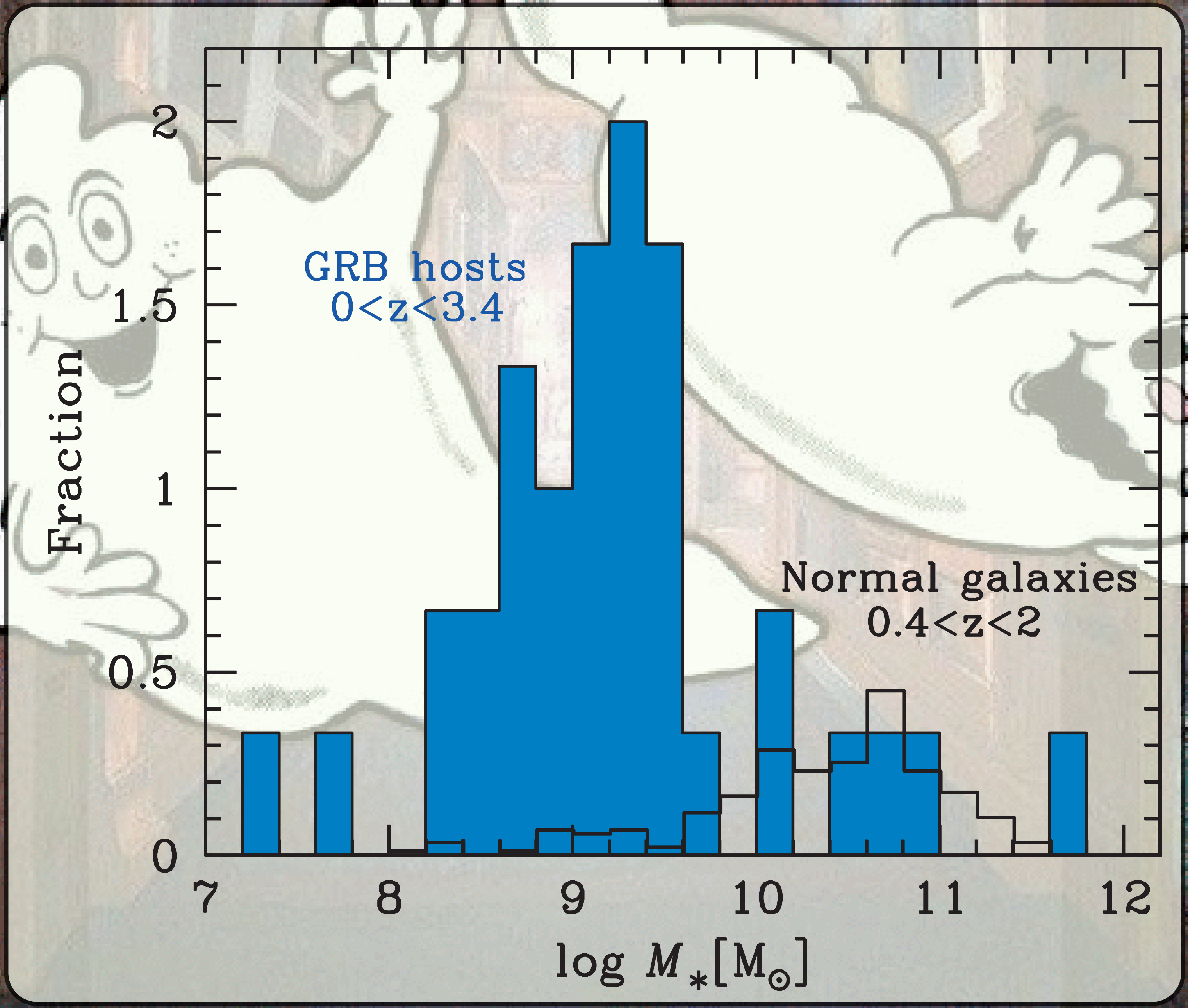
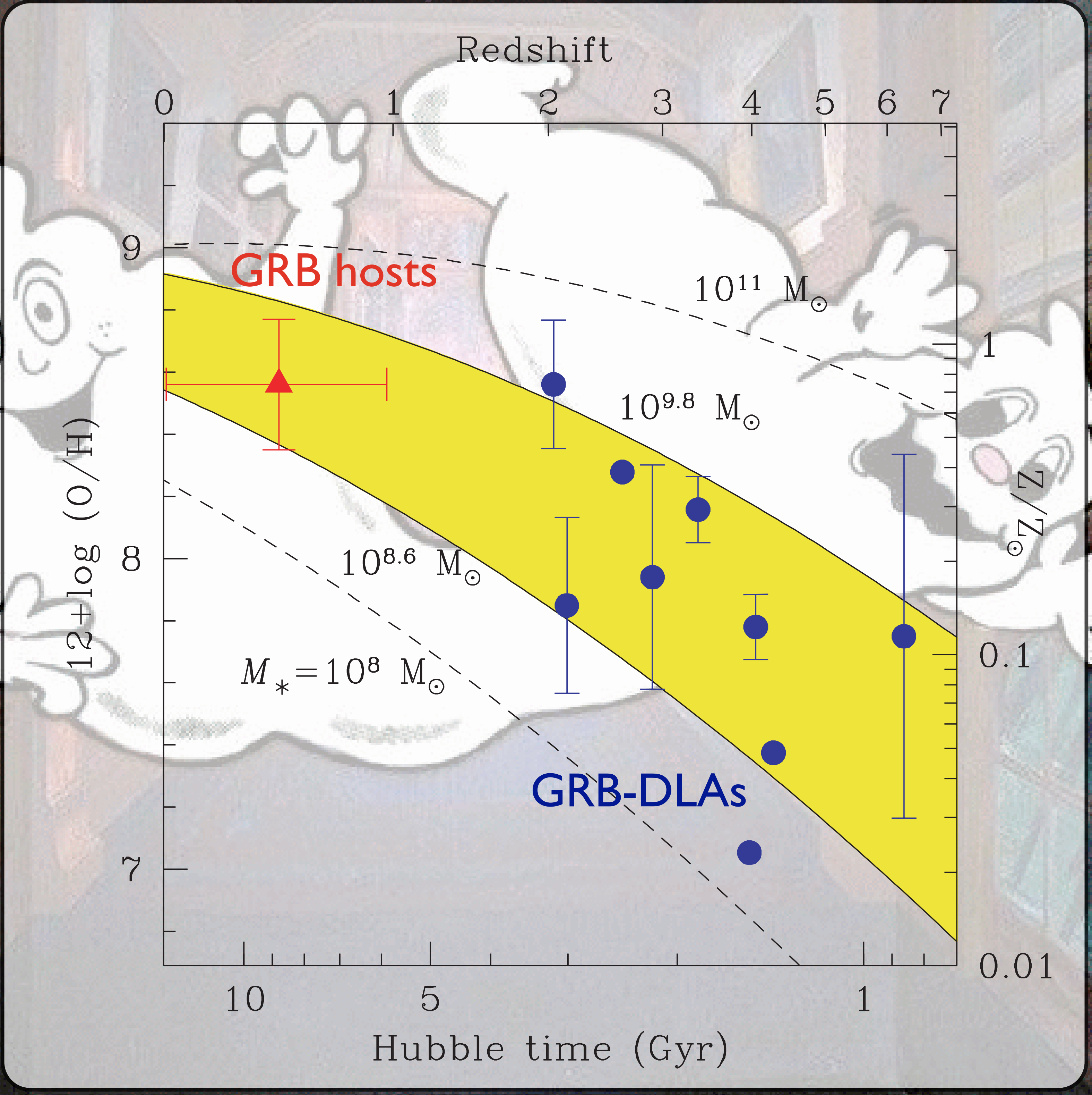


Savaglio, Glazebrook, Le Borgne (in preparation)

GRB Host Studies (GHostS)

Mass-metallicity relation in GRB hosts



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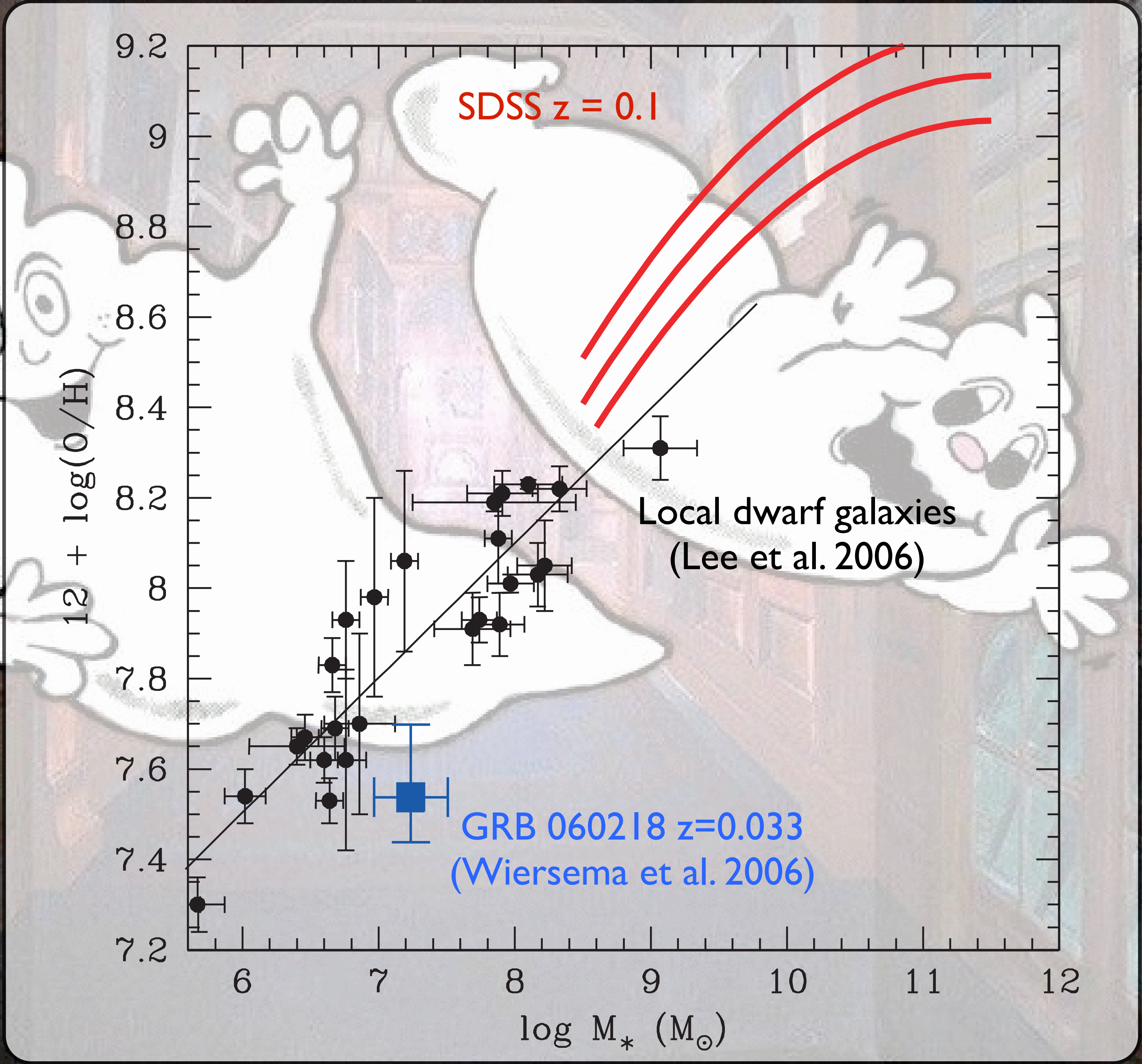

Savaglio, Glazebrook, Le Borgne (in preparation)

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❹ Future: GRB host galaxy population