Properties of Galaxies hosting Gamma-Ray Bursts

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EXTREME UNIVERSE LABORATORY

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GRB 011121
redshift z = 0.362
4.0 billion years ago

Stellar mass of the host:

$M_\star = 6.5\times10^9\ M_\odot$

Star formation rate:

$SFR = 2.2\ M_\odot\ yr^{-1}$

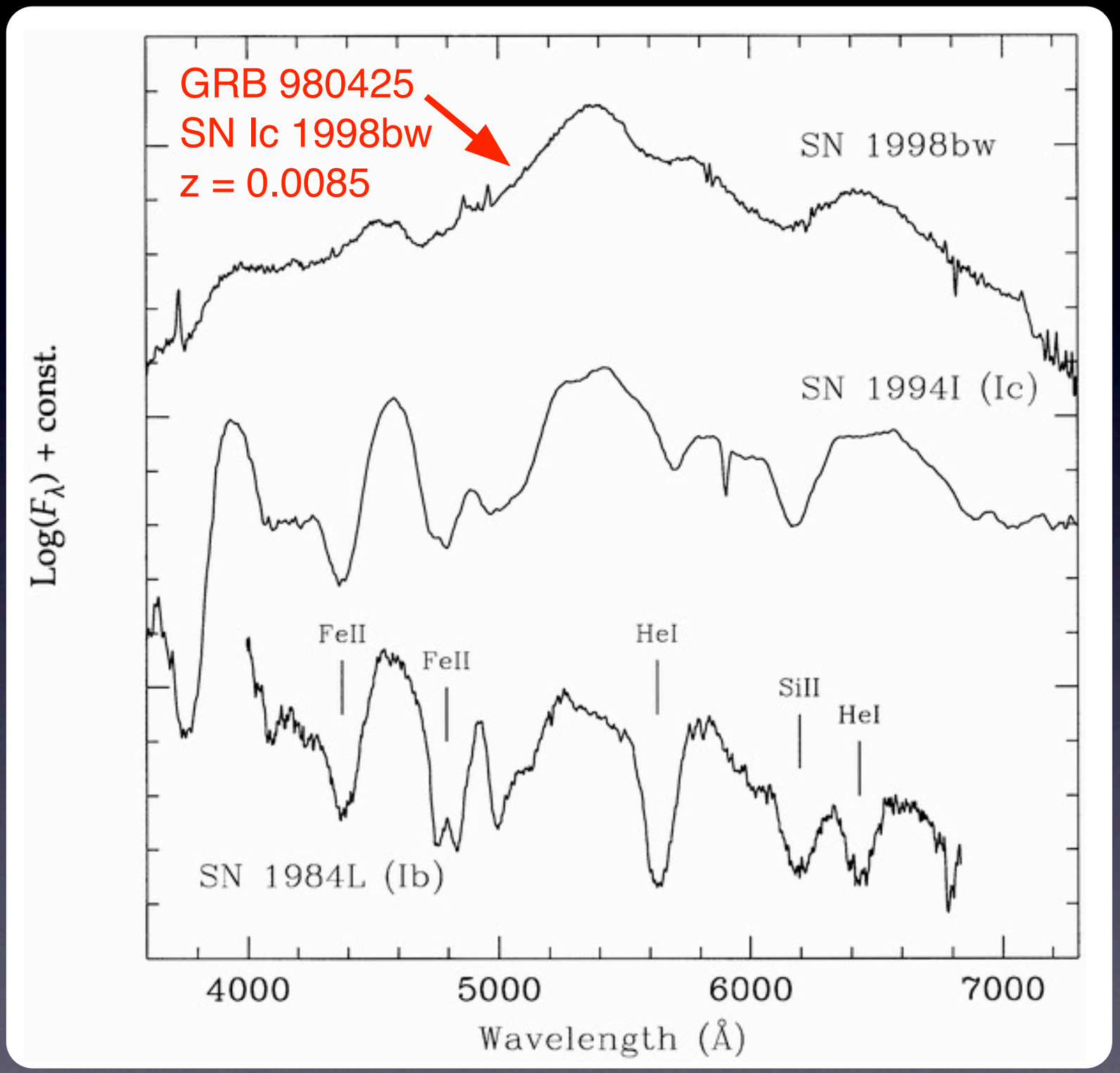
Growth time scale:

$\rho = M_\star/SFR = 1/sSFR = 2.95$ Gyr

Redshift of formation:

$z = 0.815$

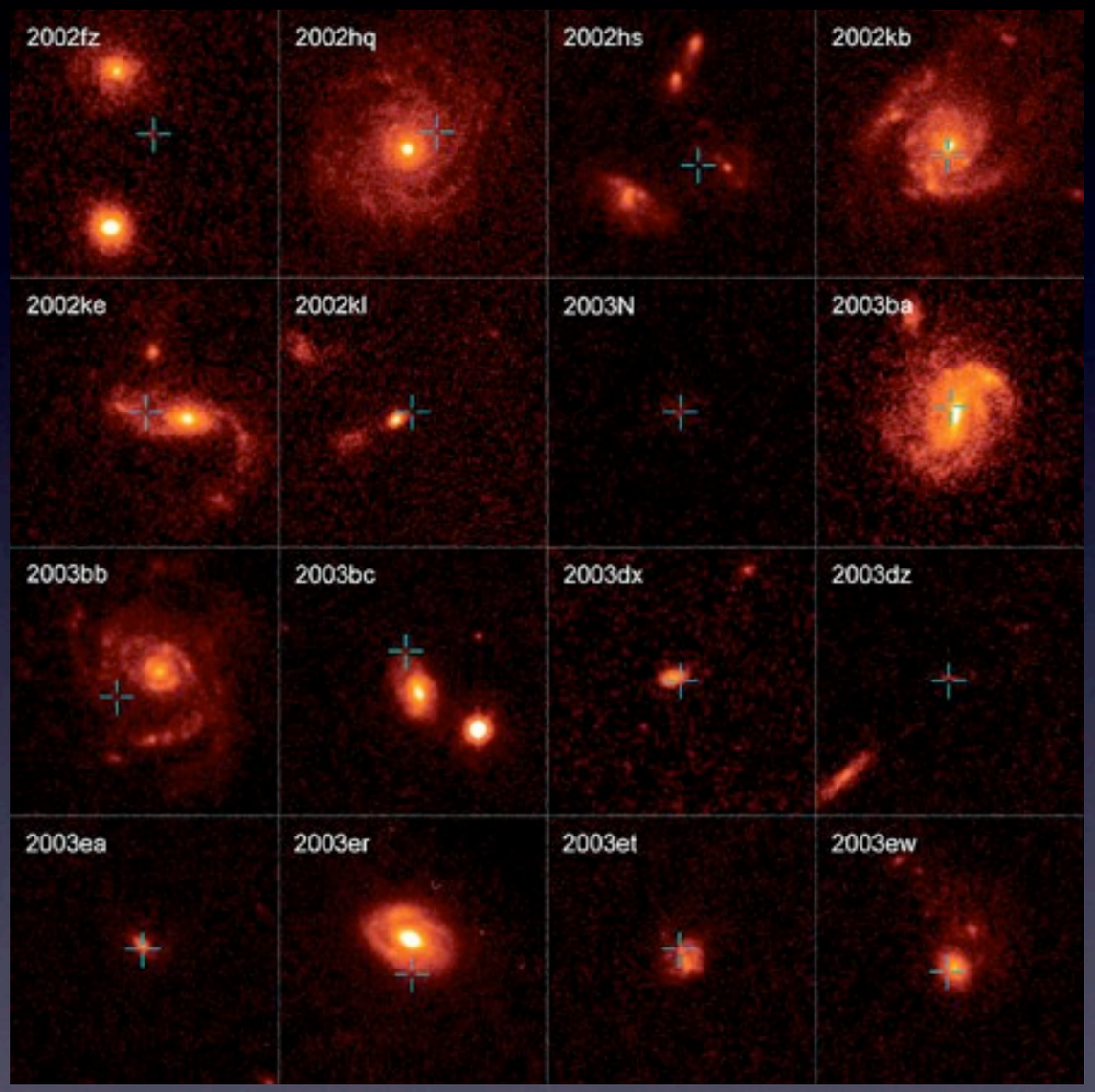
Gamma-ray burst - SN (Ic,Ib) connection



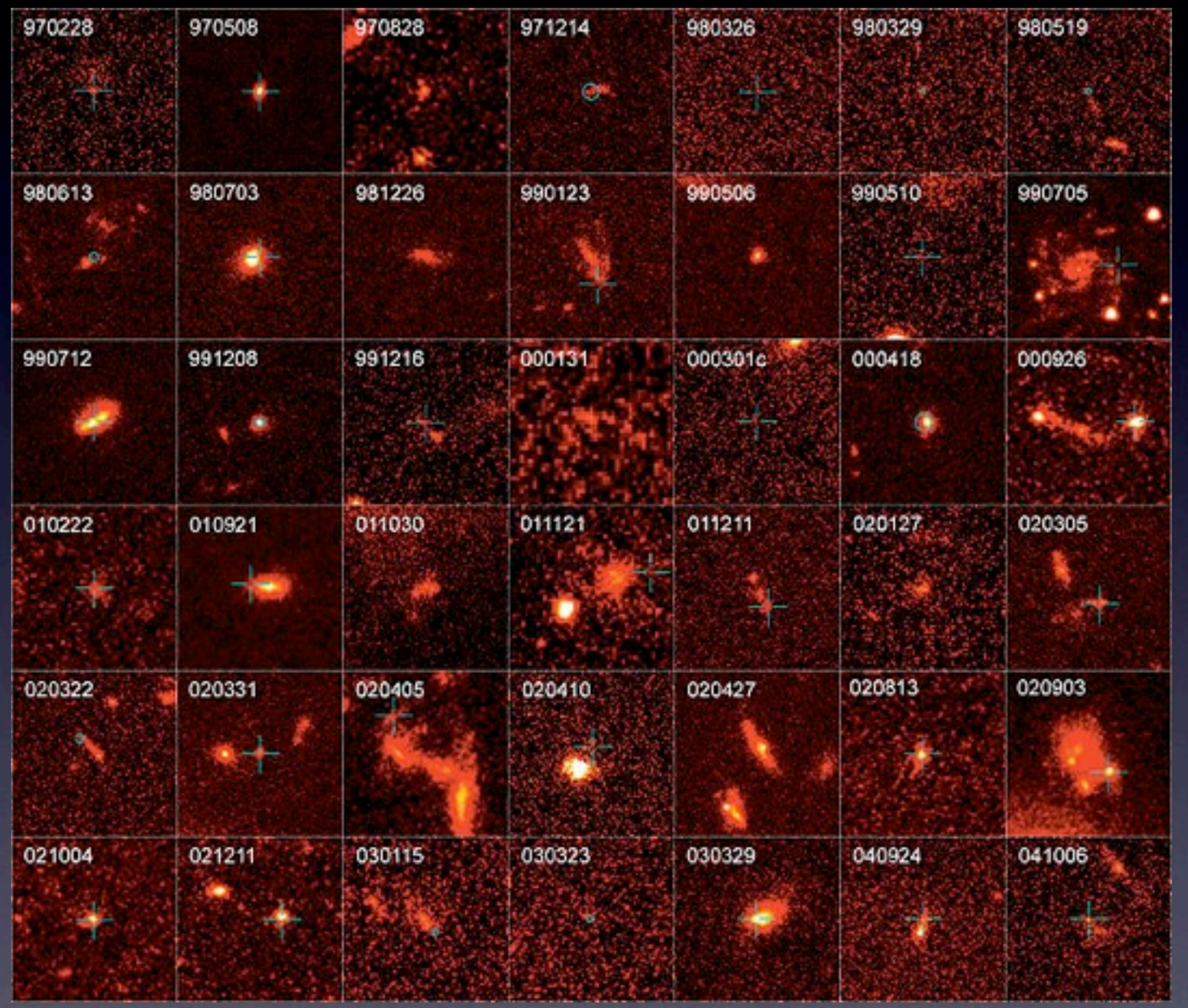
Galama et al. (1998)

GRB host galaxies

Core-collapse SN host galaxies z < 1.2

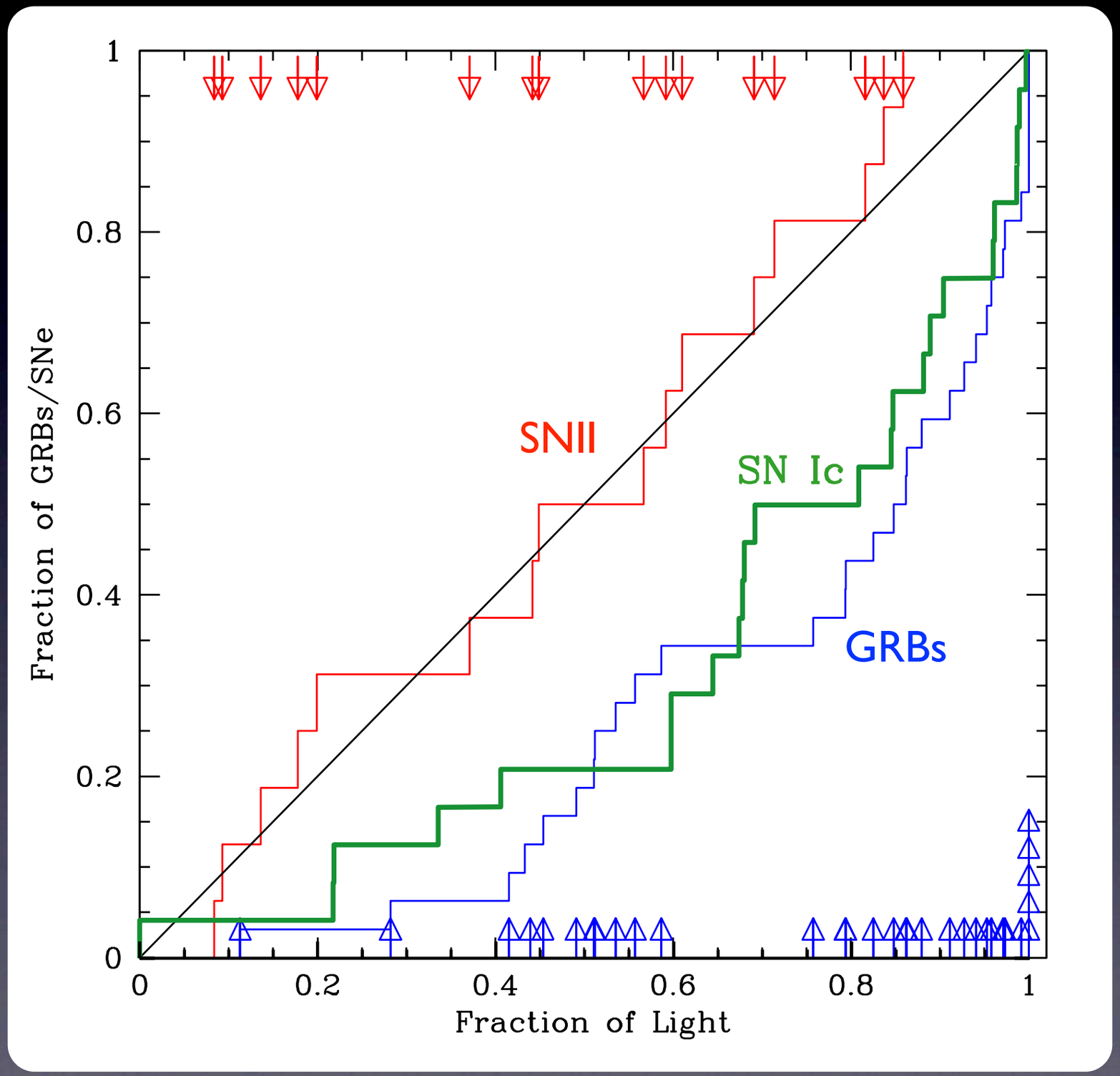


GRB host galaxies z < 1.2



Fruchter et al. (2006)
(see also Kelly, Kirshner & Pahre 2008; Svensson et al. 2010)

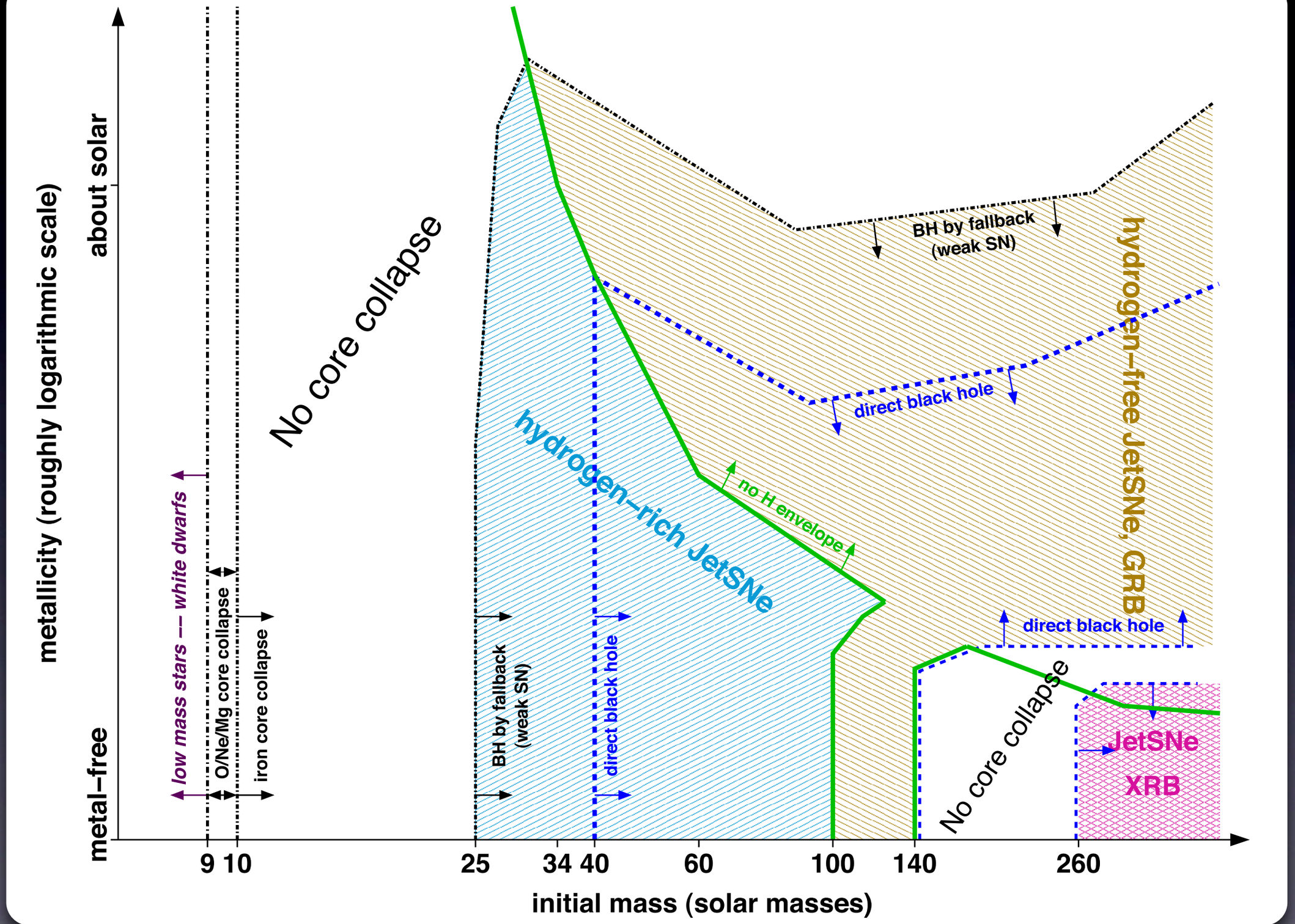
GRB environment



Fruchter et al. (2006)
(see also Svensson et al. 2010)

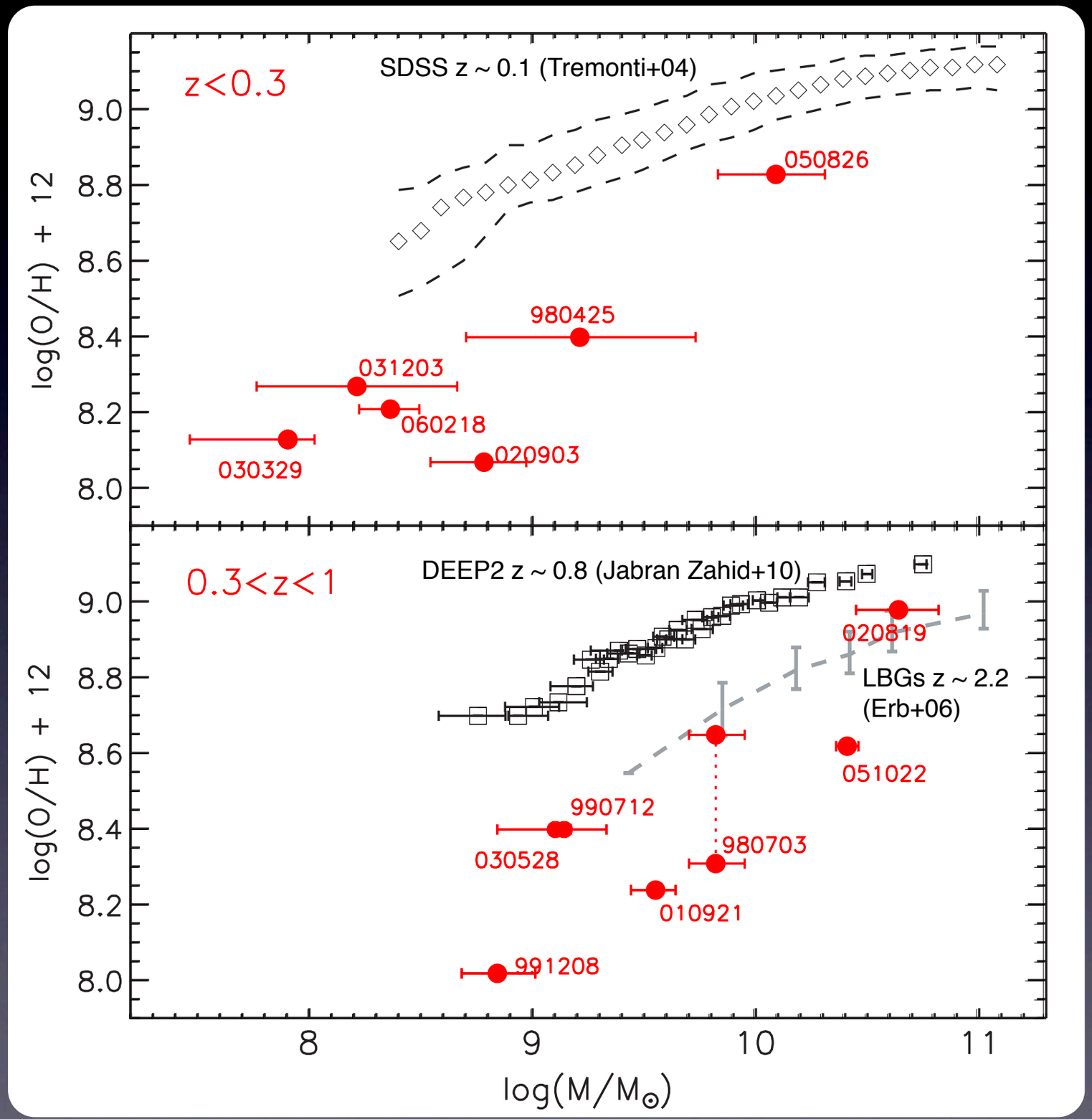
Kelly, Kirshner & Pahre (2008)

Gamma-ray burst – SN connection



Heger et al. (2003)

Mass-Metallicity relation in GRB hosts



Metallicity

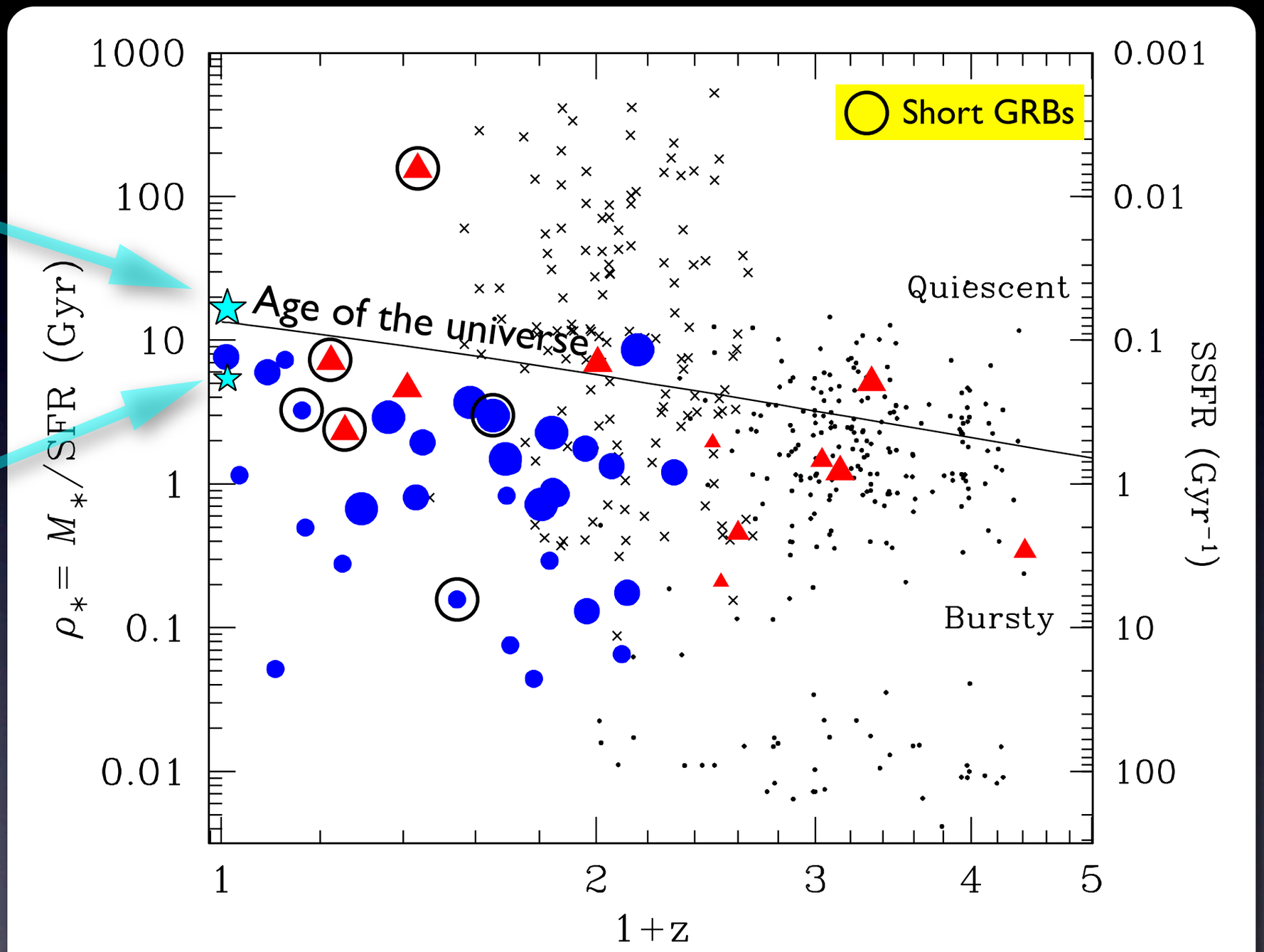
Galaxy stellar mass

Levesque et al. (2010)

Specific star formation rate of GRB hosts

MW

LMC



GRB hosts - UV

GRB hosts - emi. lines

Savaglio, Glazebrook & Le Borgne (2009)

$$\rho_* = M_*/\mathrm{SFR} = \frac{1}{\mathrm{SSFR}}$$

GRB host galaxies at z < 1.5 generally are:

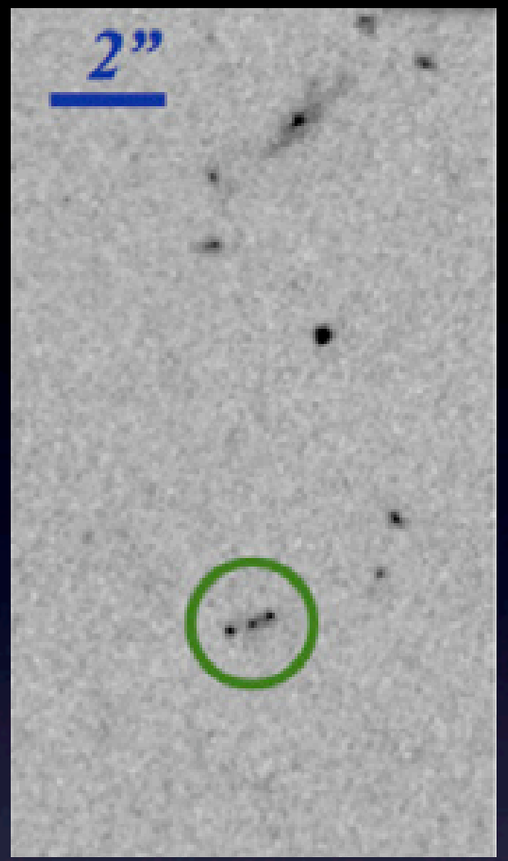
- small
- metal and dust poor
- star forming

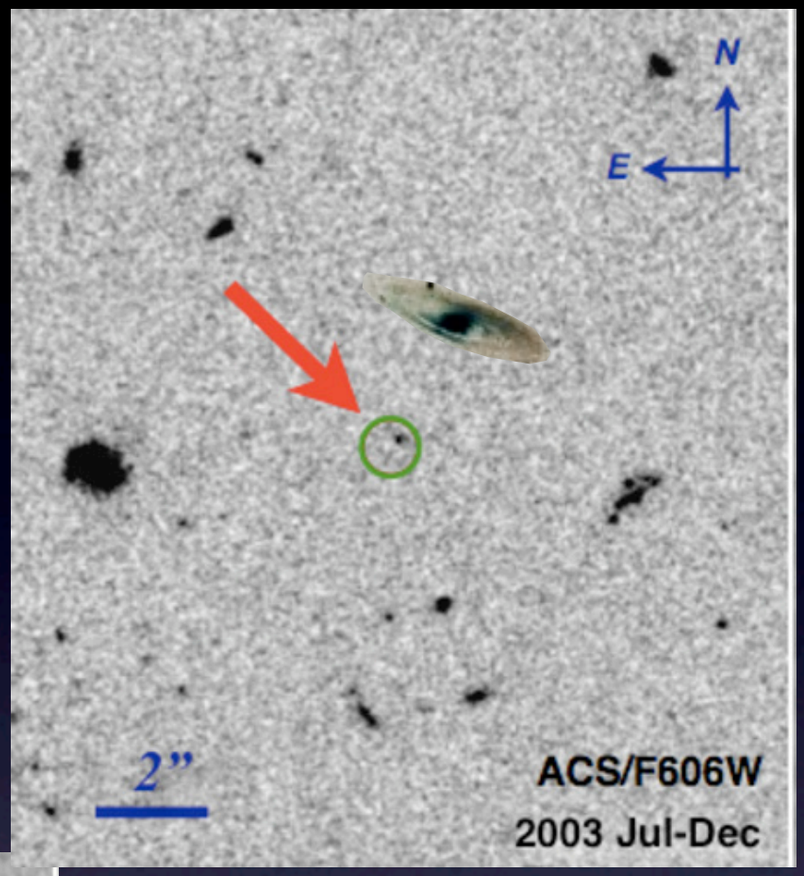
What about z > 1.5 GRB hosts?

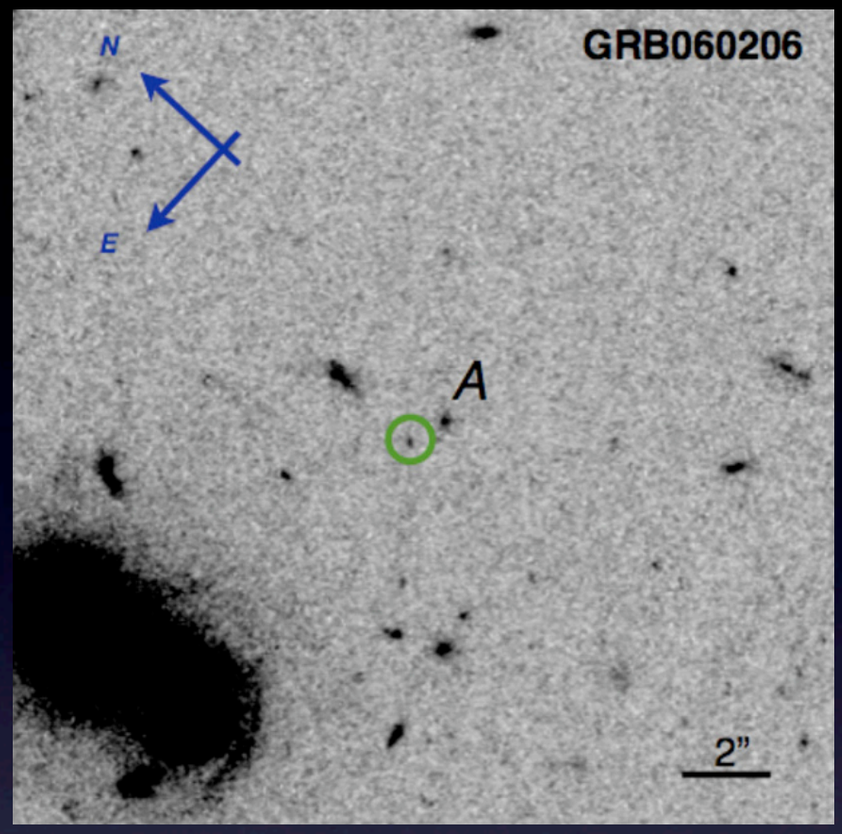
Main changes in the history of the universe:

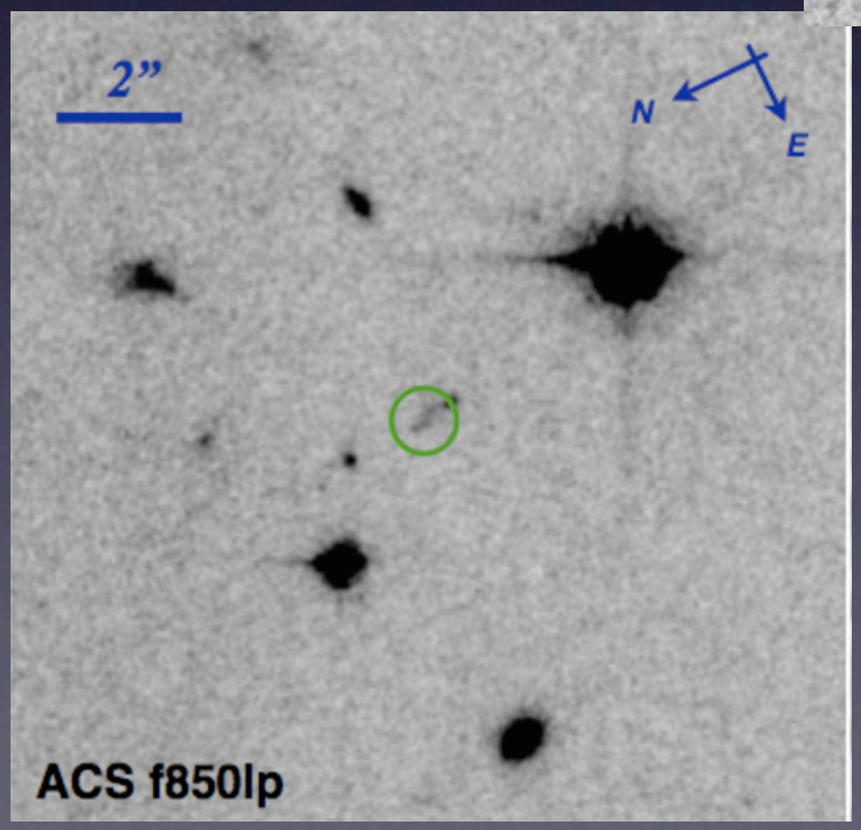
- SFR density
- stellar mass
- galaxy merger rate
- galaxy size

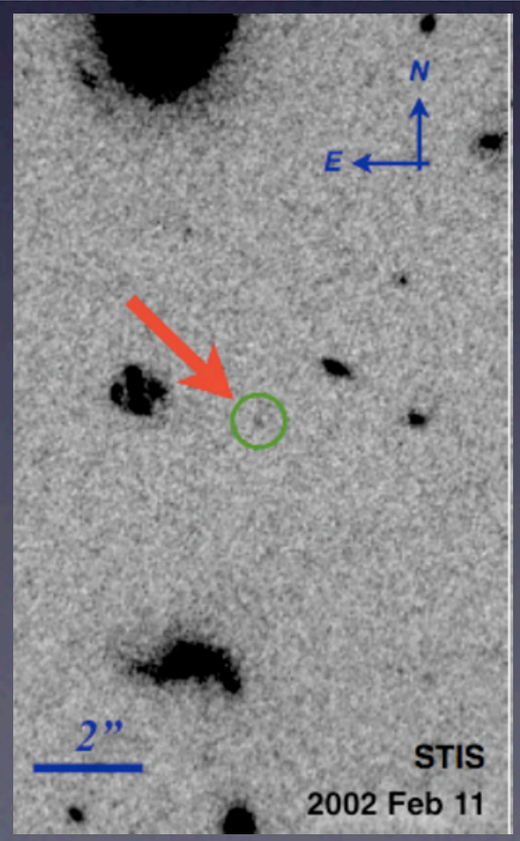
GRB hosts at redshift z > 2







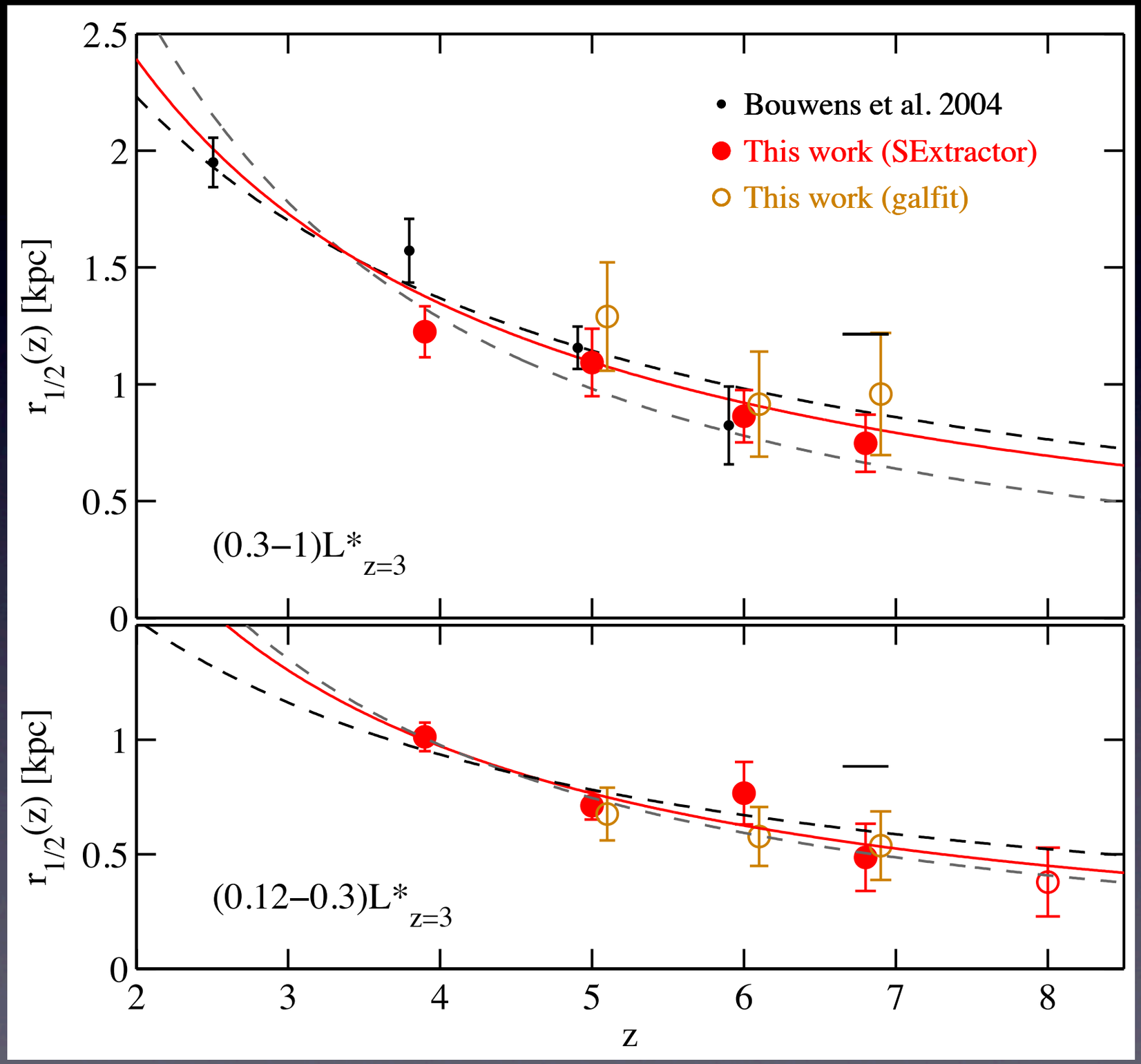




2000 Apr

Chen et al. (2009)

Redshift evolution of galaxy mean size



Dunlop (2012)

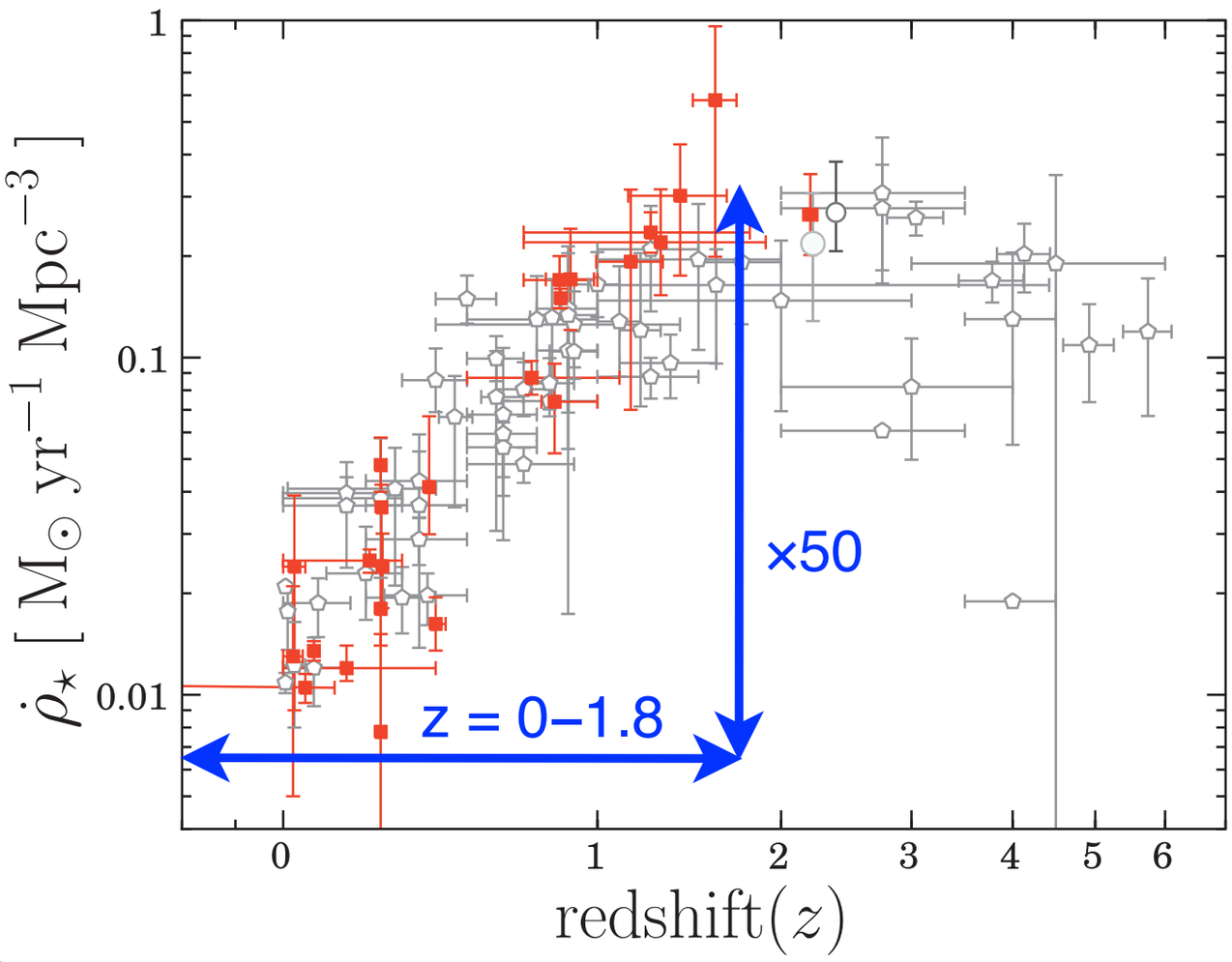
Galaxy formation and evolution:

the phenomenological context

Cosmic star formation and merger rate

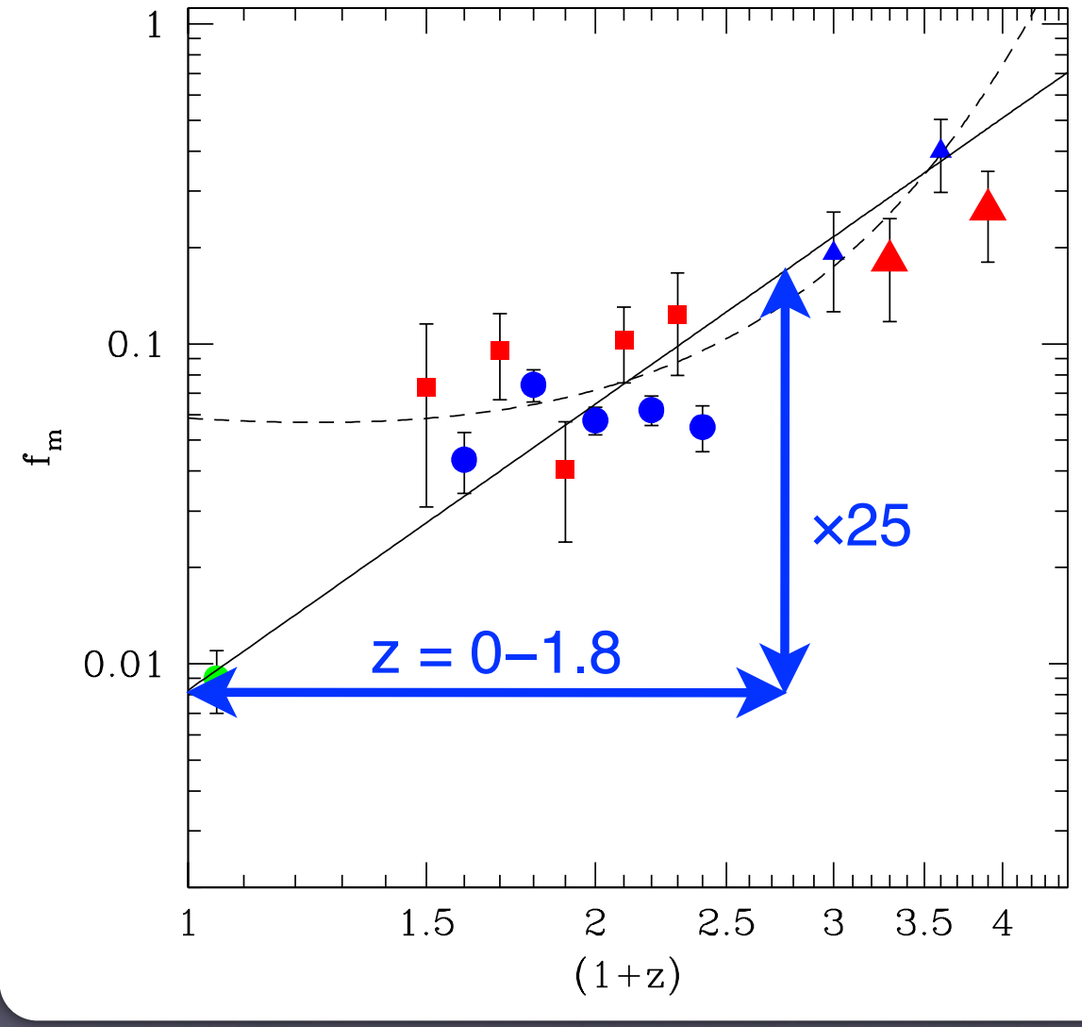
The last 10 Gyr

SFRD



Hayes, Schaerer & Östlin (2010)

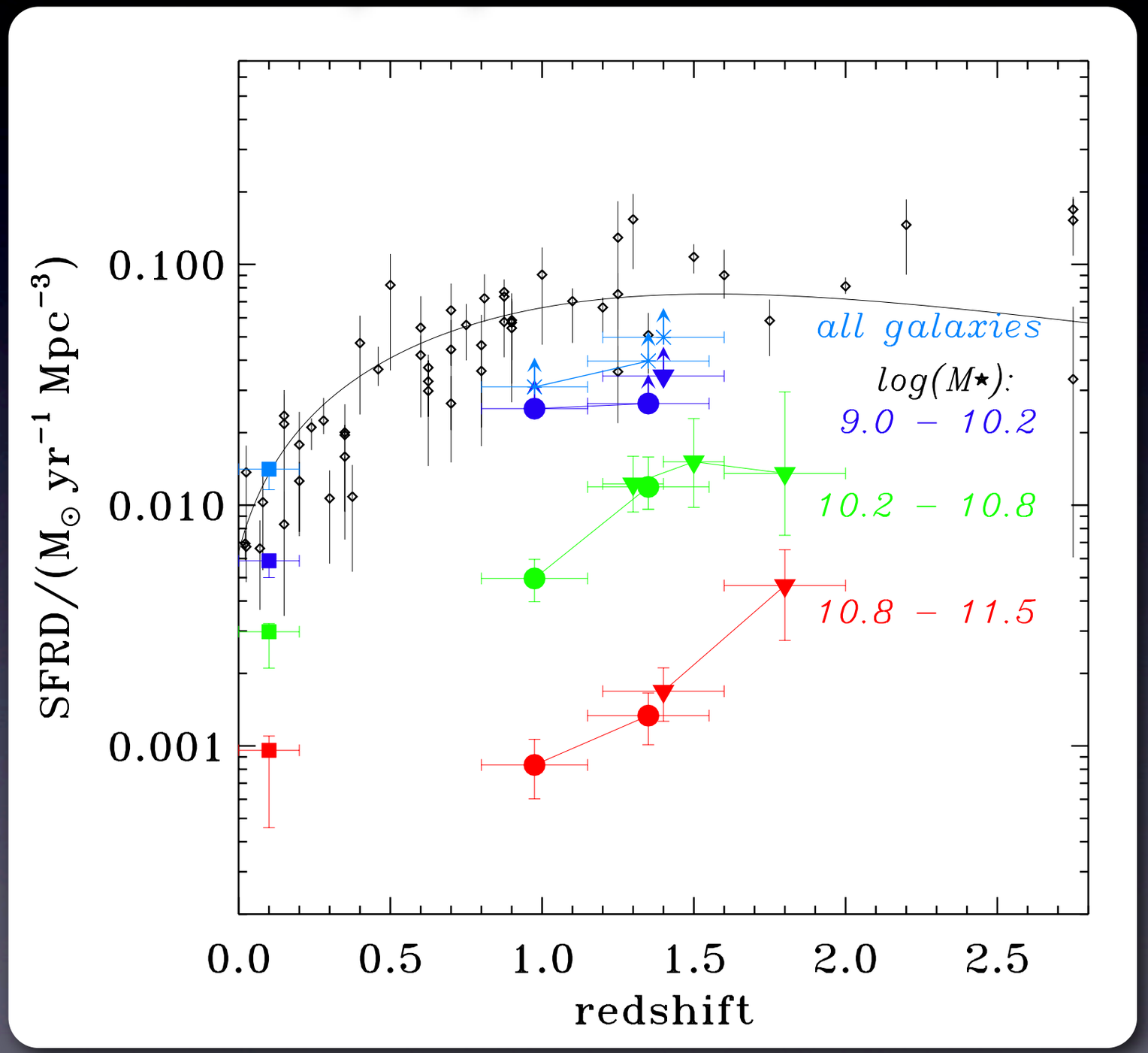
Major merger rate



Bluck et al. (2011)

Cosmic star formation rate for different masses

Madau plot per stellar–mass bin



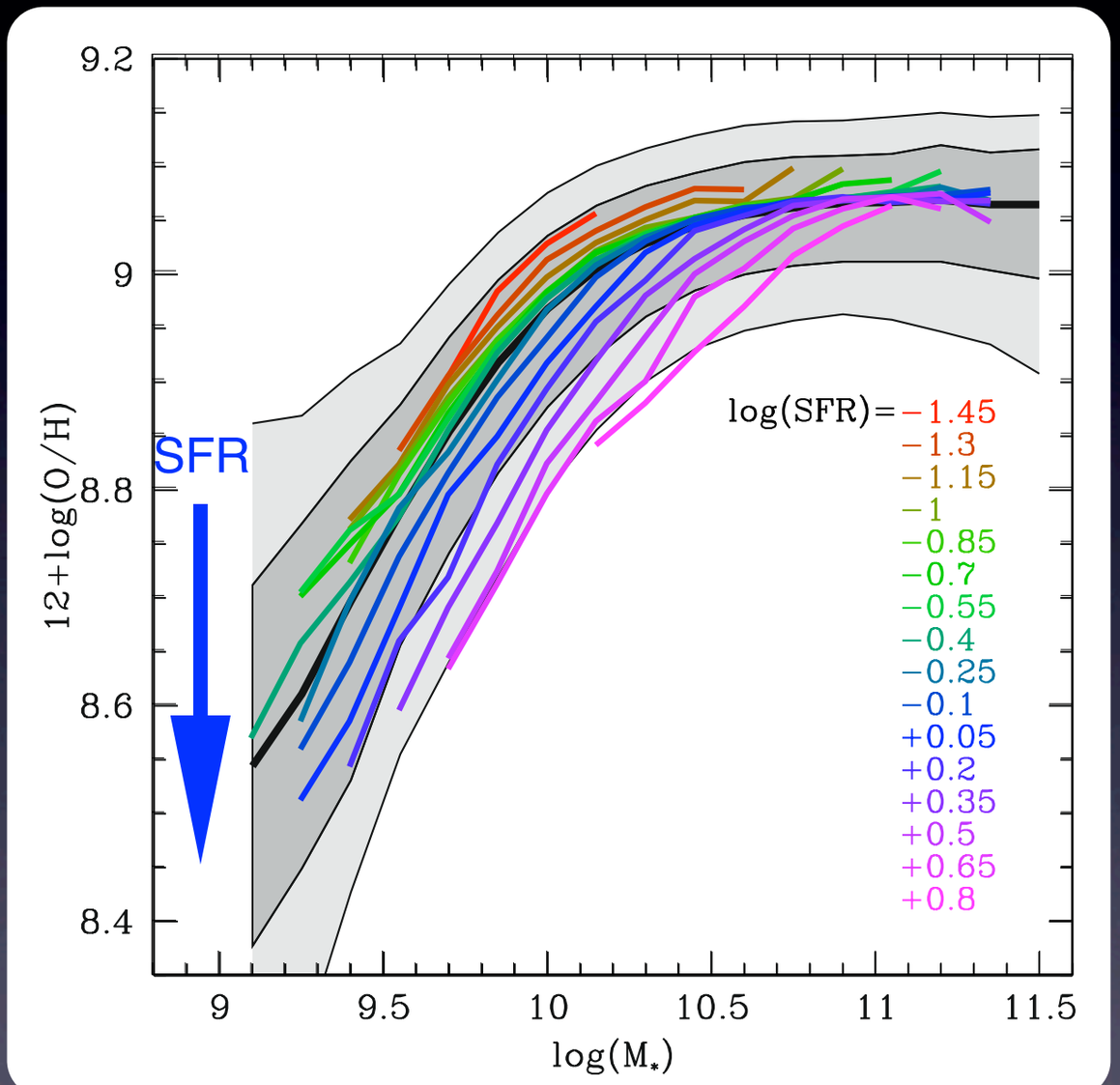
Galaxy stellar mass

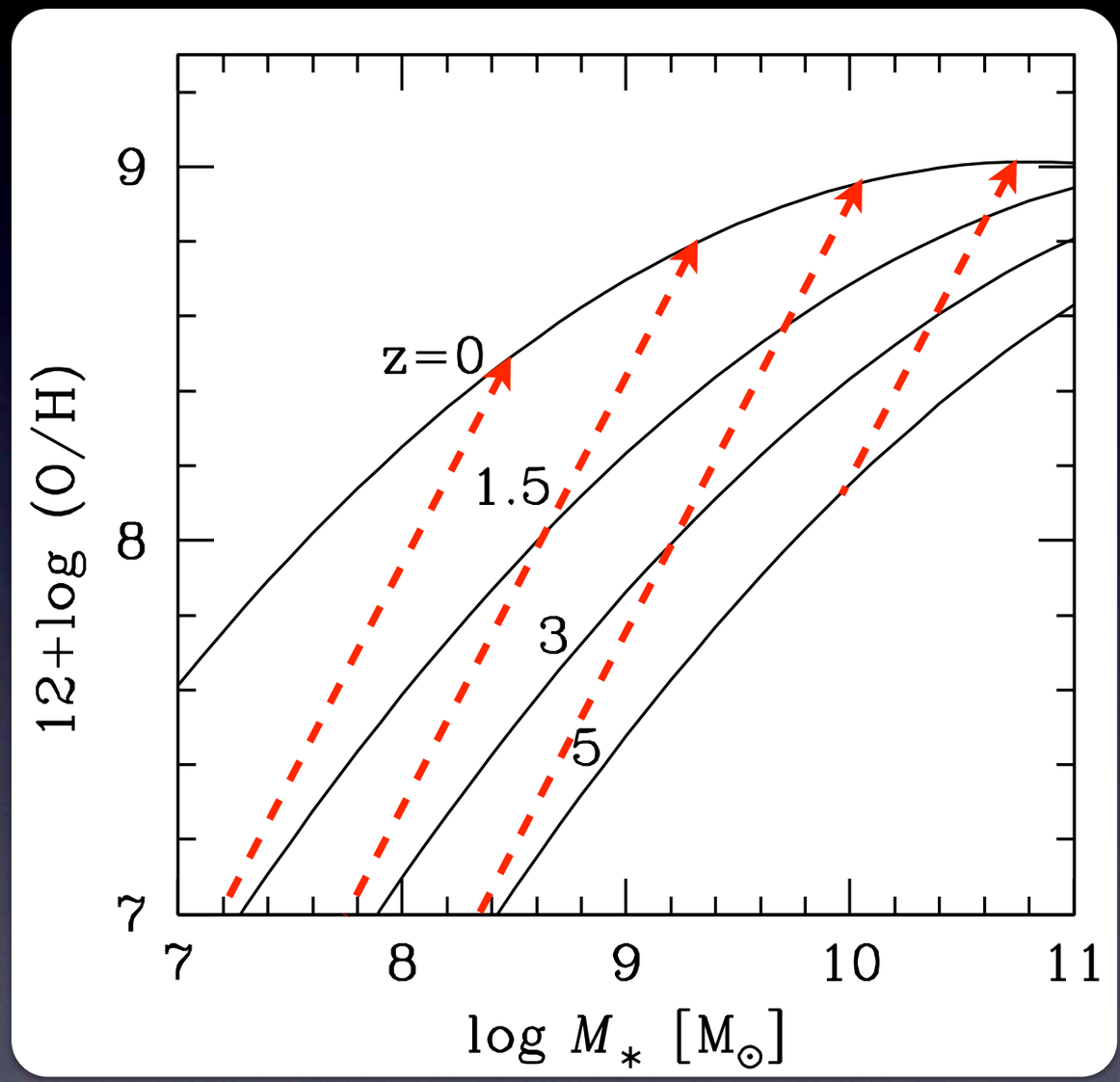
Juneau et al. (2005)

Cosmic chemical evolution

Mass–metallicity relation

Metallicity





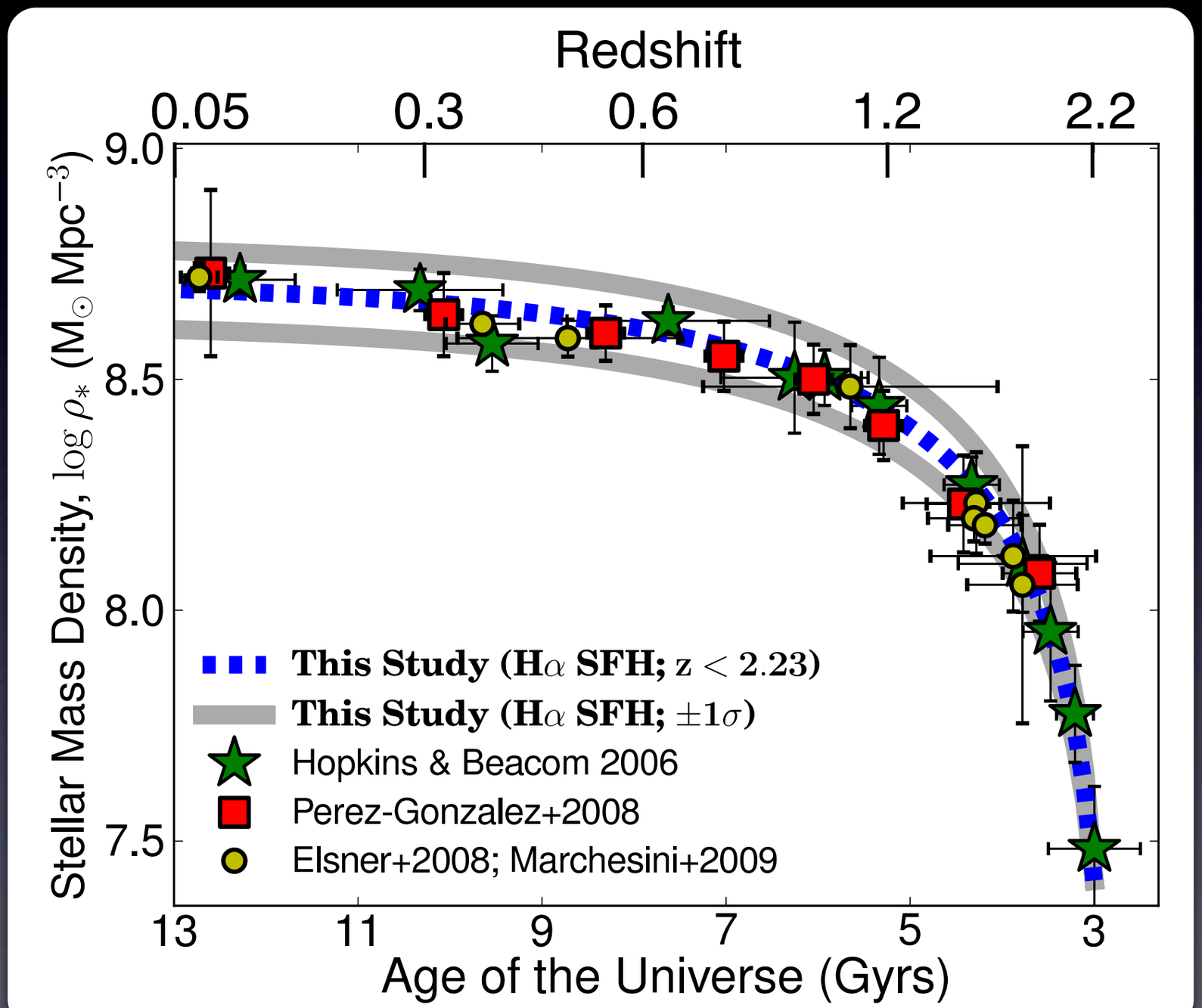
Galaxy stellar mass →

Tremonti et al. (2004)
Mannucci et al. (2010)
(see Campisi et al. 2011; Niino 2011 for FMZ of GRBHs)

Savaglio, Glazebrook, Le Borgne, et al. (2005)
(see also Erb et al. ’06, Maiolino et al. ’08)

Cosmic stellar mass assembly

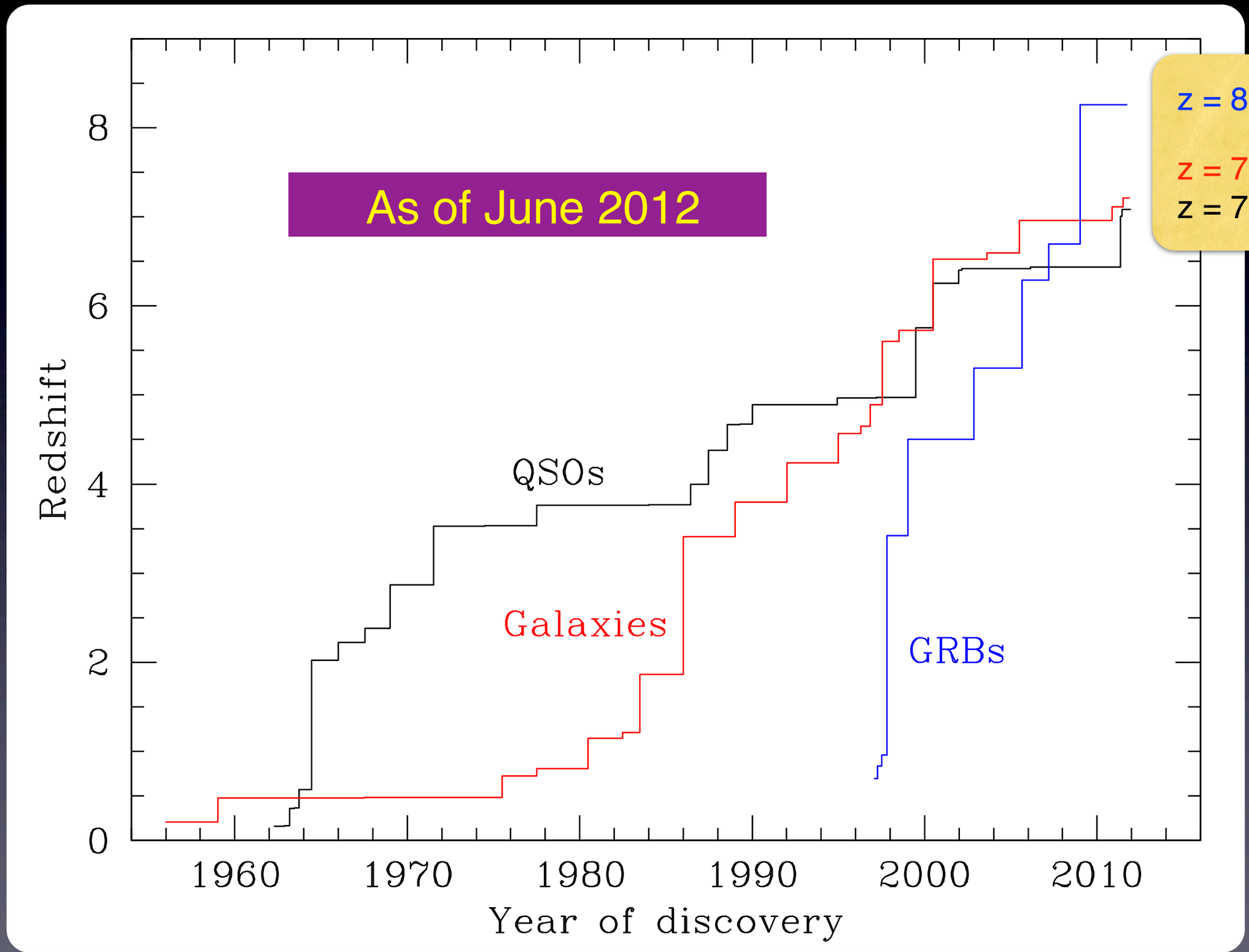
Total stellar mass redshift evolution



Sobral et al. (2012)

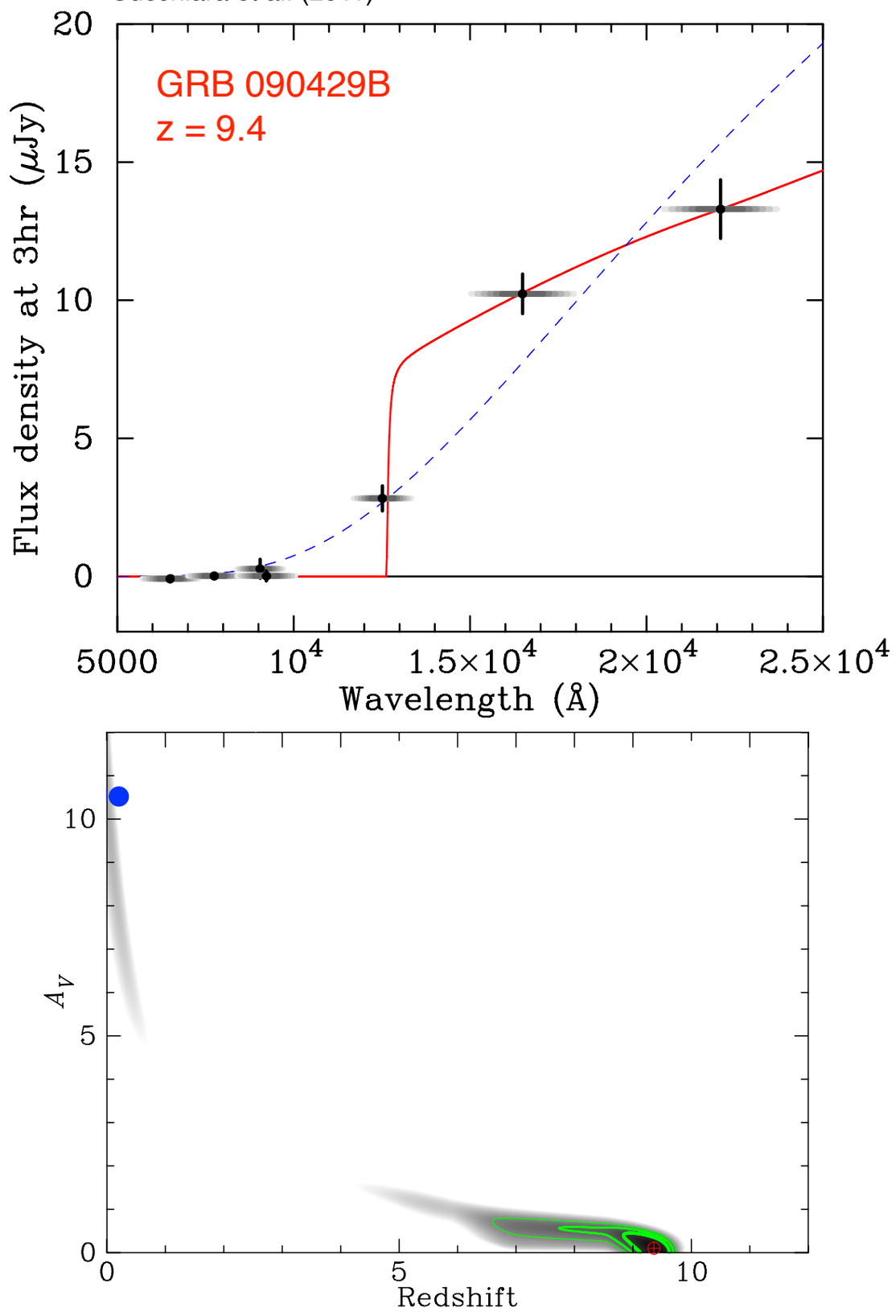
Redshift distribution of GRBs

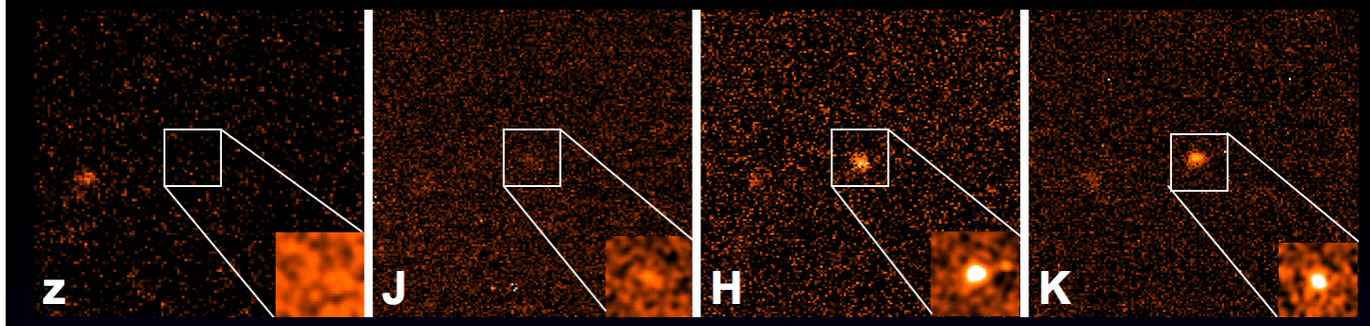
History of the most distant objects



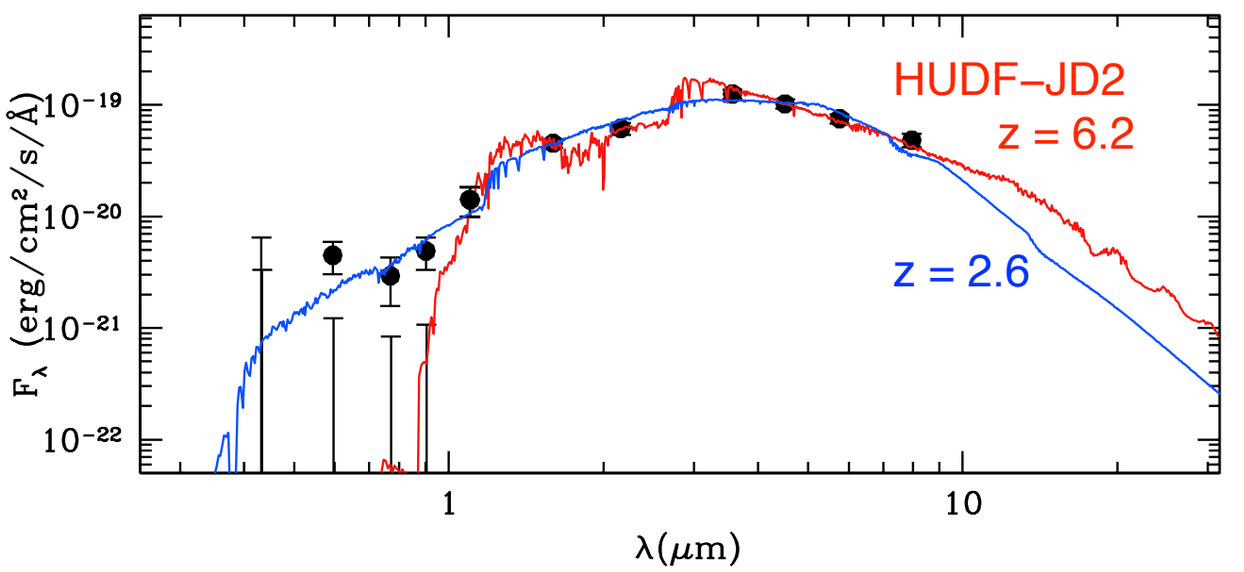
The Highest Redshift Gamma-Ray Bursts

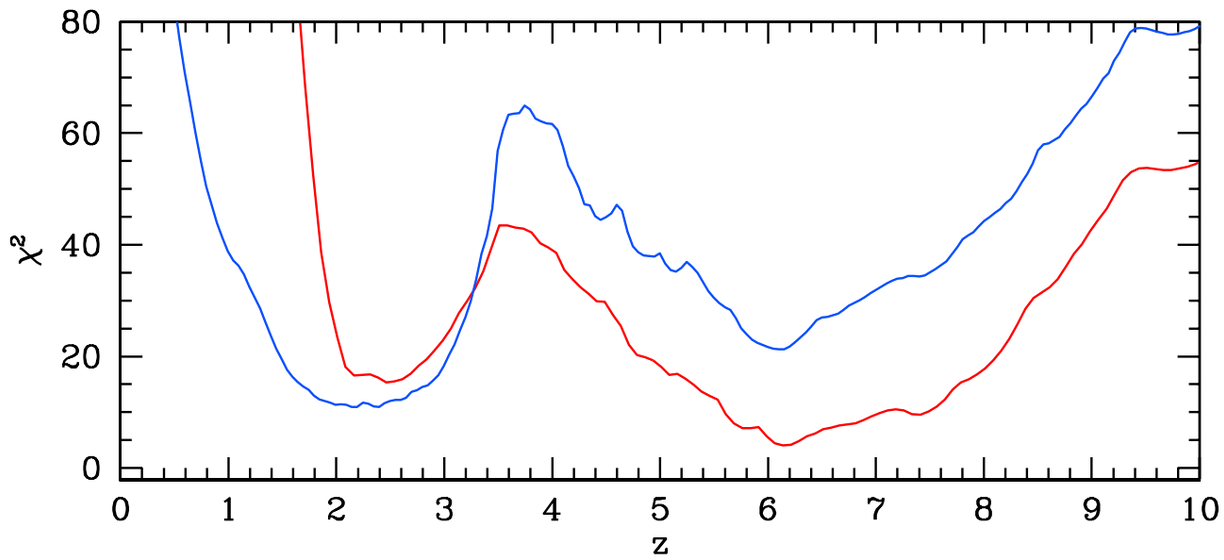
Cucchiara et al. (2011)





Dunlop, Cirasuolo, McLure 2007





The blessing and the curse

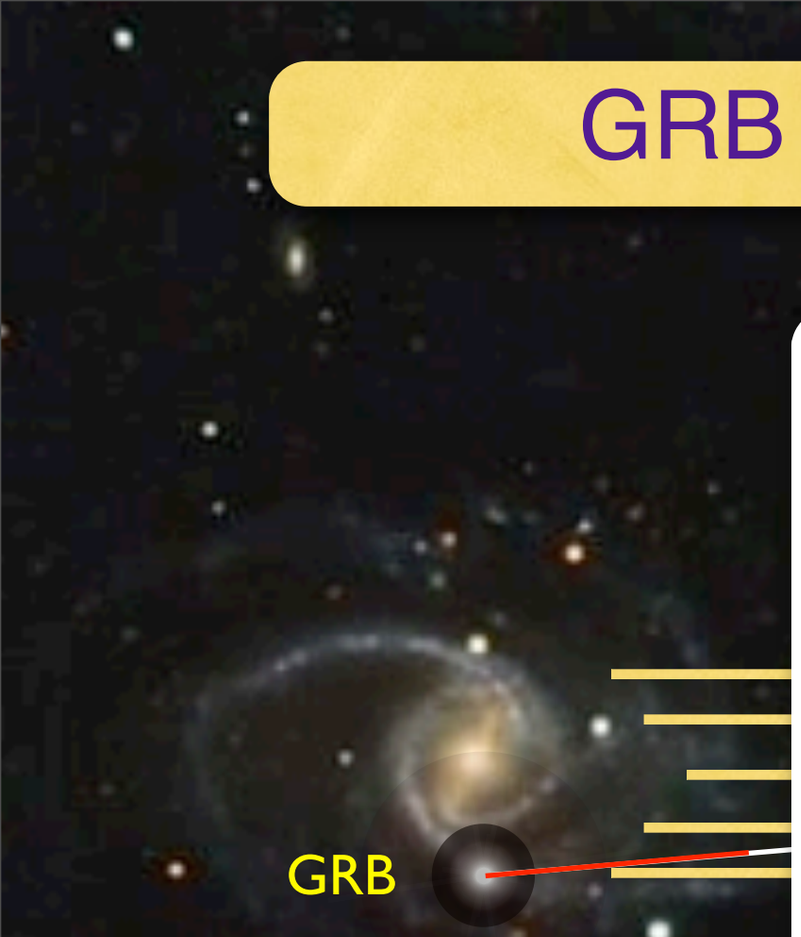
They fade away very quickly

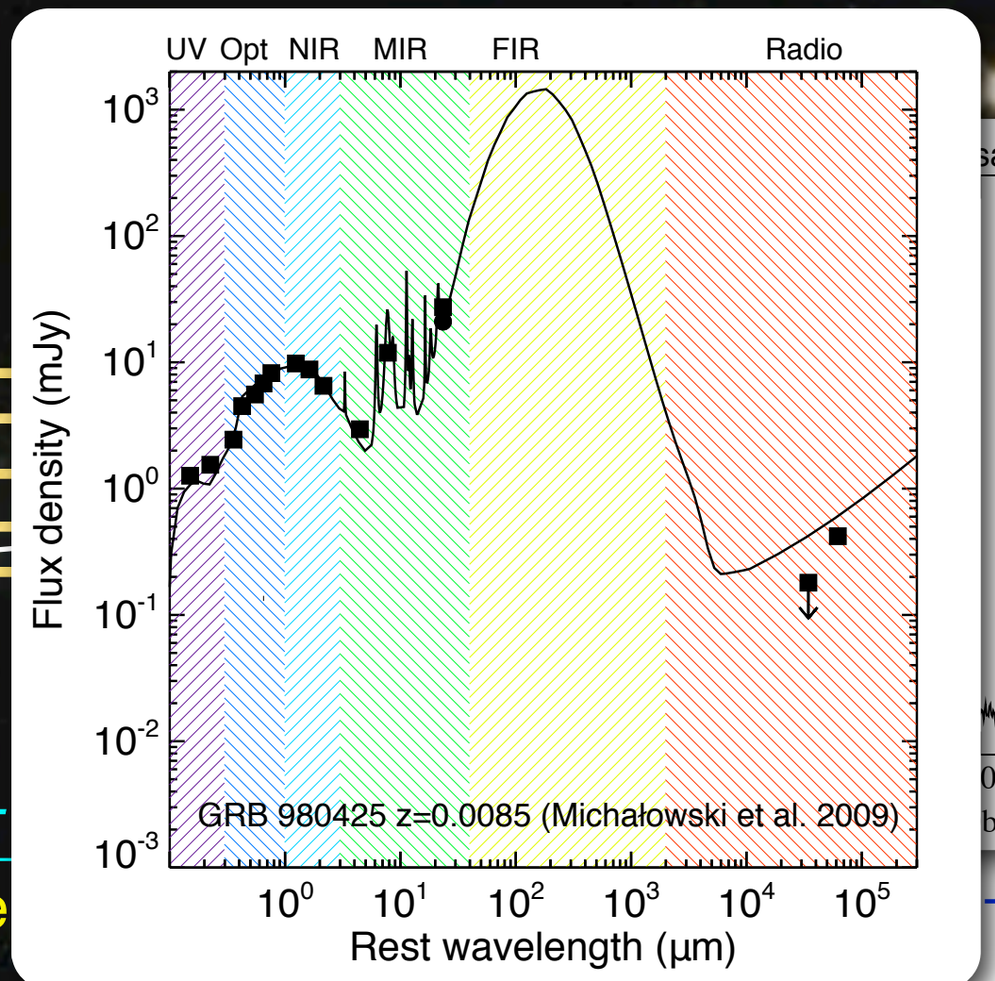
They fade away very quickly

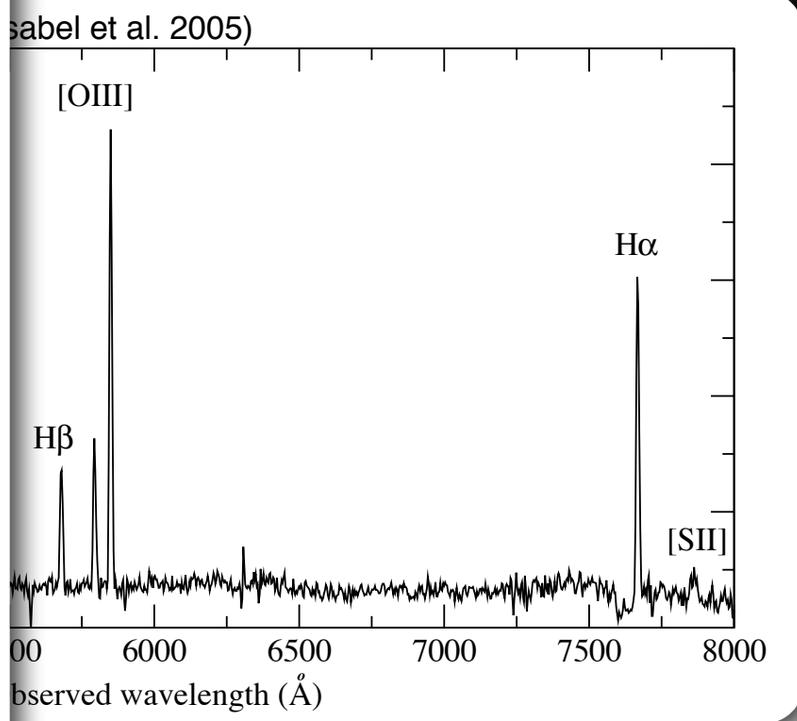
GRBs and the Cosmic Chemical Evolution

QSO

GRB afterglows and host galaxies



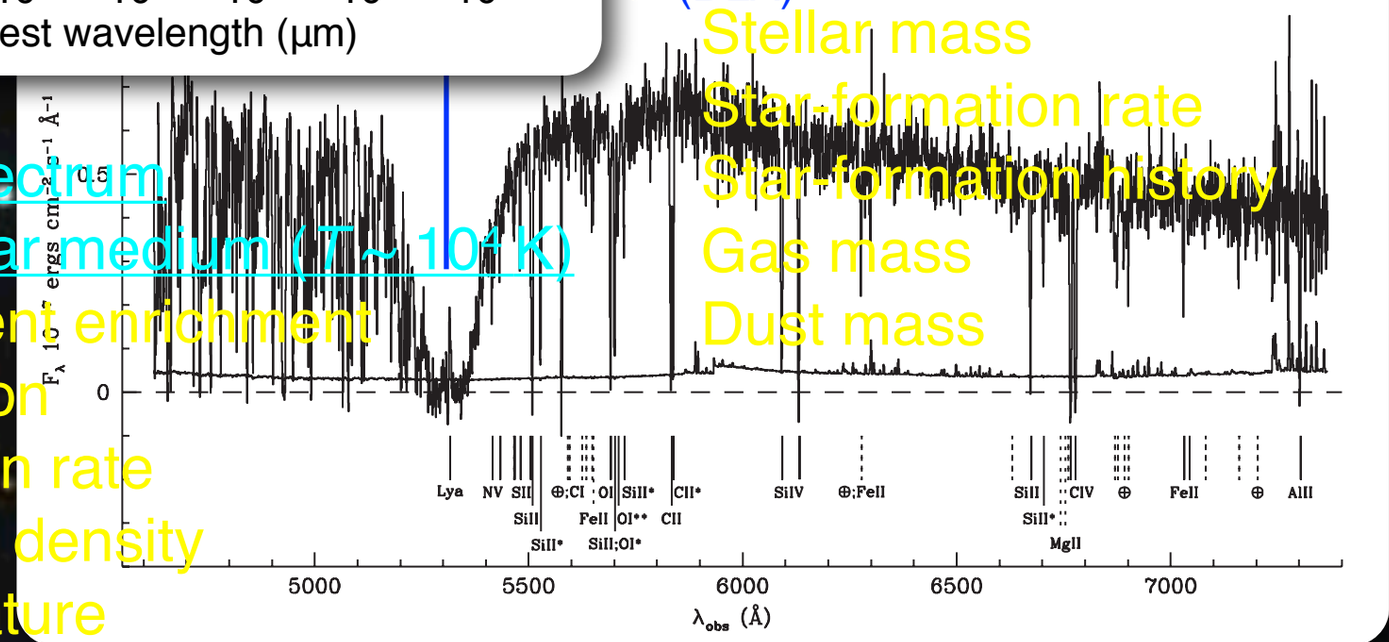




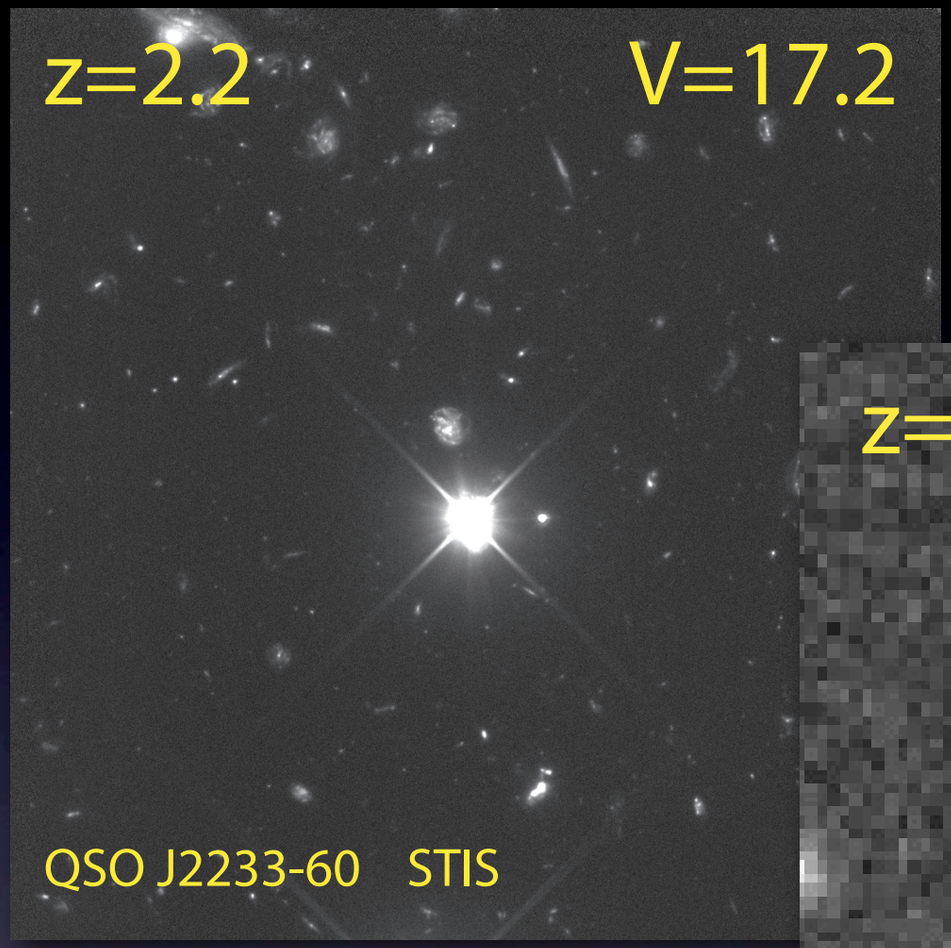
[Afterglow spectrum](#)
[Cold interstellar medium (*T*](#)
- Heavy element enrichme
- Molecular hydrogen
- Dust extinction
- Dust depletion

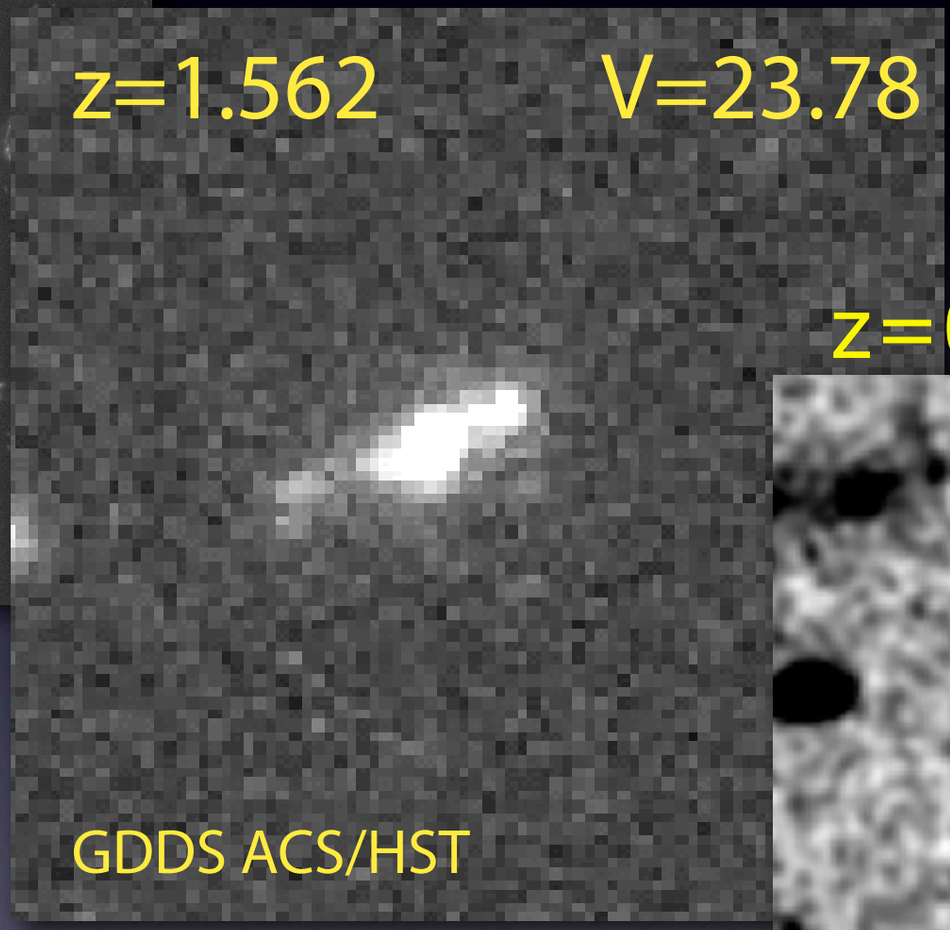
[Host galaxy spectrum](#)
[Warm interstellar medium (*T* ~ 10⁴ K)](#)
- Heavy element enrichment
- Dust extinction
- Star formation rate
- Gas electron density
- Gas temperature

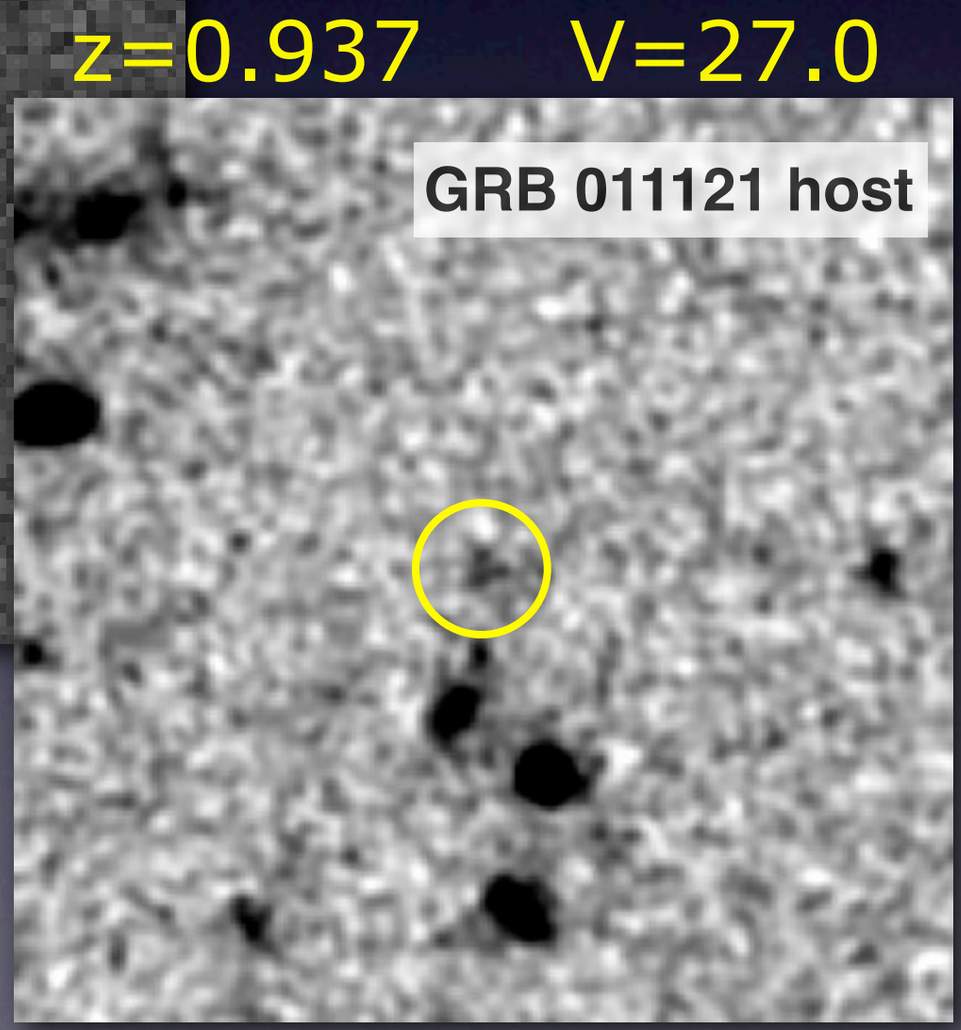
[Spectral Energy Distribution](#)
- α (DLA)
- Stellar mass
- Star-formation rate
- Star-formation history
- Gas mass
- Dust mass



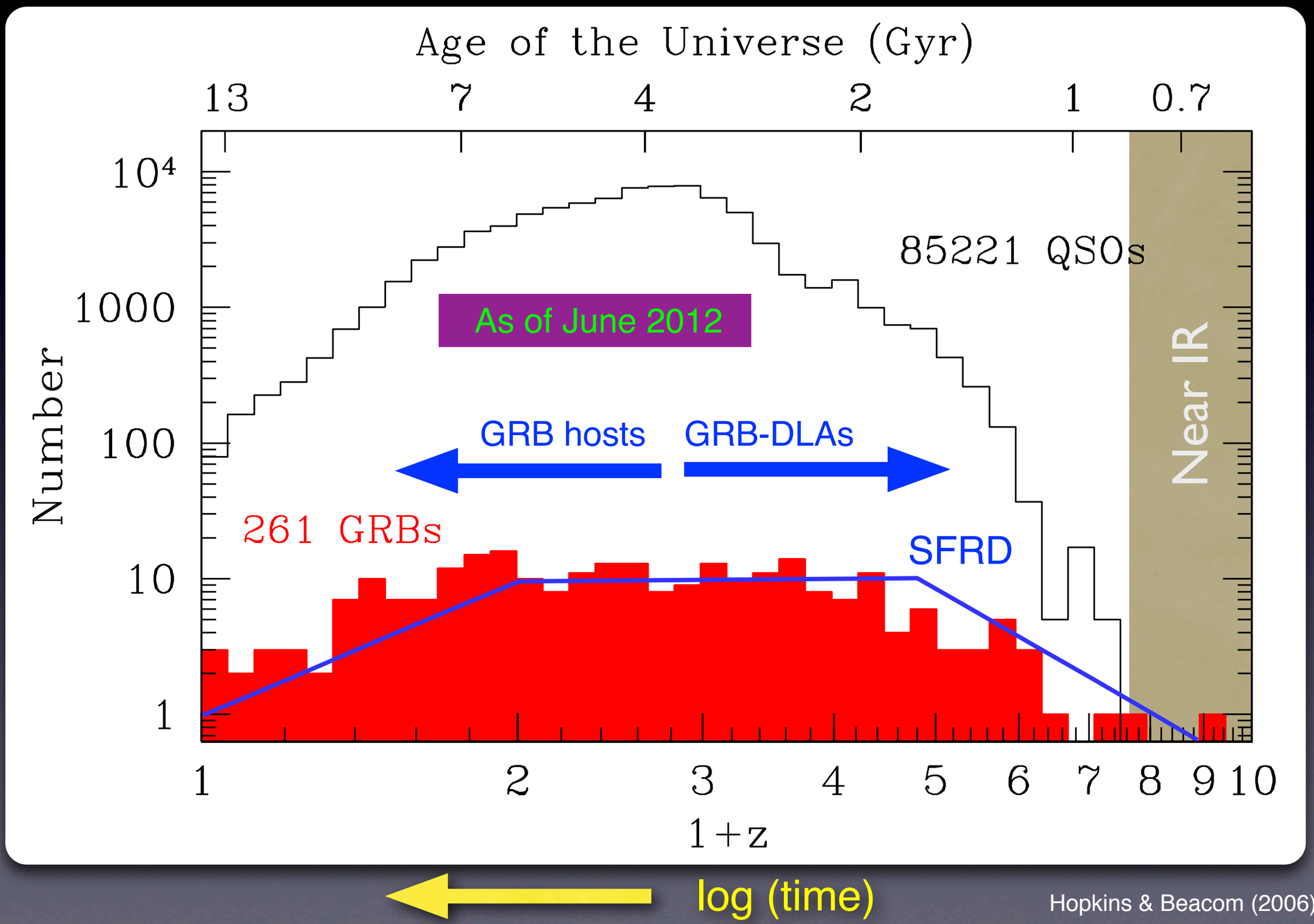
High redshift galaxies







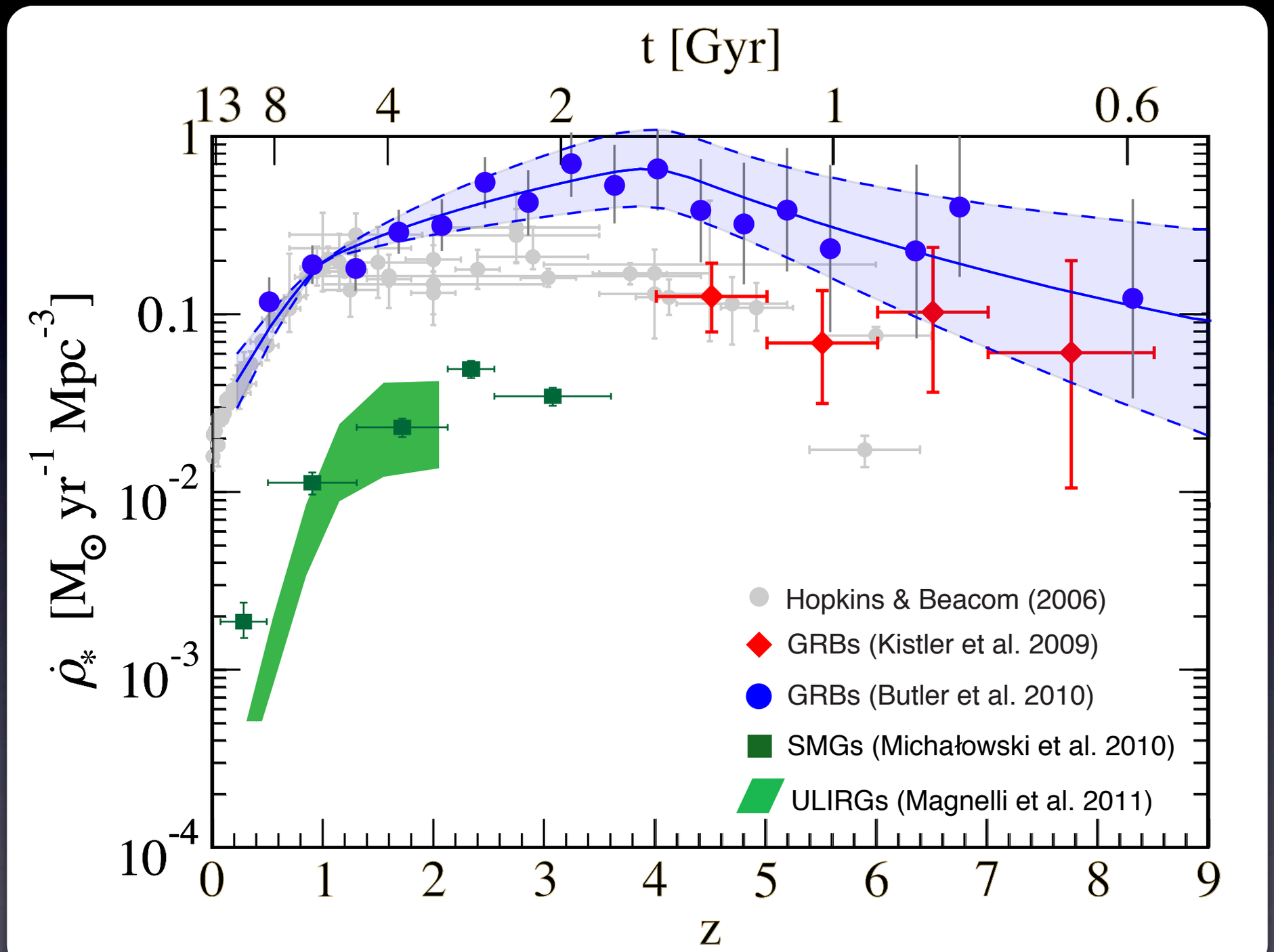
Gamma-Ray Burst redshift distribution



log (time)

Hopkins & Beacom (2006)

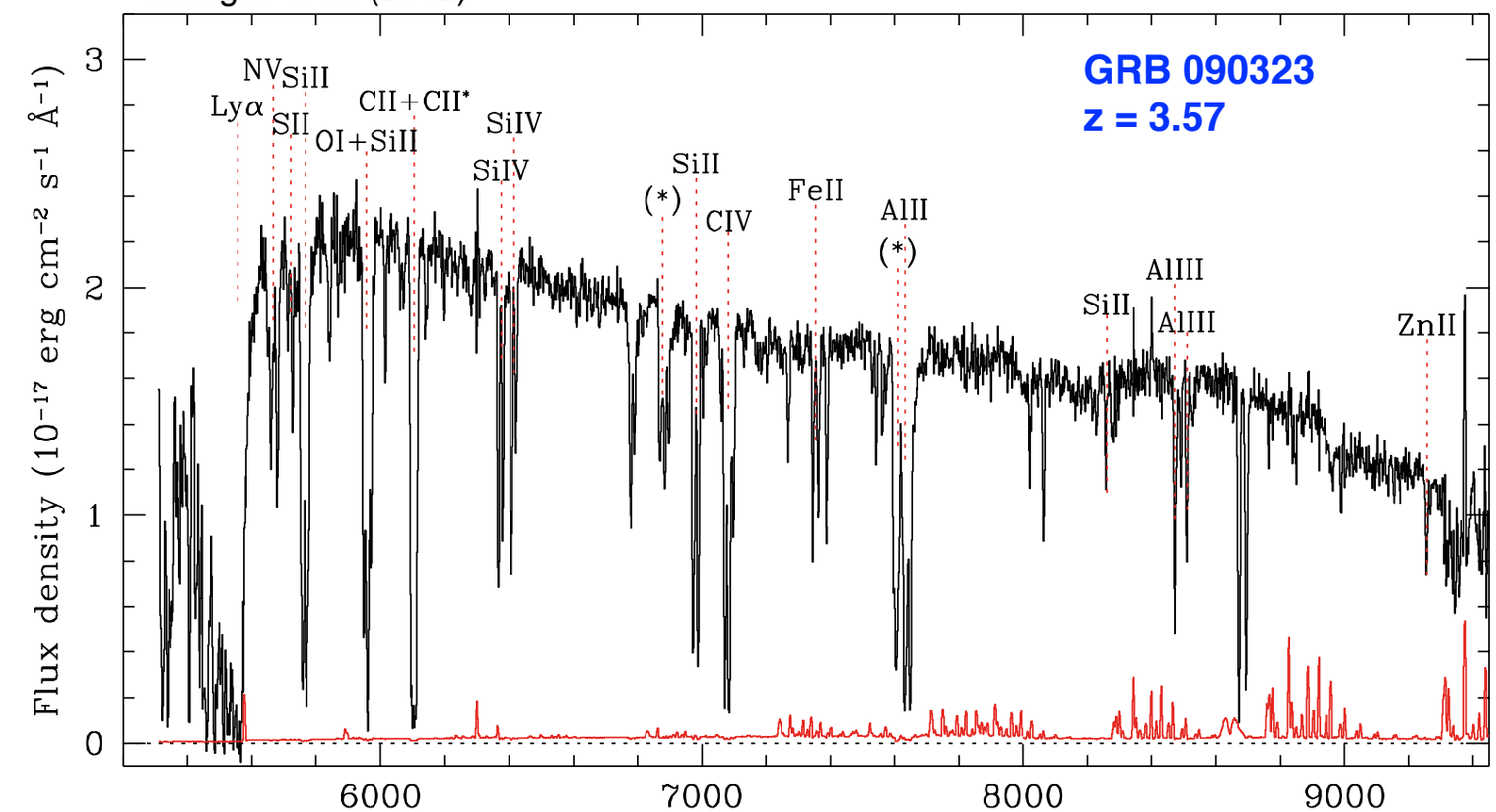
Star Formation Rate Density of the Universe



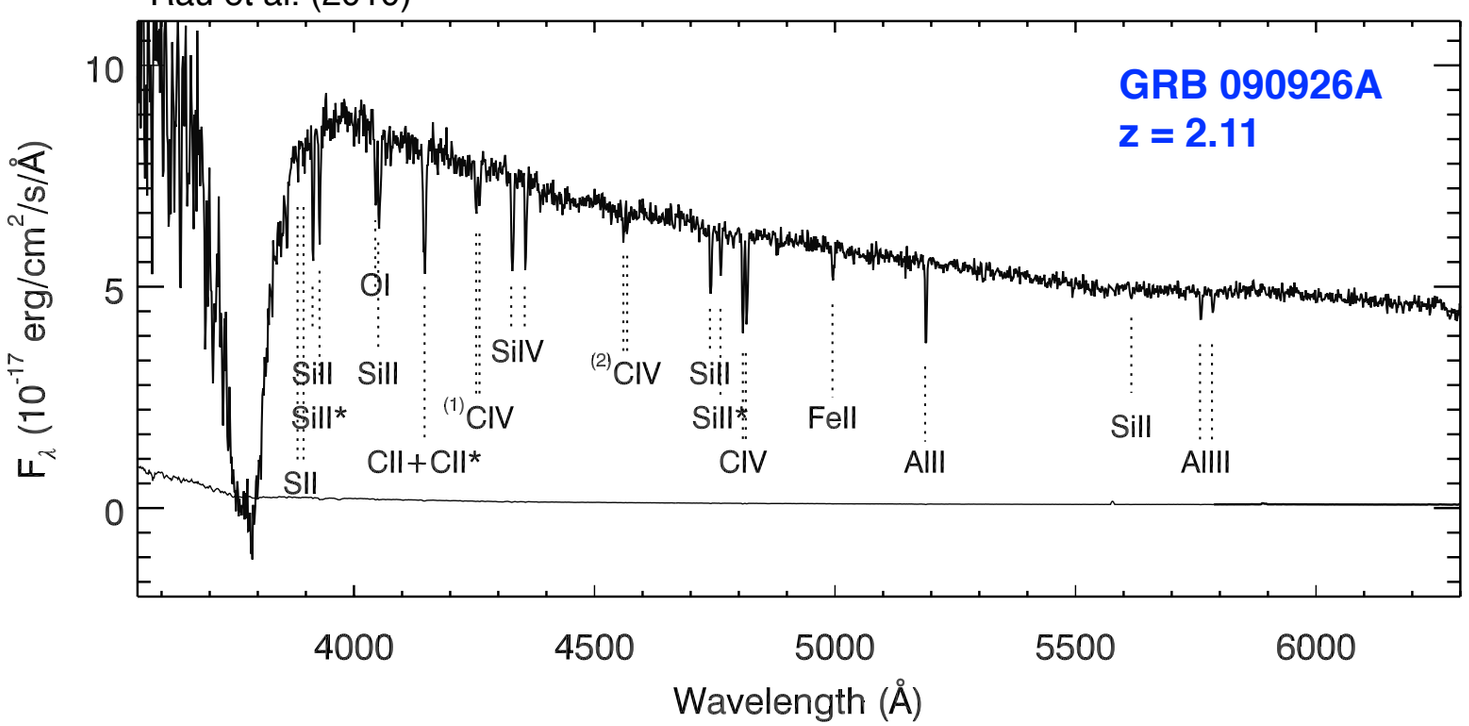
(see also Elliott et al. 2012)

The highest and lowest metallicity GRB-DLAs

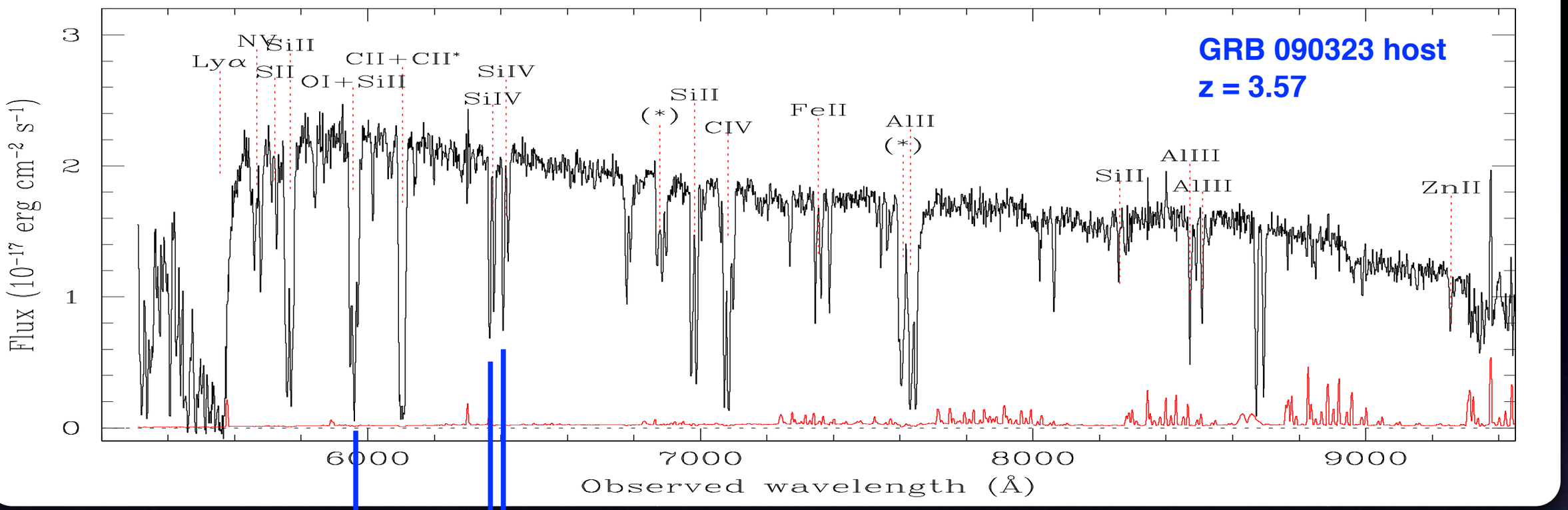
Savaglio et al. (2012)



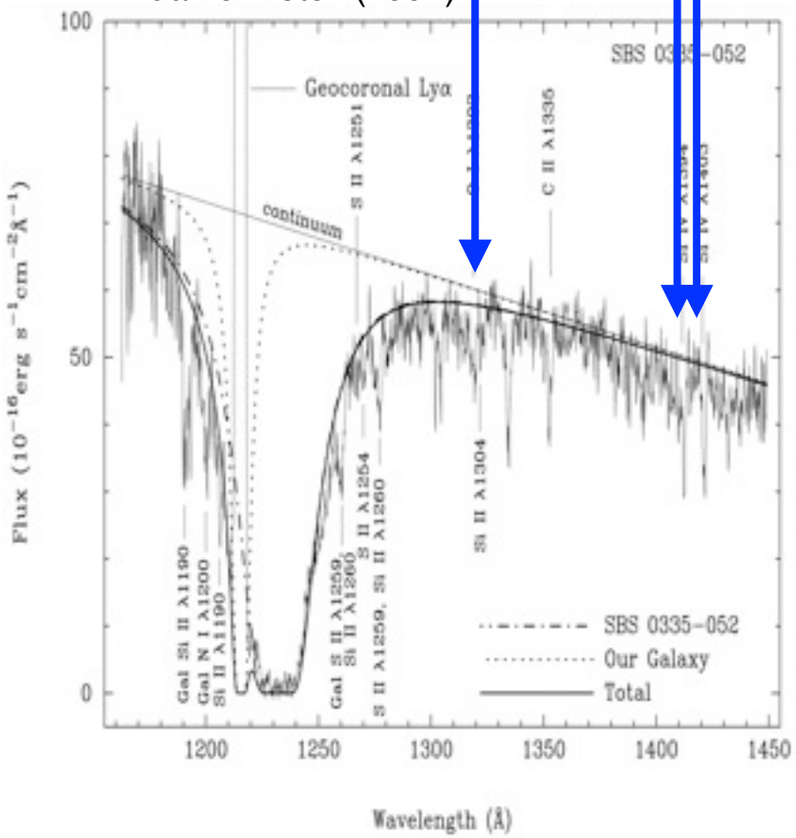
Rau et al. (2010)



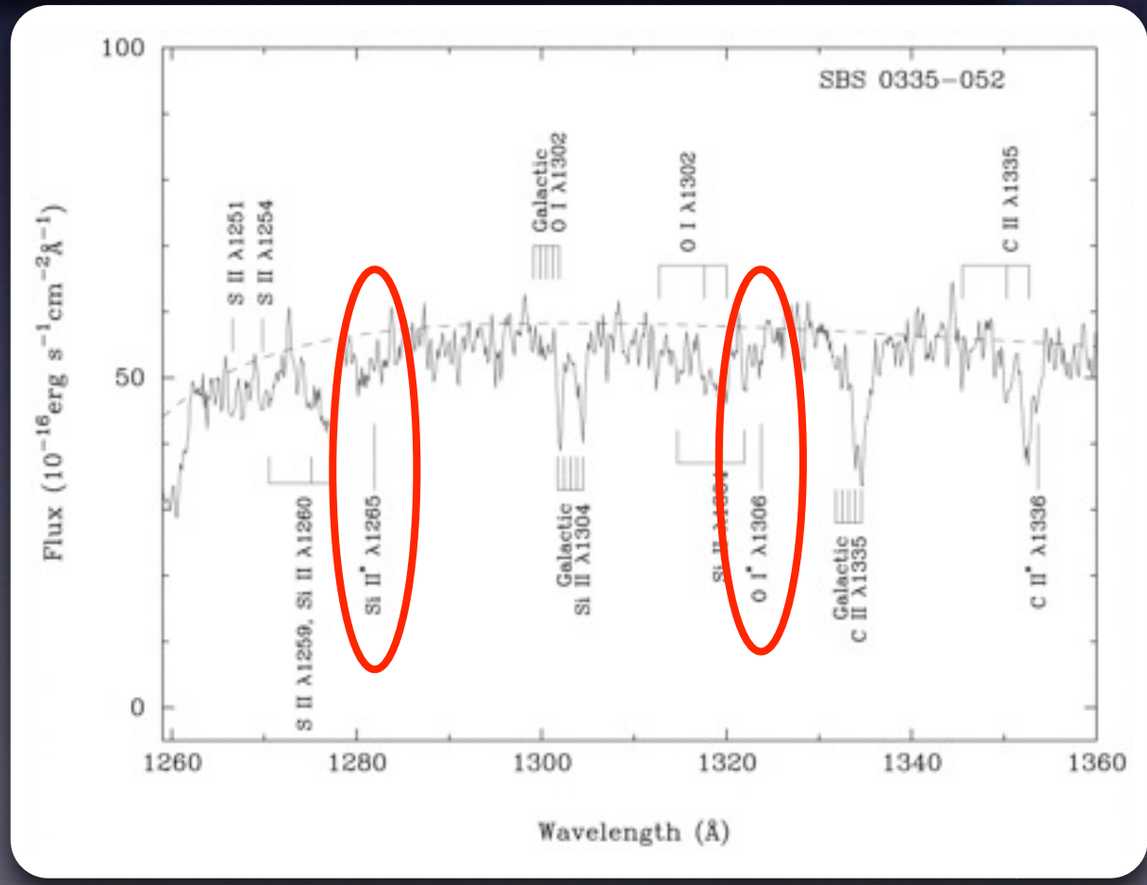
Is there a typical GRB host?



Thuan & Izotov (1997)



Local dwarf galaxy
SBS 0335-052
z = 0.0125



Is there a typical GRB host?

Local dwarf galaxy

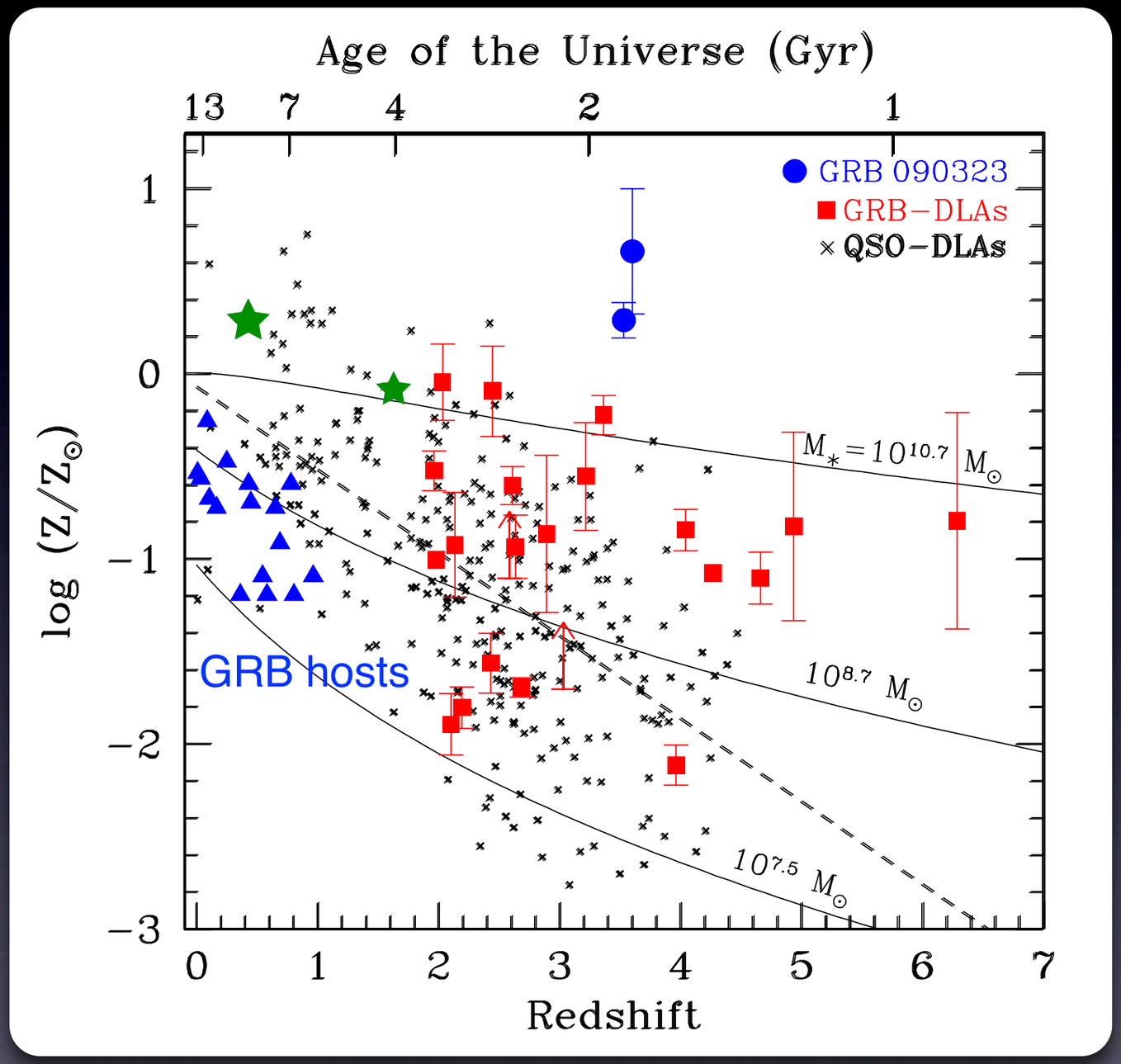
Low-z GRB host

High-z GRB host

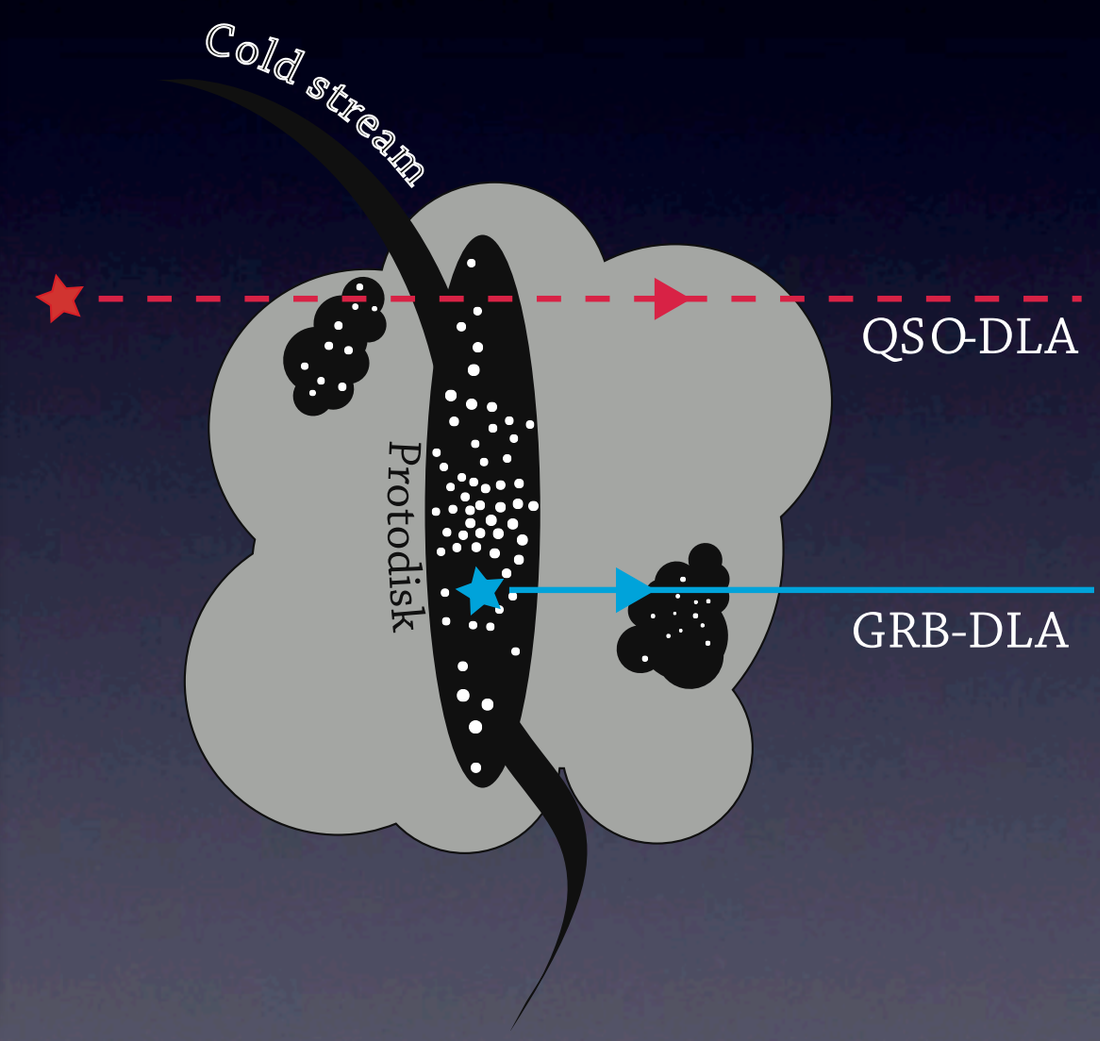
	SBS 0335-052	**GRB 980425 host**	**GRB 090323 host**
Redshift	0.0125	0.0085	3.57
M_B	-16.9	-18.6	-24.9
Size	6×5 kpc^2	30×20 kpc^2	< 6 kpc
log ($Z/Z_\odot$)	-1.4	-0.5	+0.25
M(HI)	~ 8×10^8 M$_\odot$	–	–
M(star)	~ 4×10^7 M$_\odot$	~ 2×10^9 M$_\odot$	~ 6×10^{10} M$_\odot$
SFR	0.5 M$_\odot$ yr^{-1}	0.2 M$_\odot$ yr^{-1}	> 6 M$_\odot$ yr^{-1}
SSFR	12.5 Gyr^{-1}	0.1 Gyr^{-1}	> 0.1 Gyr^{-1}
N(HI)	7.0×10^{21} cm^{-2}	–	5.6×10^{20} cm^{-2}
Age	< 400 Myr	~ 900 Myr	< 500 Myr

Cosmic chemical evolution

Levesque et al. (2010) **Krühler et al. (2012)**



Savaglio (2006)
Prochaska et al. (2007)
Fynbo et al. (2008)
Rau, Savaglio, Krühler, Afonso, Greiner et al. (2010)
Savaglio, Rau, Greiner, Krühler et al. (2012)
Based on modeling in Savaglio et al. (2005)

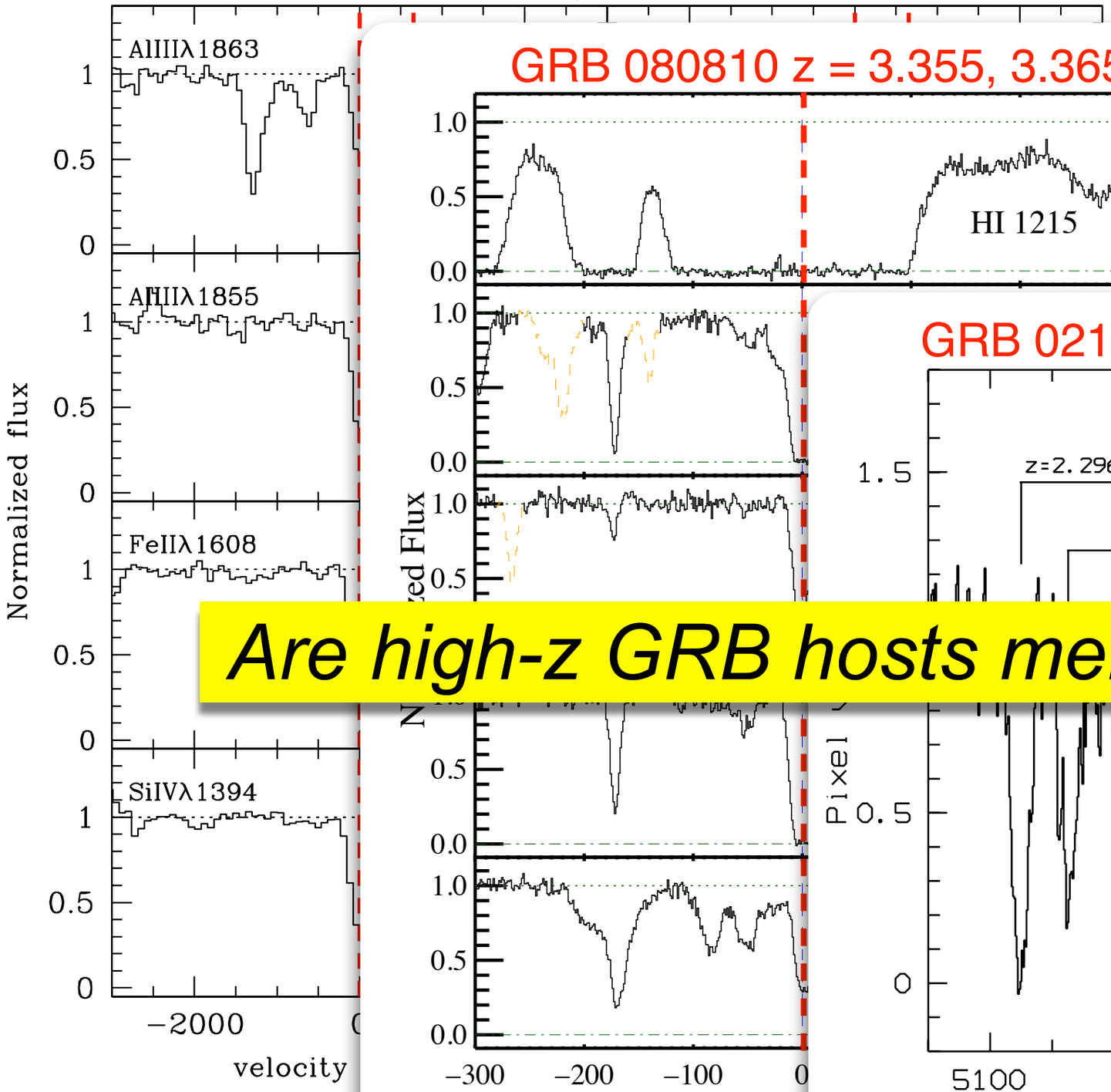


Pontzen et al. (2010)

High-z GRB hosts are merging systems?

Double absorbers in high-z GRB afterglows

GRB 090323 z = 3.567, 3.577



Savaglio, Rau, Greiner, K[illegible] (2012)

GRB 080810 z = 3.355, 3.365

Page et al. (2009)

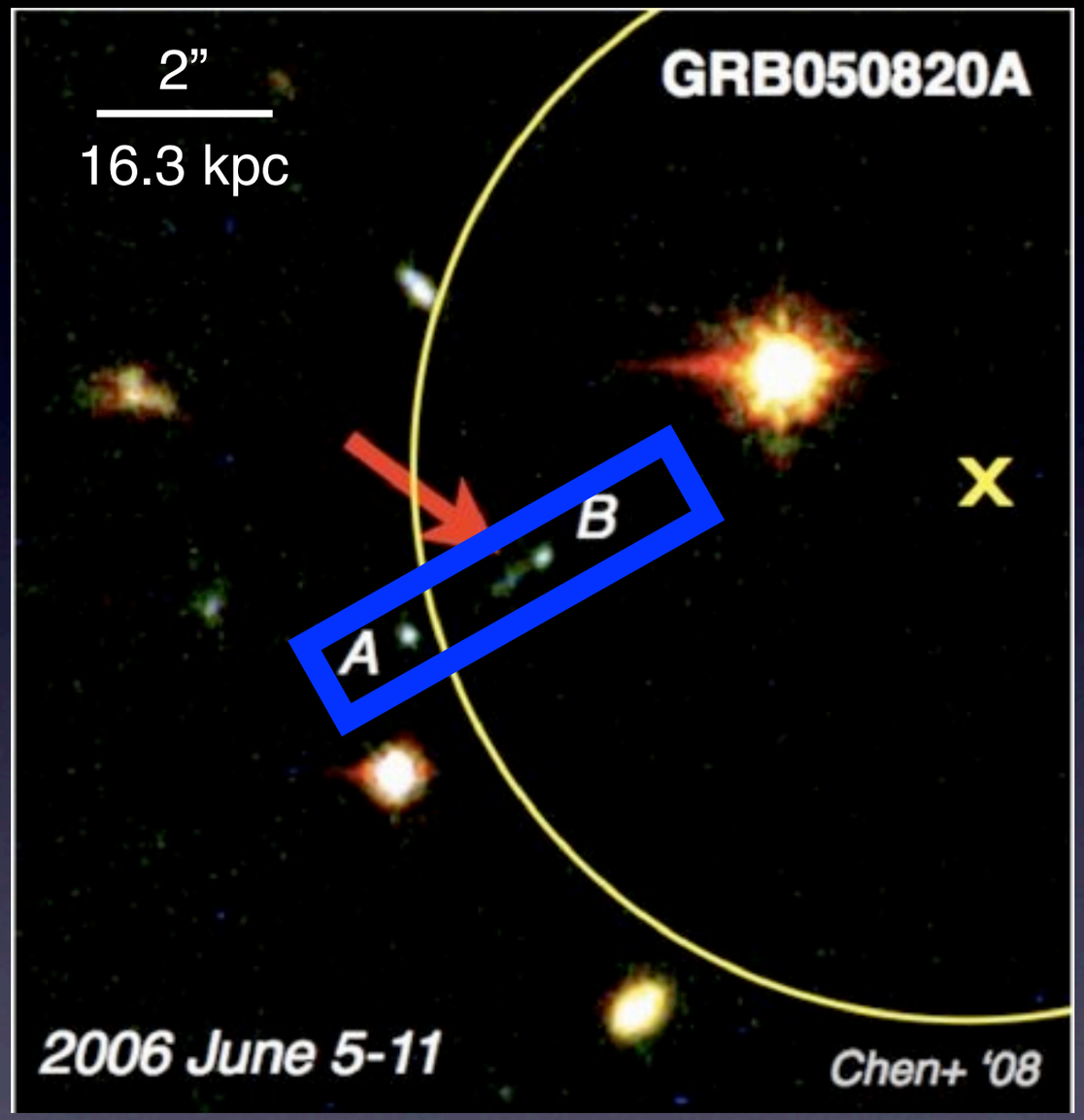
GRB 021004 z = 2.321, 2.328

Fiore et al. (2005)
Castro Tirado et al. (2010)

Are high-z GRB hosts merging systems?

The interacting-galaxies idea

GRB 050820 z = 2.6147



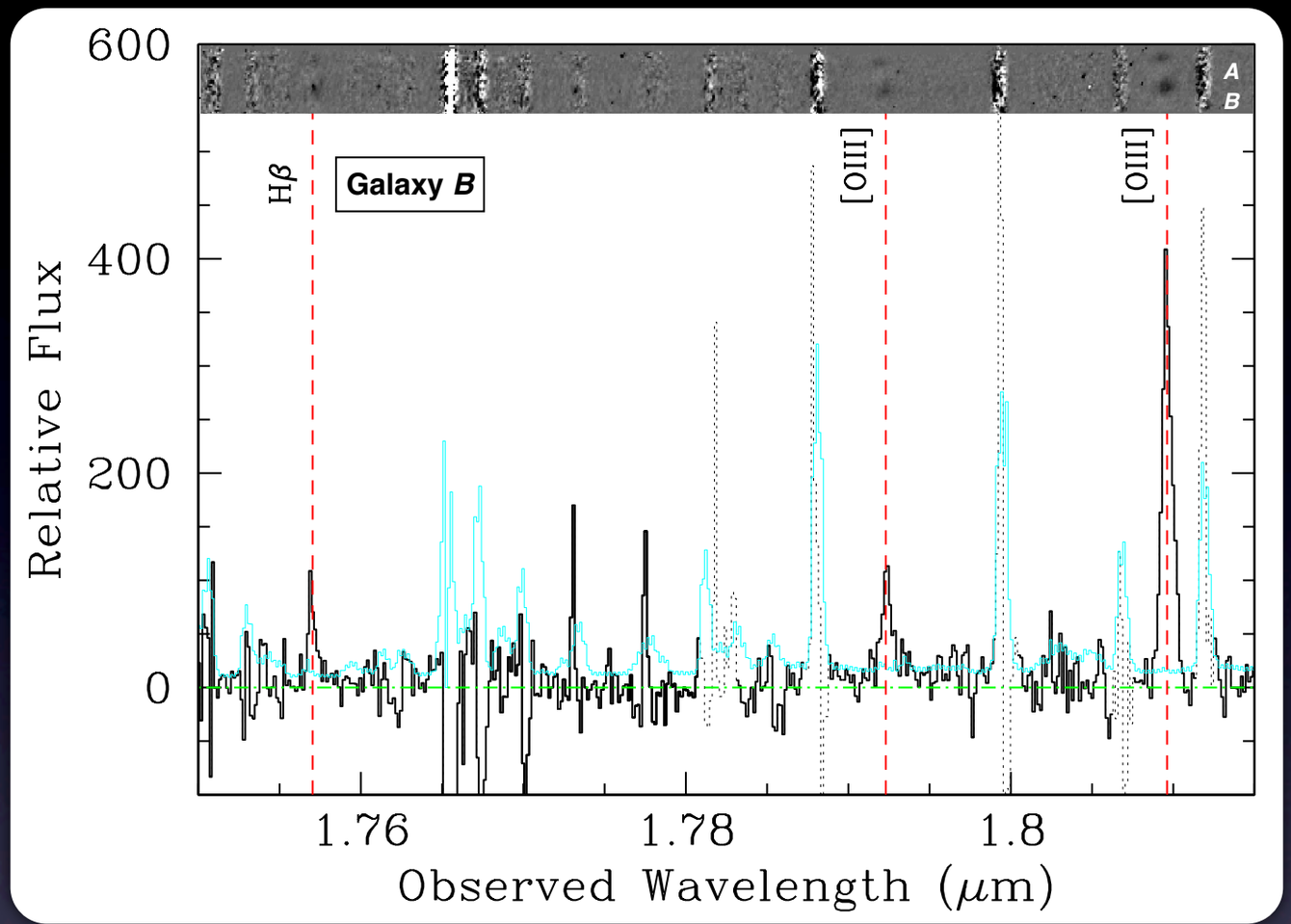
$M_\star = 10^{9.29\pm0.52}\ M_\odot$

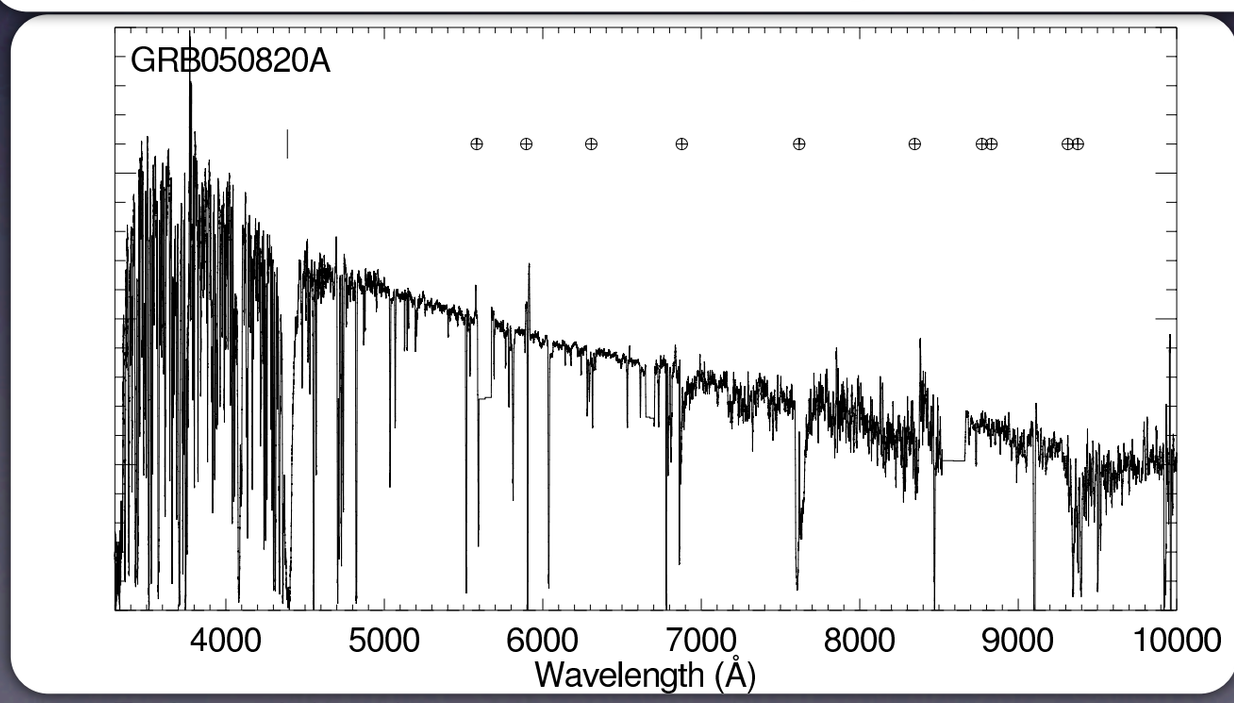
$\log N_{HI} = 21.0\pm0.1$

$\log Z/Z_\odot = -0.6\pm0.1$

SFR ~ 0.6 $M_\odot\ yr^{-1}$

Chen (2012)





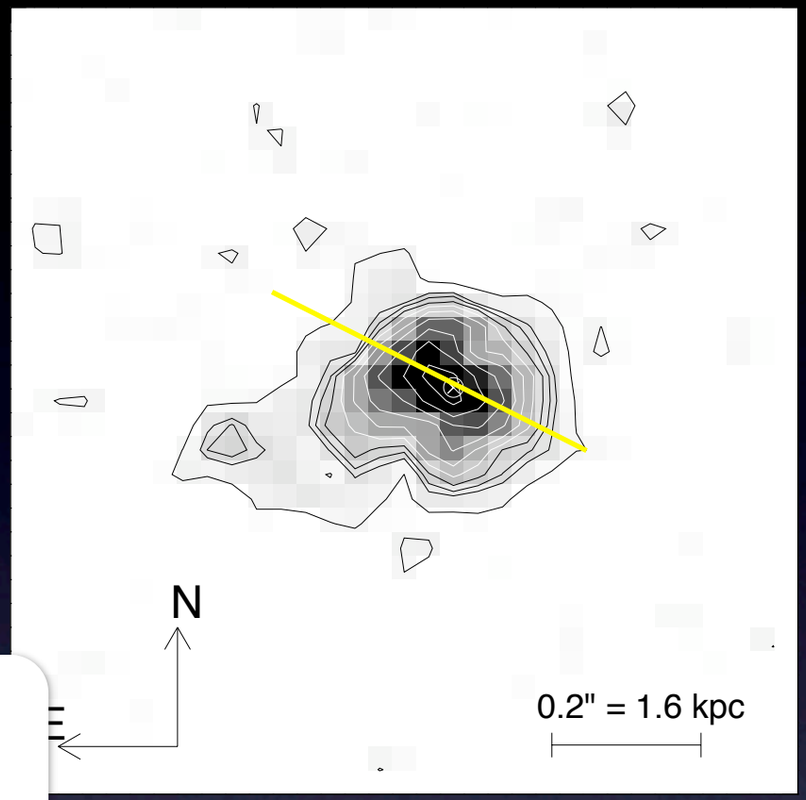
Fynbo et al. (2009)

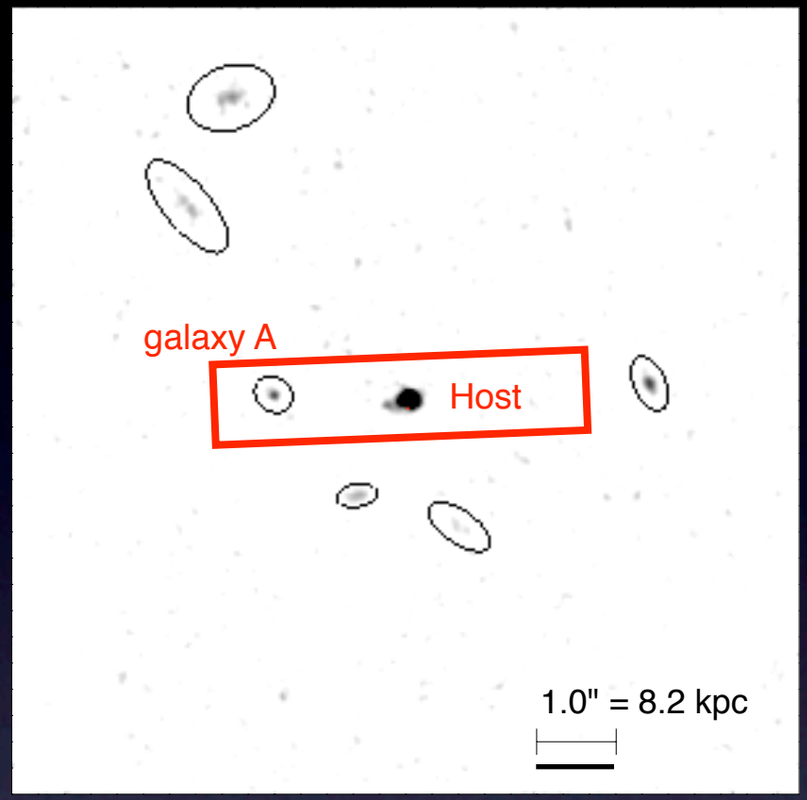
The interacting-galaxies idea

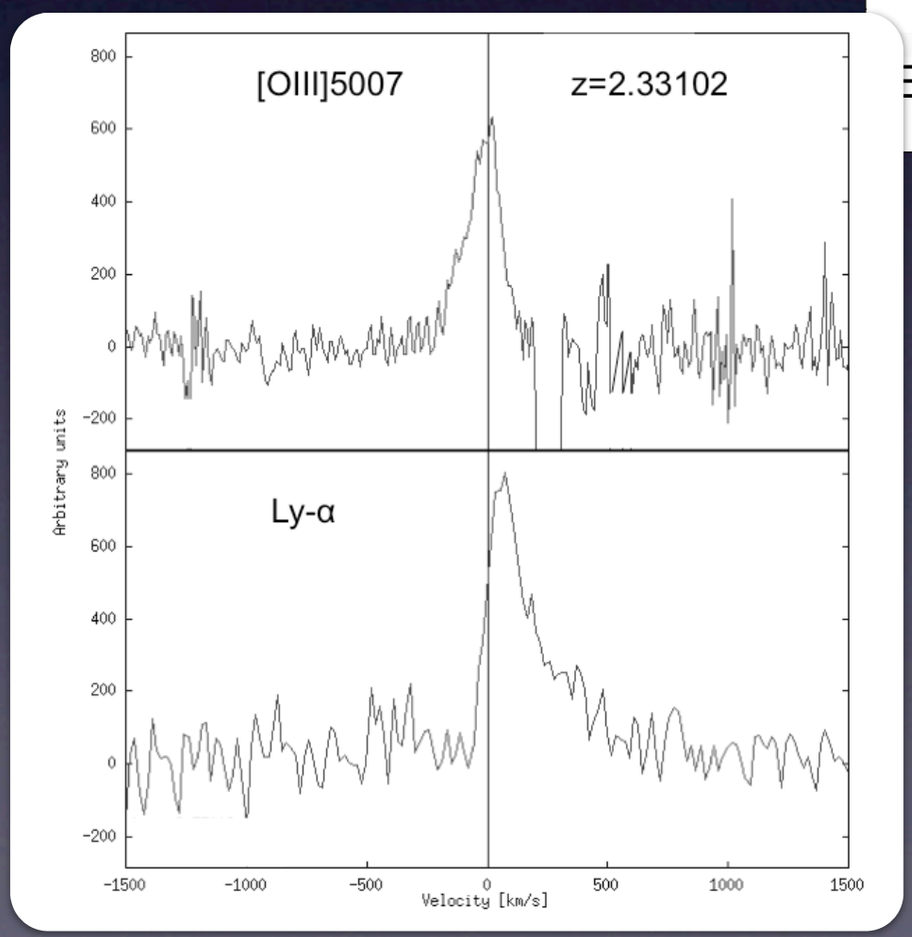
Host galaxy of long GRB 021004

$z = 2.33$ $M_* = 1.6\times10^{10}\,M_\odot$

SFR = 29 $M_\odot$ yr^{-1}

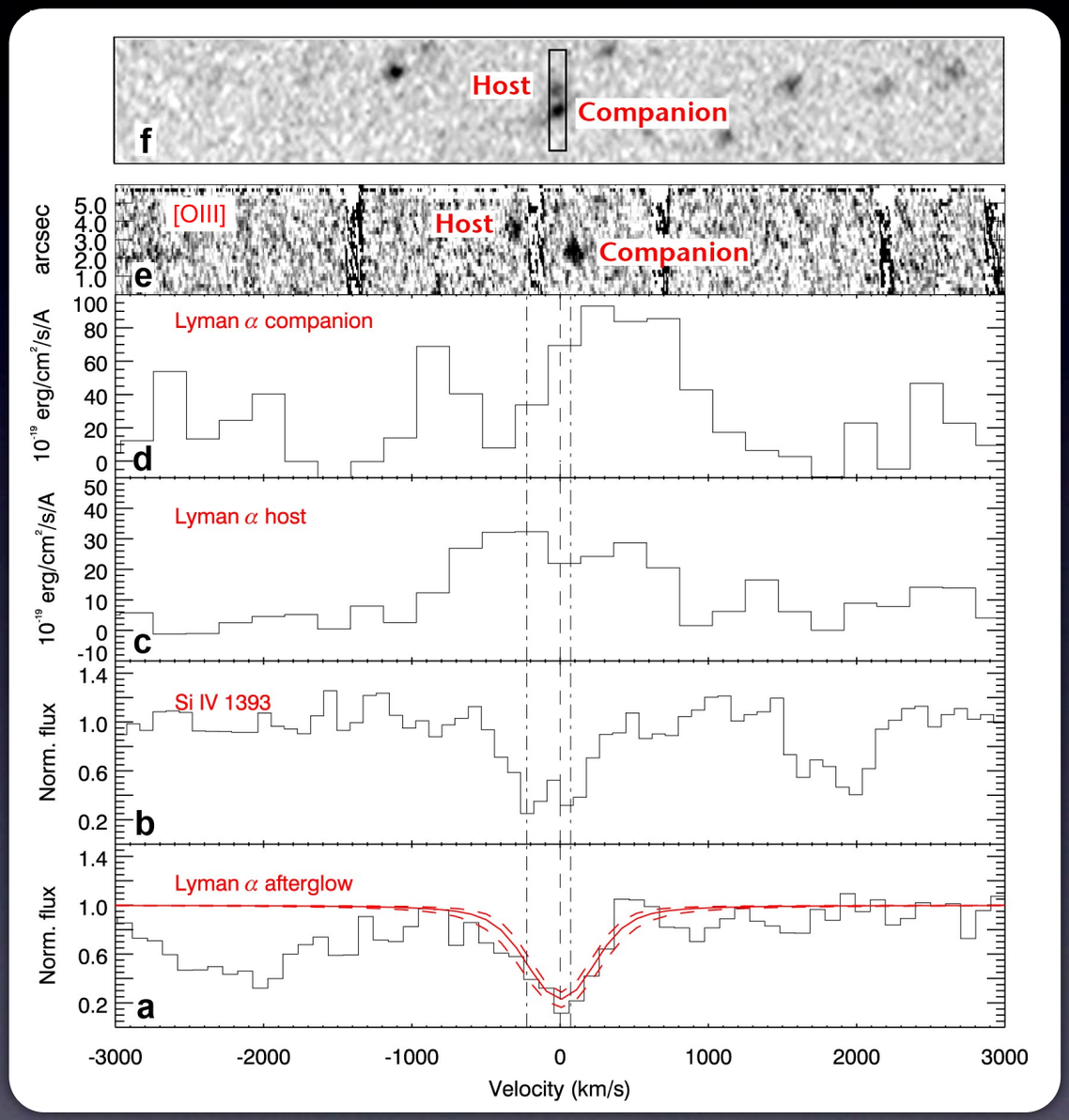




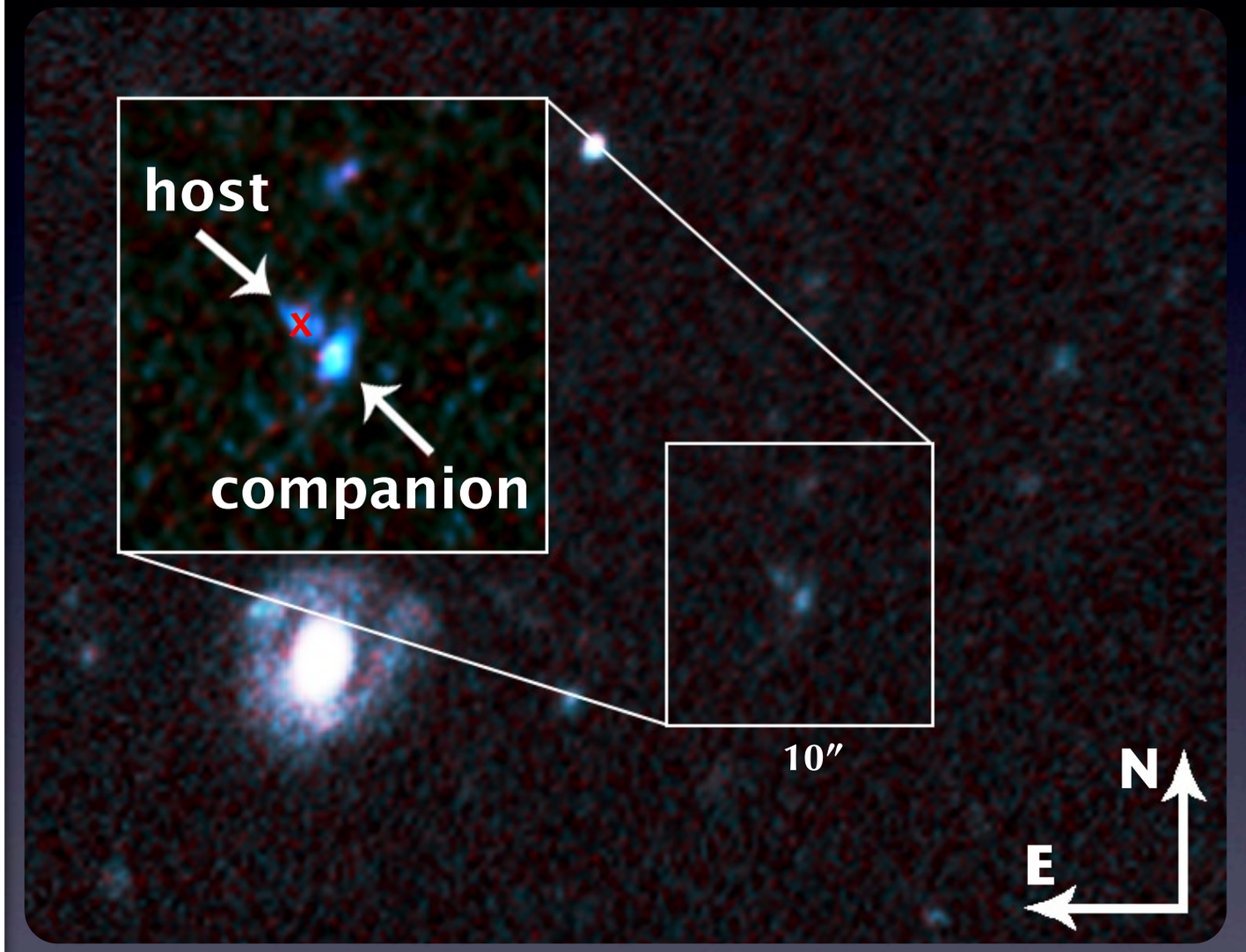


Vergani et al. (2011)

The interacting-galaxies idea



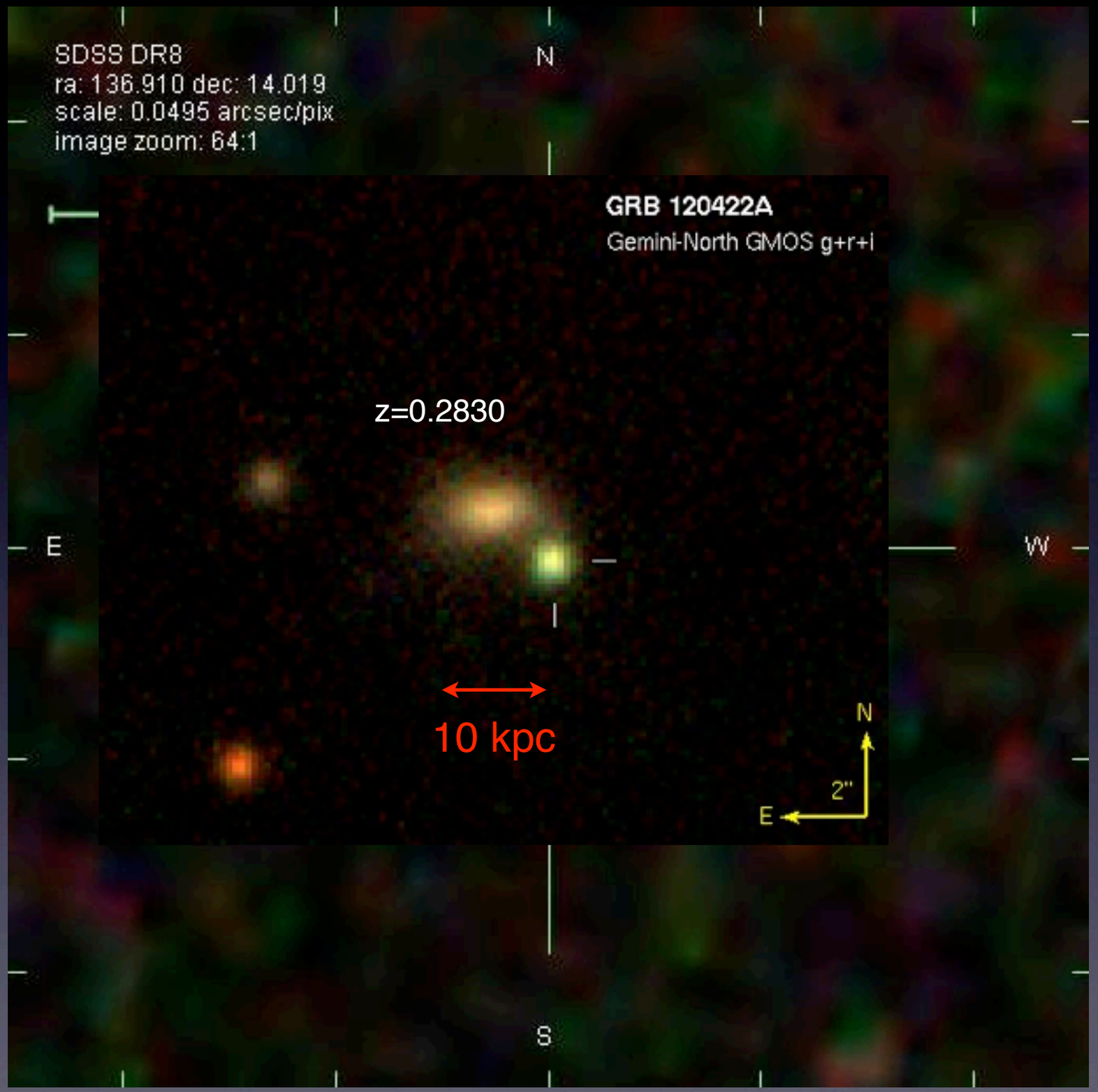
GRB 090426 z = 2.609



Thöne et al. (2011)
Levesque et al. (2010)

$M_\star = 6.5\times10^{10}\ M_\odot$
$\log N_{HI} = 18.7\pm0.1$
$SFR \sim 1.7\ M_\odot\ yr^{-1}$

The interacting-galaxies idea



Perley et al. (2012, GCN)

Perley et al. (2012)

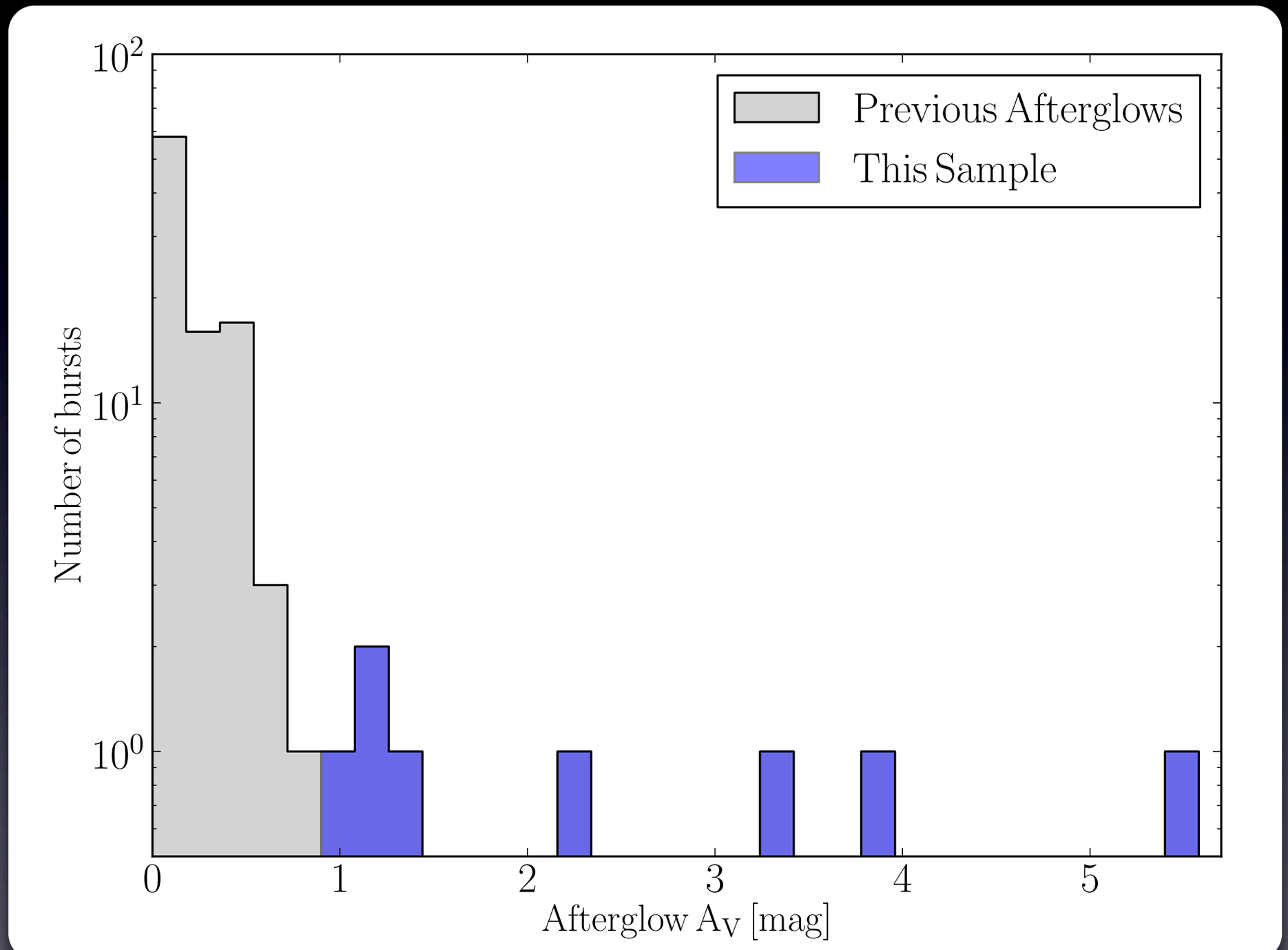
Mystic Mountain with HST

A multi-wavelength exploration of the GRB host population: from UV to radio

Mystic Mountain with HST

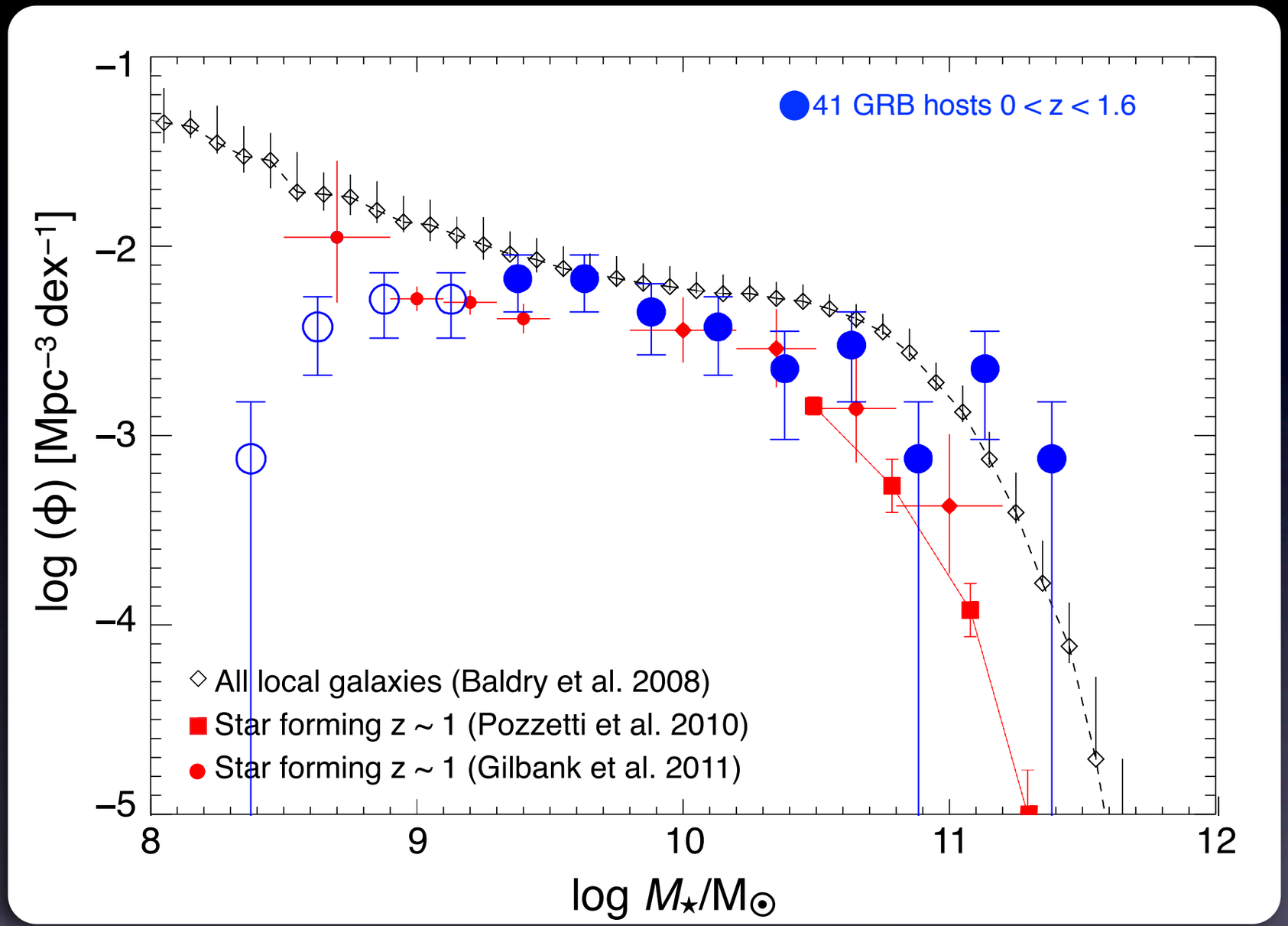
A multi-wavelength exploration of the GRB host population: from UV to radio

Dust extinction in GRBs



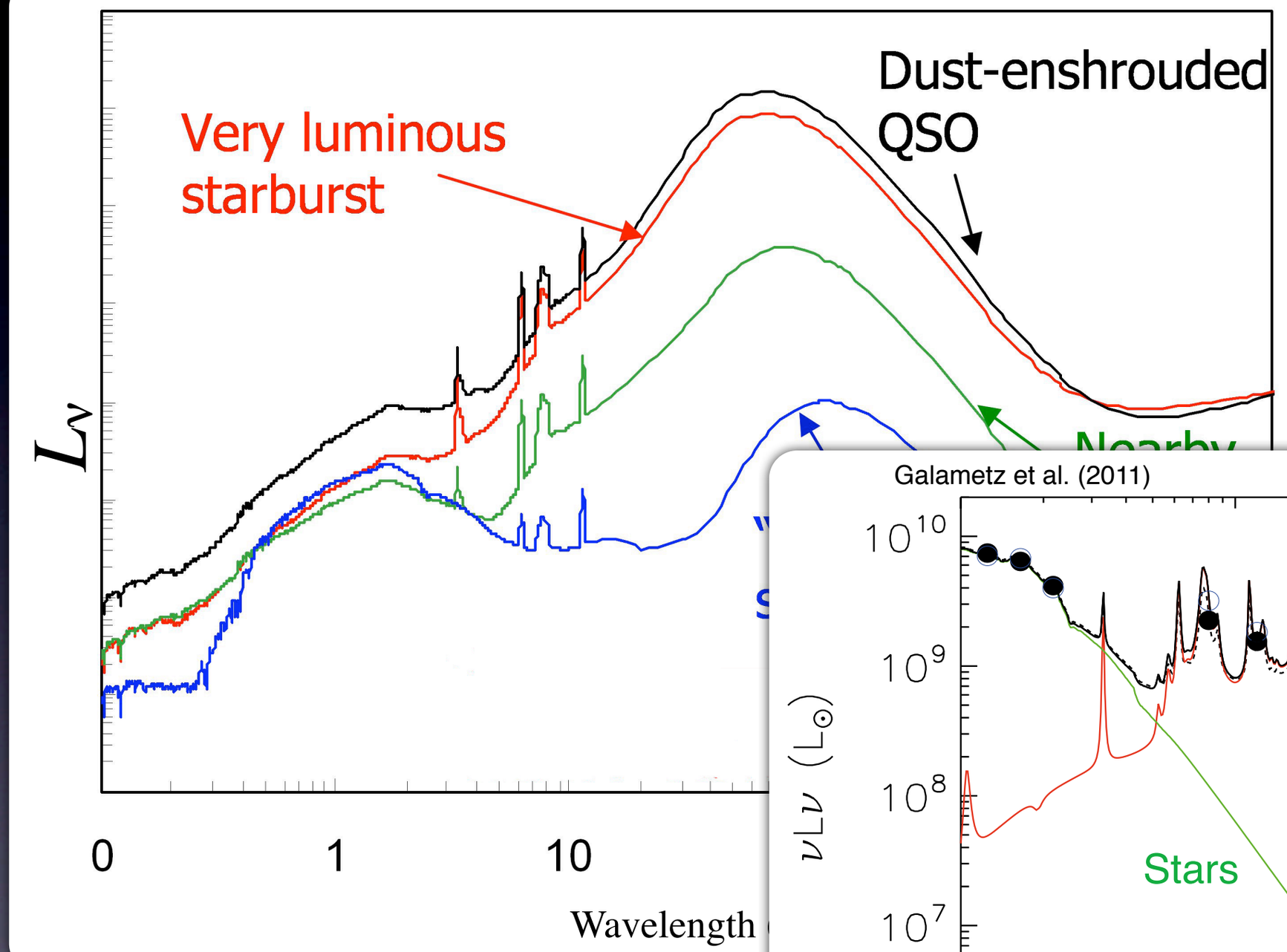
Krühler, Greiner, Schady et al. (2011, from complete GRB sample detected with GROND)

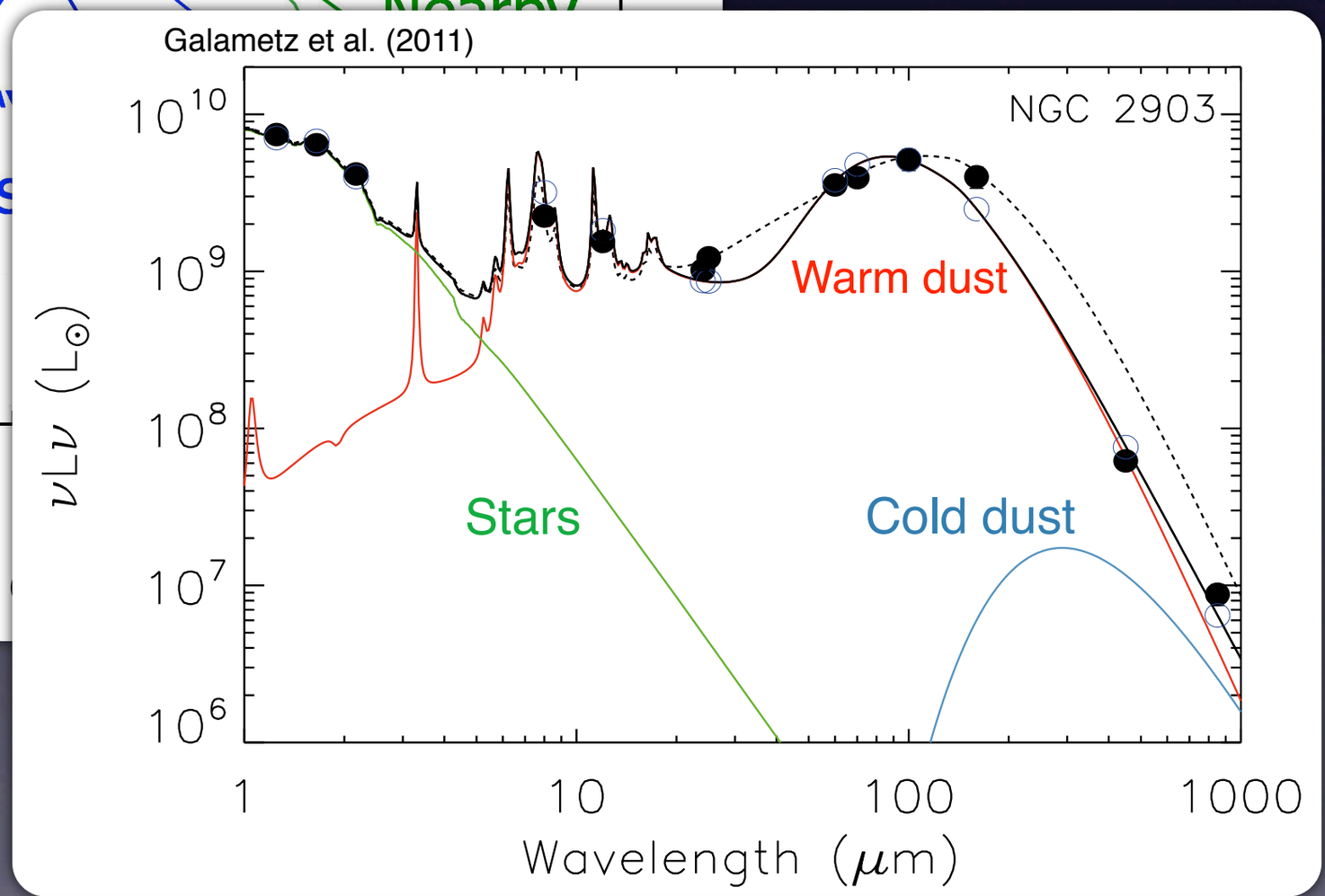
GRB host galaxy mass function



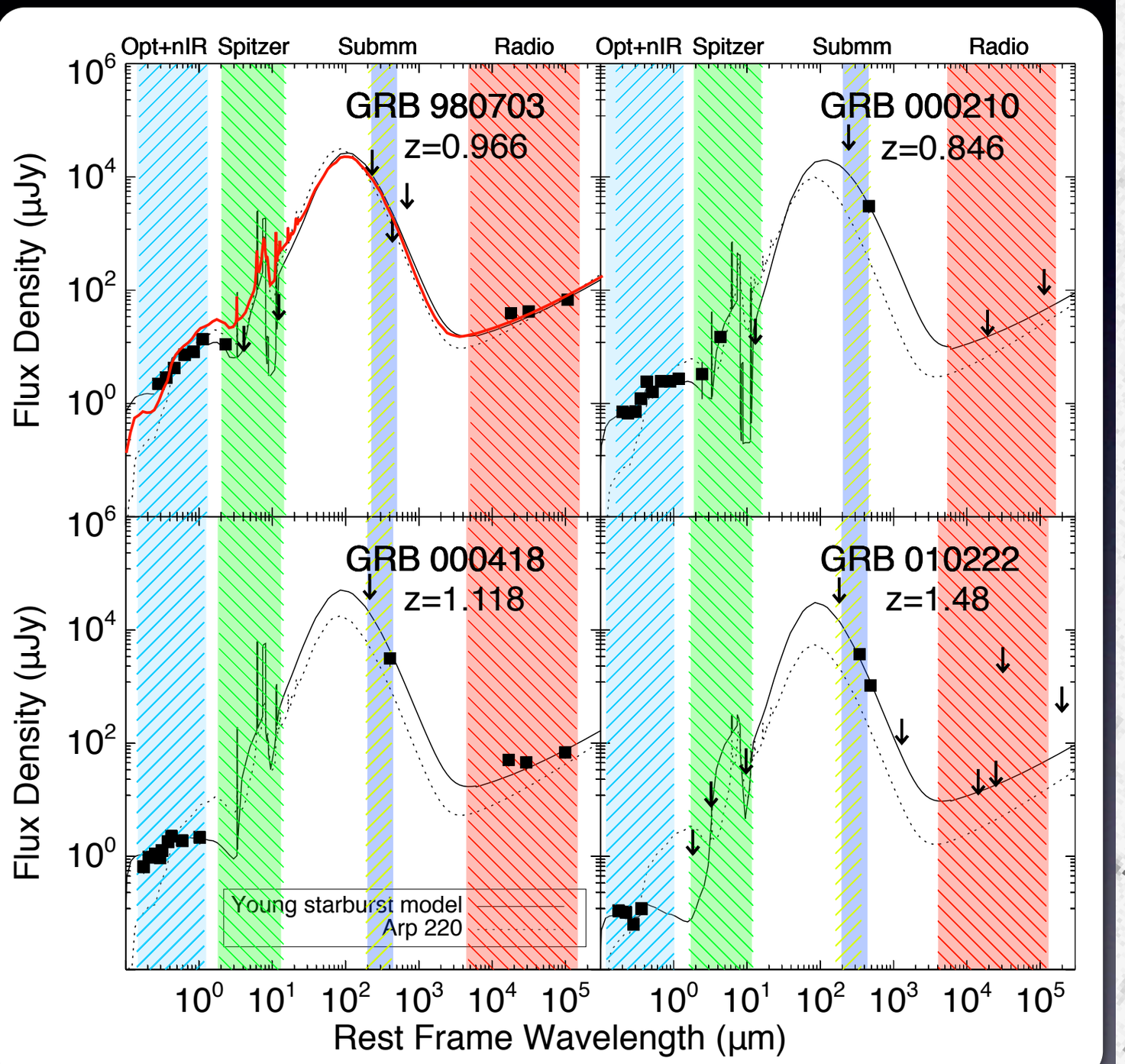
PRELIMINARY

Galaxy SED from UV to radio

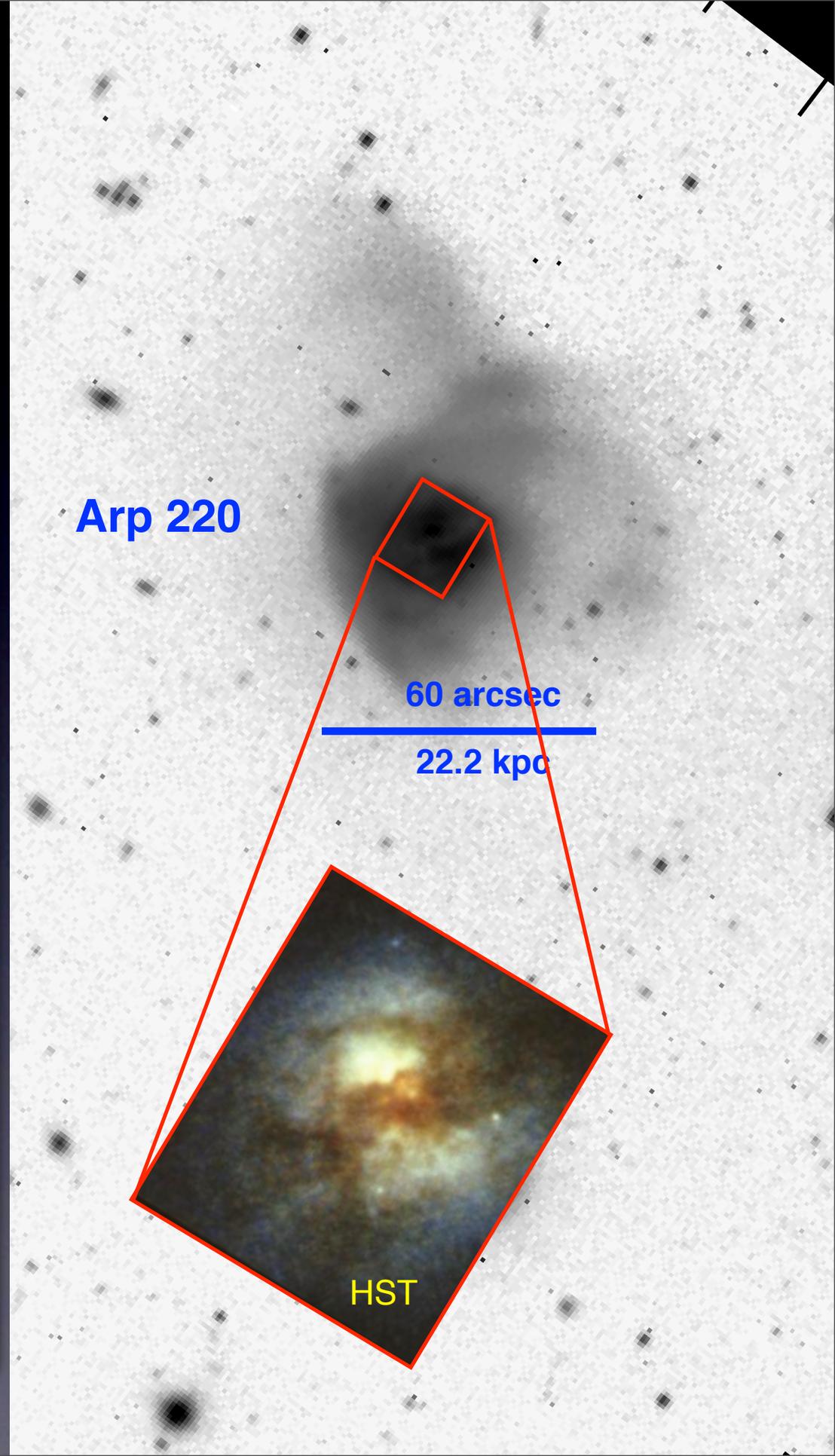




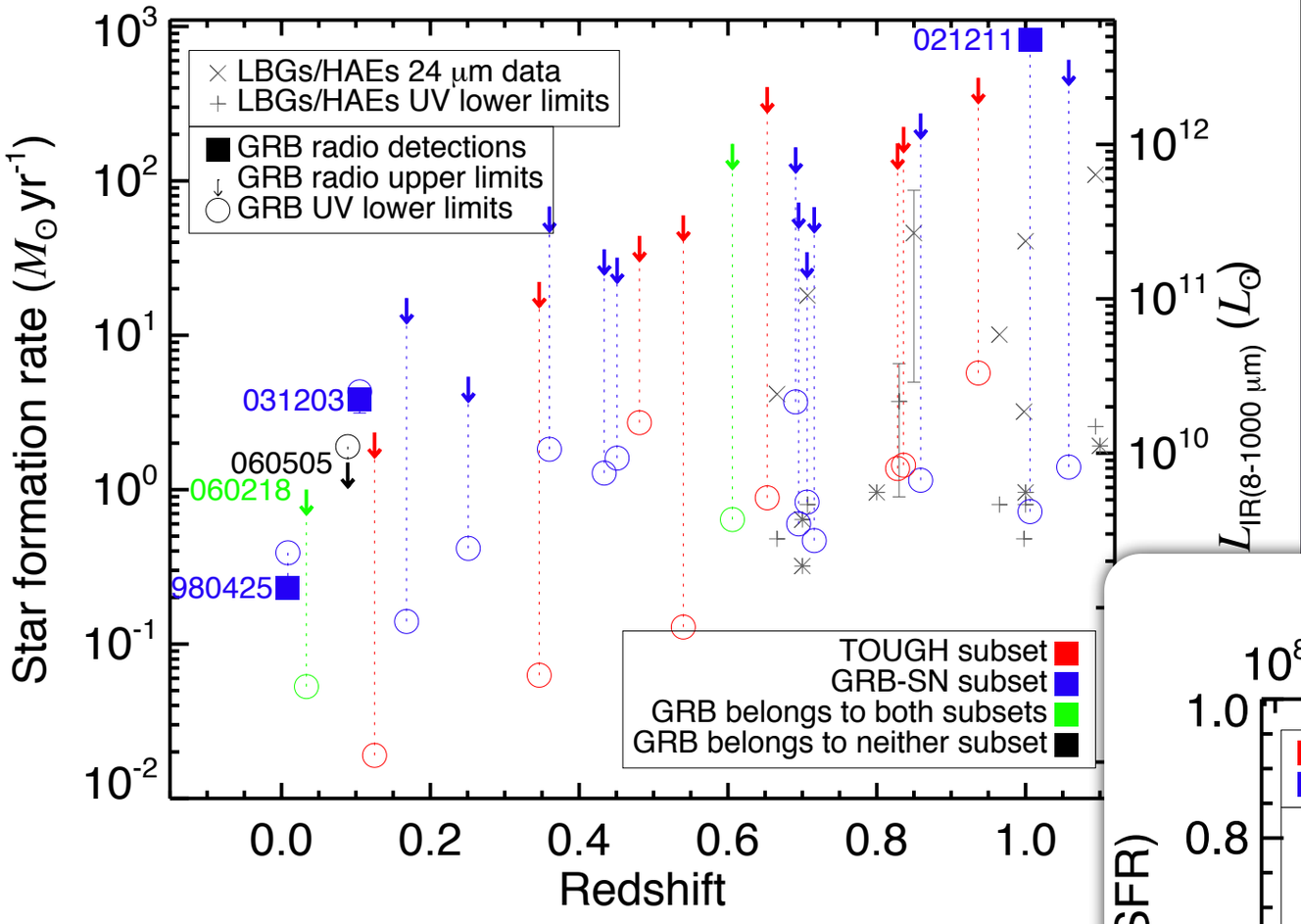
GRB host SED opt-radio

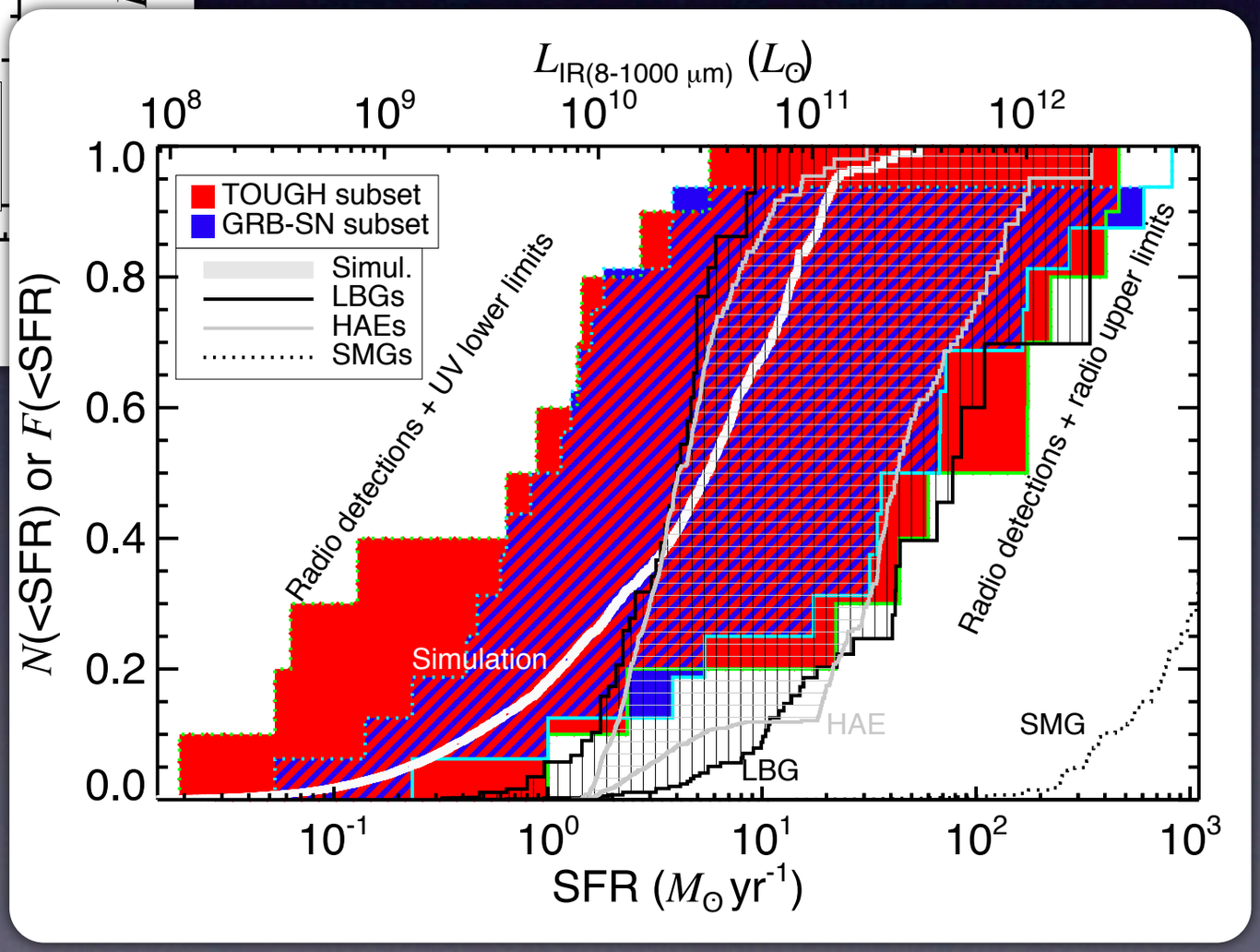


Michałowski, Hjorth, Castro Cerón & Watson (2008)



Radio observations of GRB hosts





ATCA, GMRT, VLA, WSRT

Michałowski et al. (2012)

Conclusions / Future

❶ GRB hosts important probe of galaxy formation & evolution

❷ Dusty obscured galaxies detected with GRBs

❸ GRB hosts show large spread in cosmic chemical enrichment

❹ Star formation activity important in GRB hosts ==> SFRD

❺ We rely on Swift, future γ-ray missions required