# Unveiling the Fundamental Properties of Gamma-Ray Burst Host galaxies

Sandra Savaglio (MPE Garching)

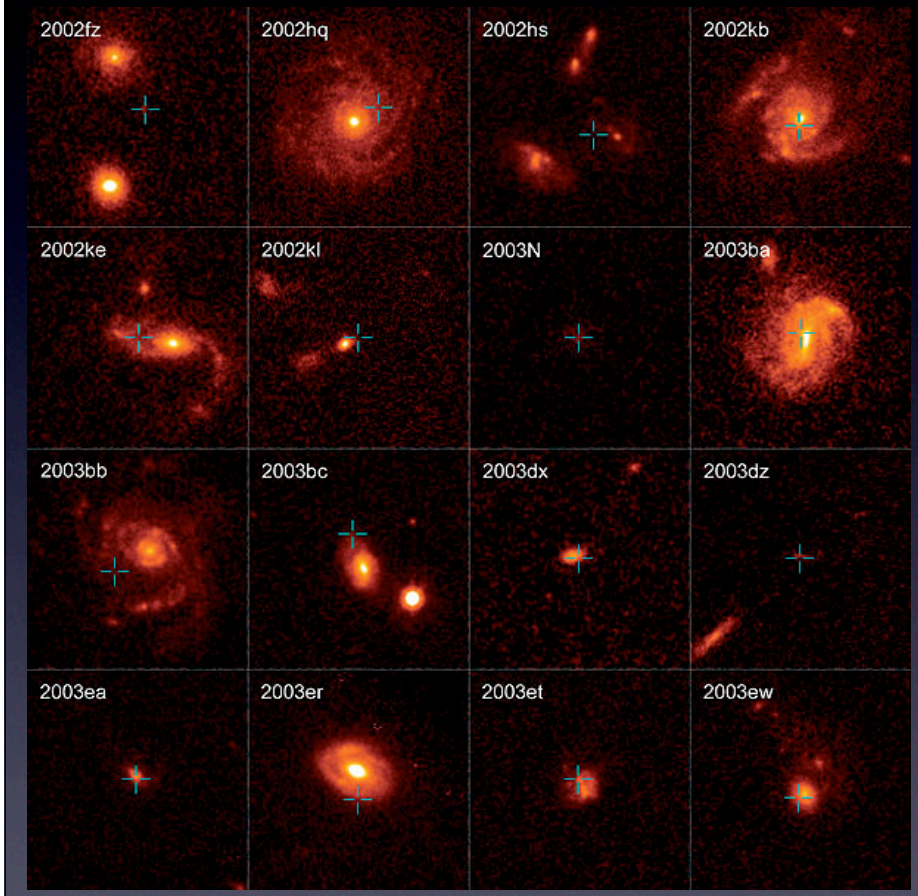
Stéphane Basa *(OAMP, Marseille)*
Stefano Berta *(MPE, Garching)*
Jochen Greiner *(MPE, Garching)*
Karl Glazebrook *(Swinburne, Melbourne)*
Leslie Hunt *(INAF Florence)*
Sylvio Klose *(TLS Tautenburg)*
Thomas Krühler *(Dark Centre, Copenhagen)*
Damien Le Borgne *(IAP, Paris)*

Emeric Le Floc'h *(CEA-Saclay)*
Sheila McBreen *(U. College Dublin)*
Michal Michałowski *(Edinburgh Uni.)*
Eliana Palazzi *(INAF–IASF Bologna)*
Arne Rau *(MPE, Garching)*
Andrea Rossi *(TLS Tautenburg)*
Patricia Schady *(MPE, Garching)*

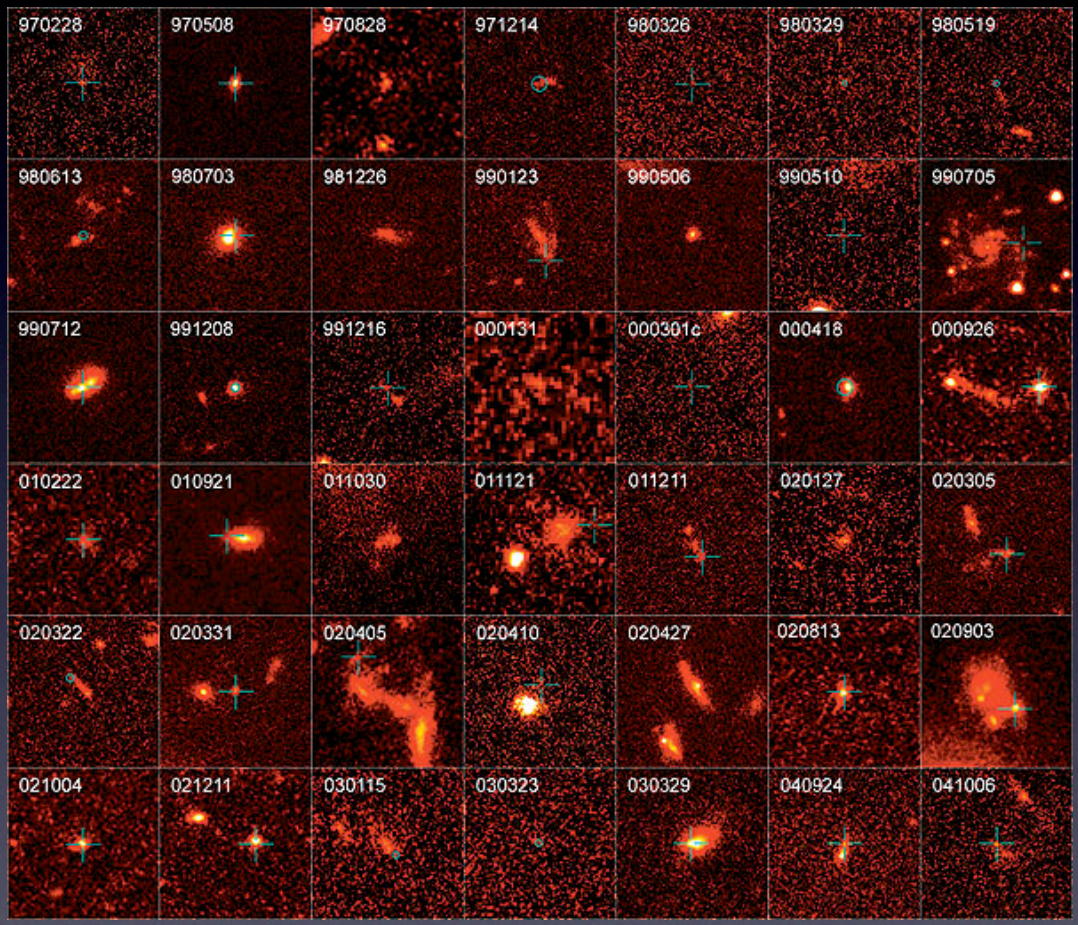
Death of Massive stars:
Supernovae & Gamma-Ray Bursts
IAU Symposium 279, Nikko, March, 2012

# GRB host galaxies

Core-collapse supernova host galaxies z < 1.2




GRB host galaxies z < 1.2




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

GRB host galaxies at $z < 1.5$ generally are:

- small
- metal and dust poor
- star forming

What about $z > 1.5$ GRB hosts?

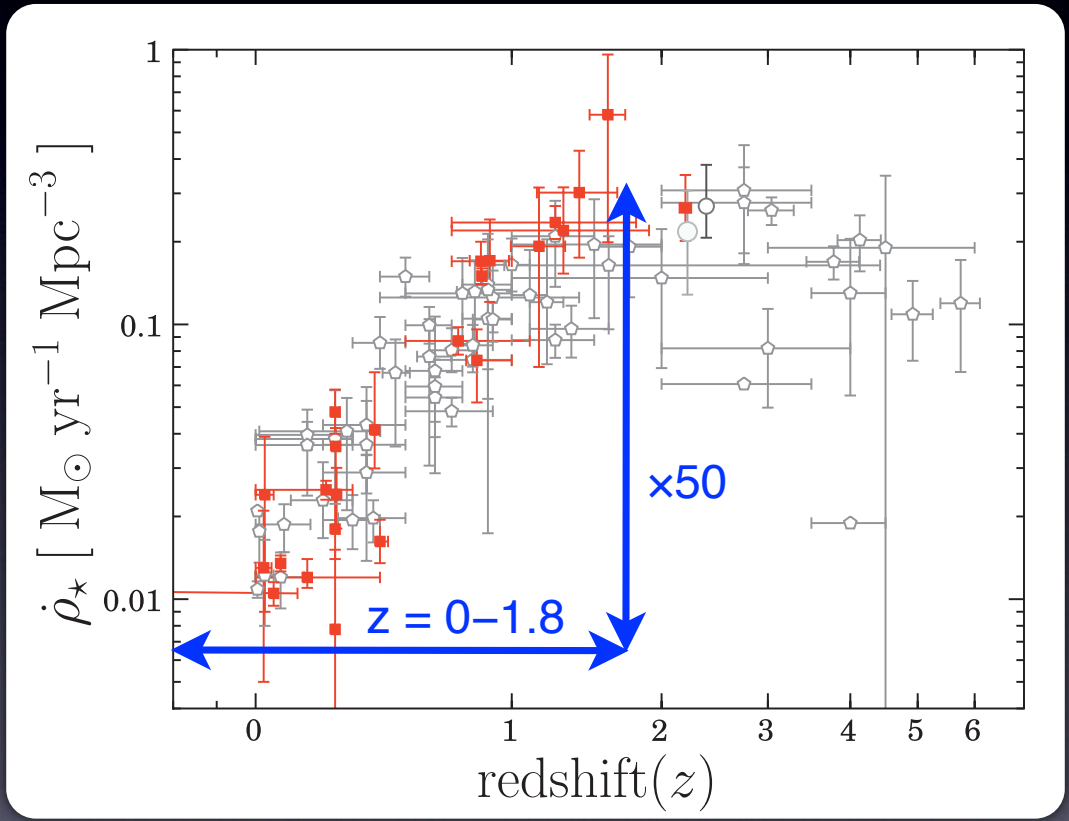
Main changes in the history of the universe:

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

# Cosmic star formation and merger rate

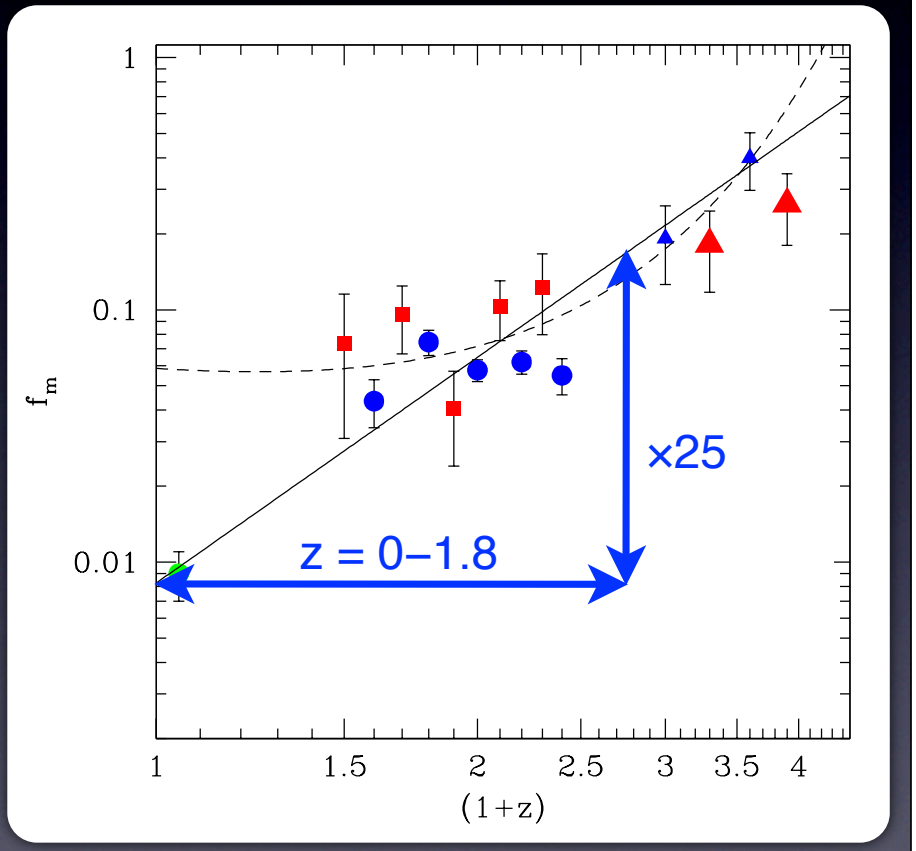
## The last 10 Gyr

### SFRD




Hayes, Schaerer & Östlin (2010)

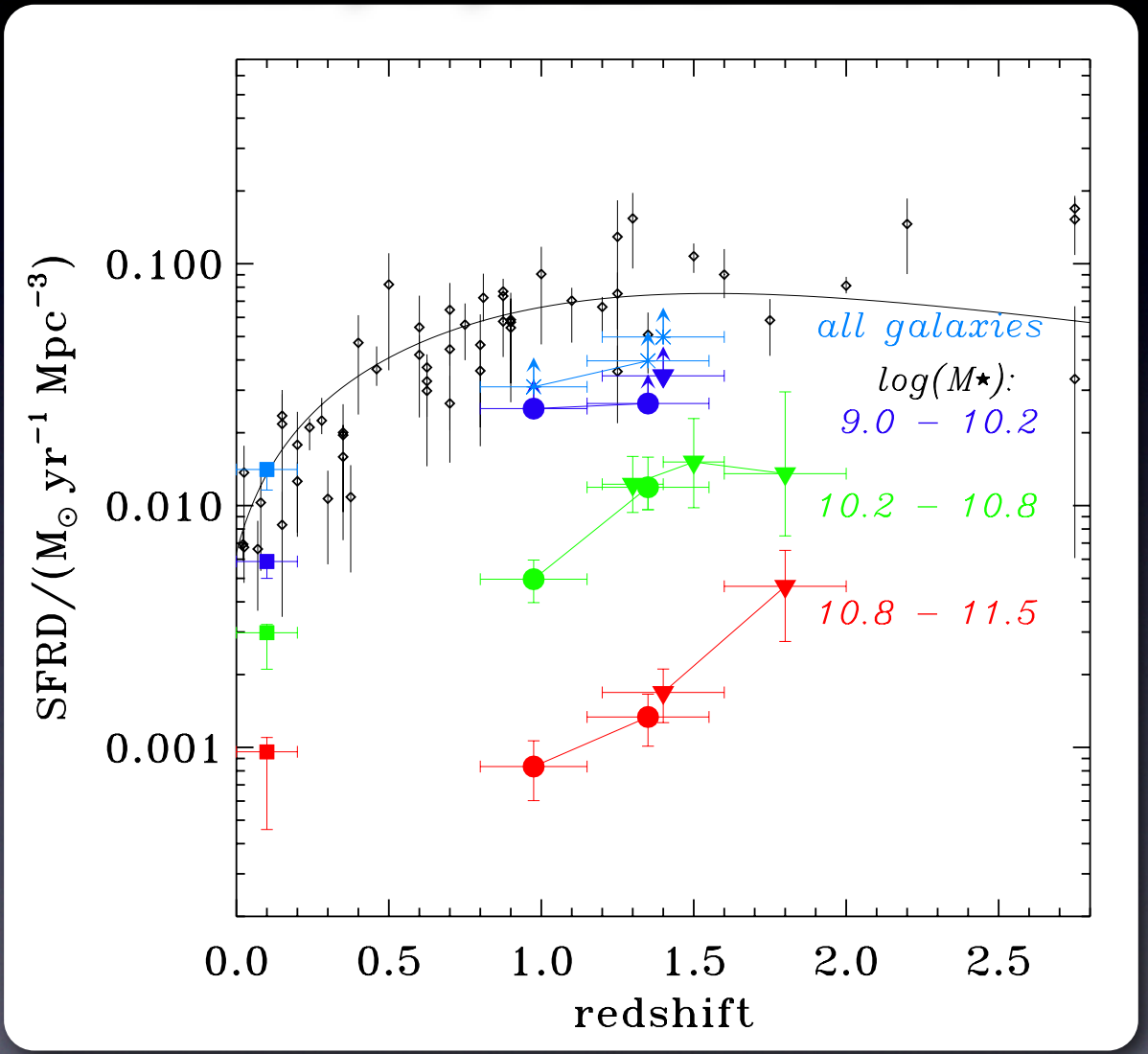
### Major merger rate




Bluck et al. (2011)

# Cosmic star formation rate for different masses

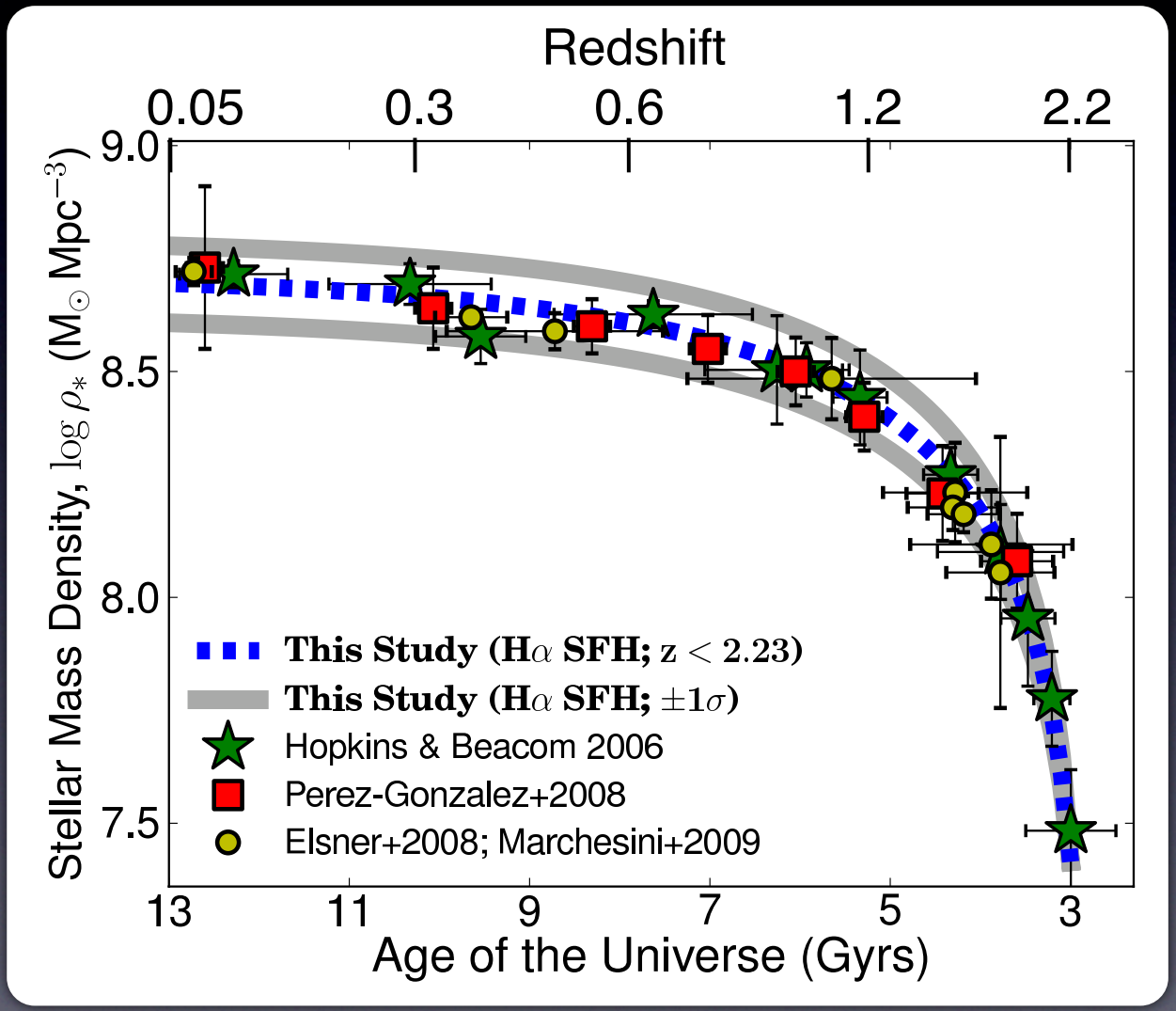
## Madau plot per stellar–mass bin




Juneau et al. (2005)

# Cosmic stellar mass assembly

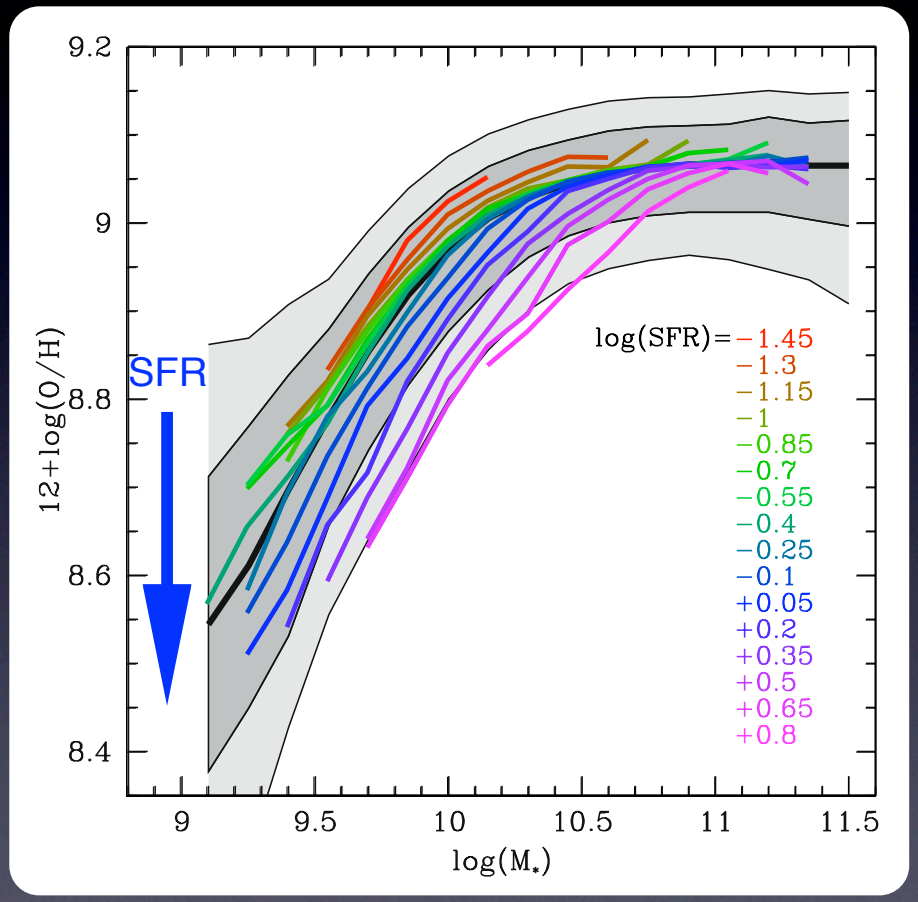
## Total stellar mass redshift evolution



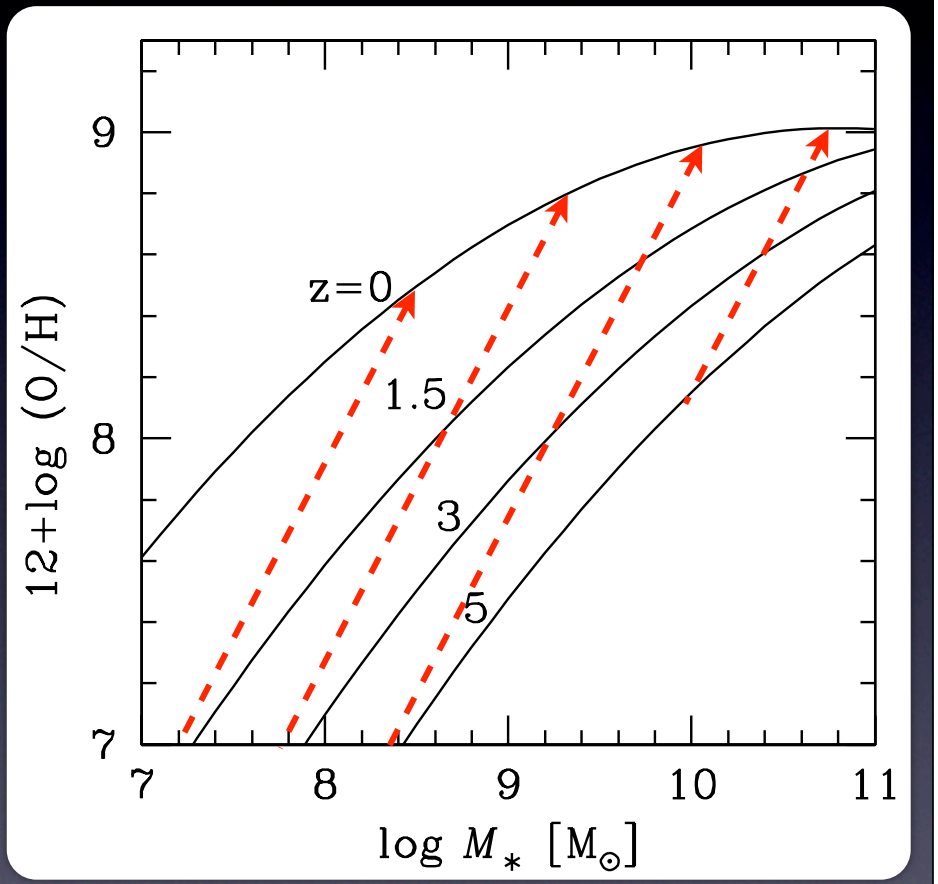

Sobral et al. (2012)

# Cosmic chemical evolution

## Mass–metallicity relation




Metallicity



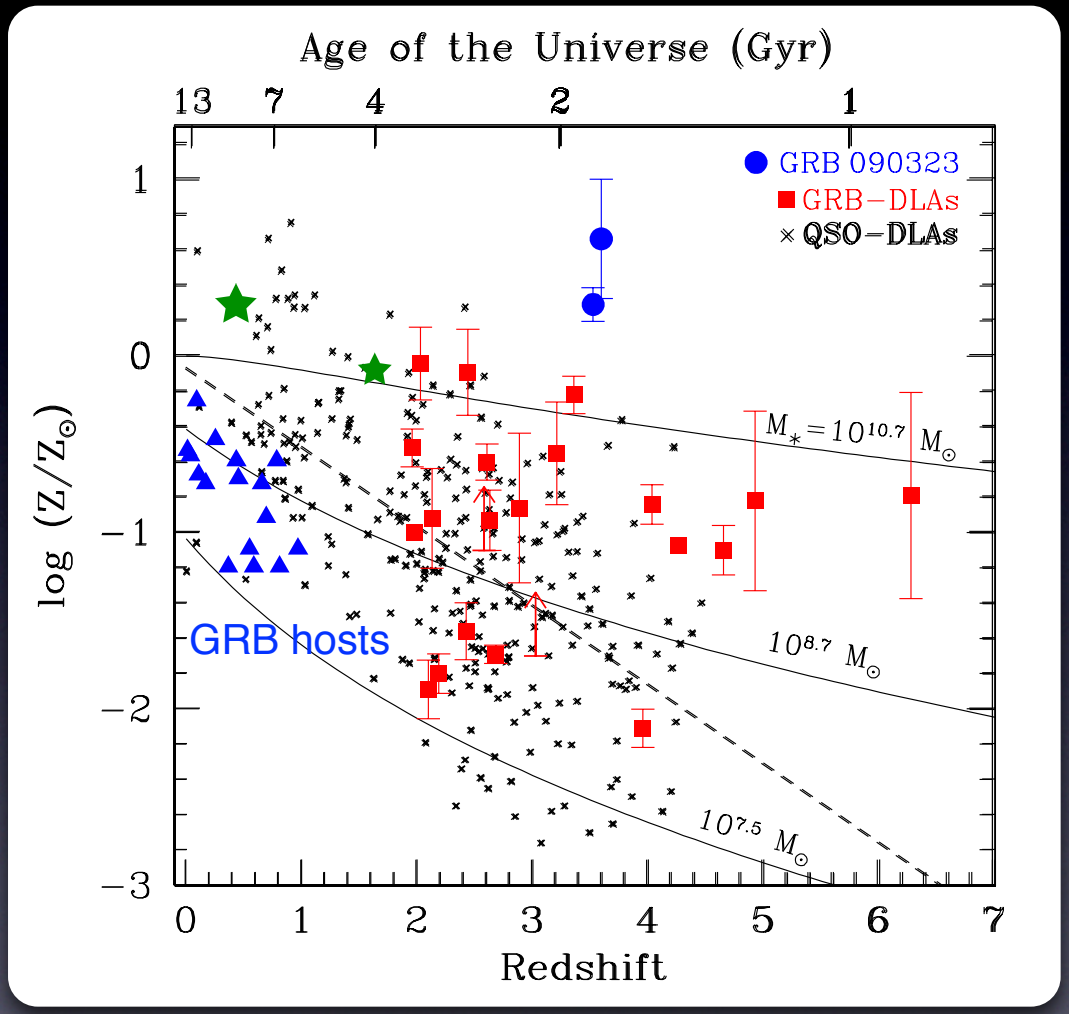

Galaxy stellar mass

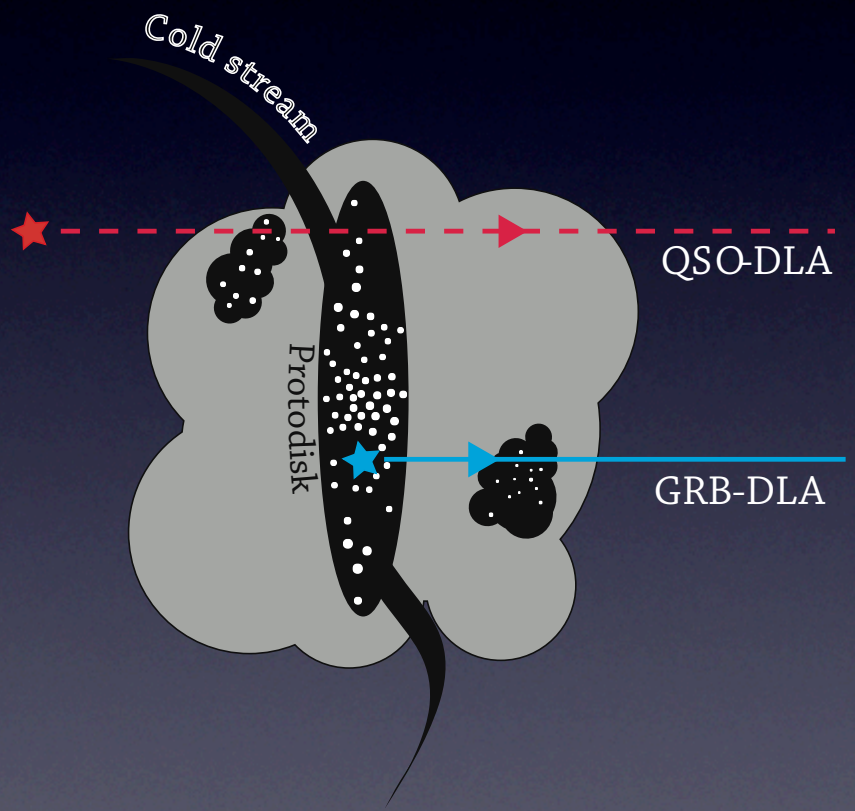
Tremonti et al. (2004)
Mannucci et al. (2010)
(see Campisi et al. 2011; Niino 2011 for FMZ of GRBHs)

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

# Cosmic chemical evolution

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



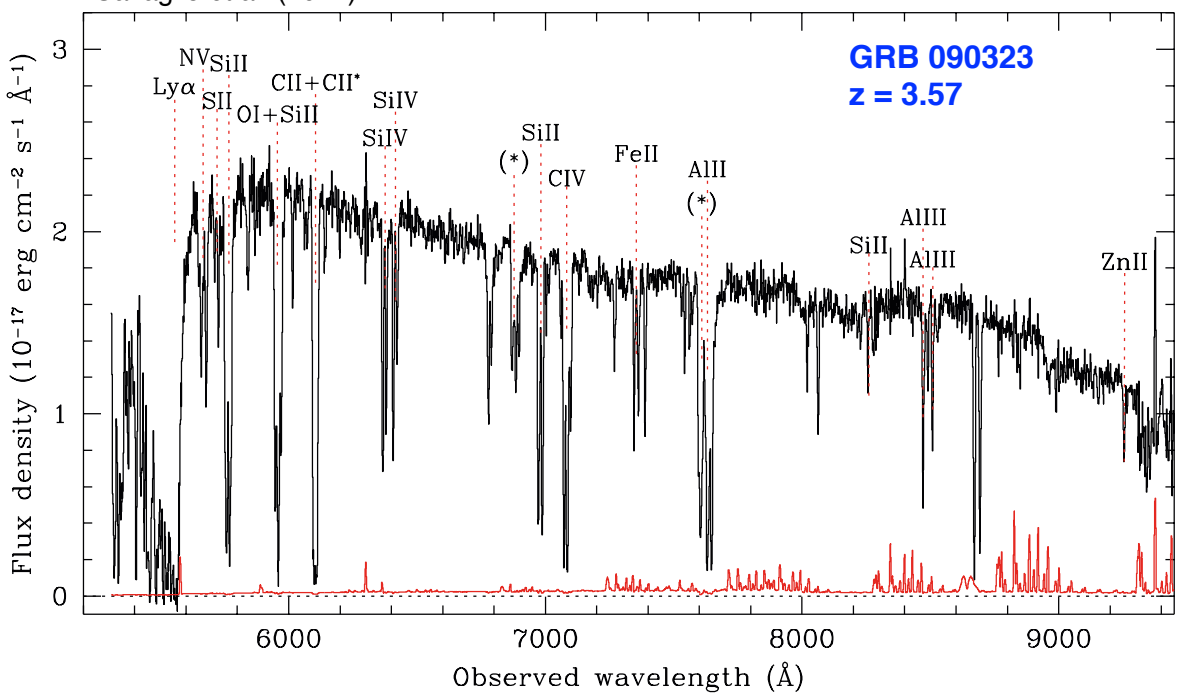




Savaglio (2006)
Prochaska et al. (2007)
Fynbo et al. (2008)
Rau, Savaglio, Krühler, Afonso, Greiner et al. (2010)
Savaglio, Rau, Greiner, Krühler et al. (2012)
Based on modeling in Savaglio et al. (2005)

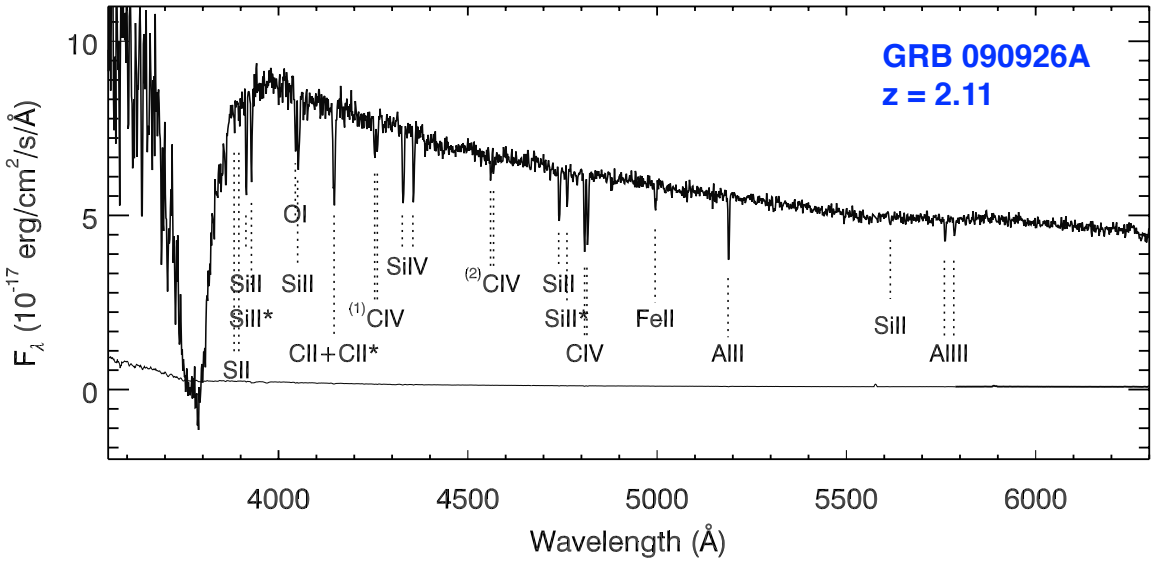
Pontzen et al. (2010)

# The highest and lowest metallicity GRB-DLAs

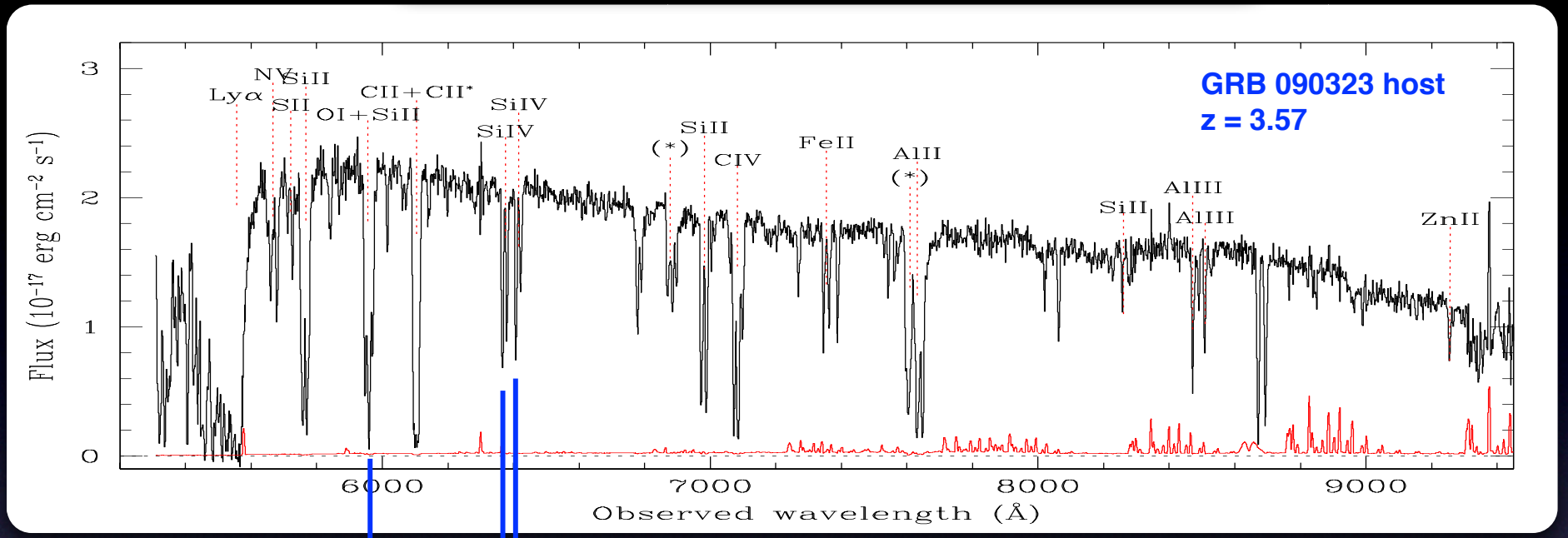
Savaglio et al. (2012)



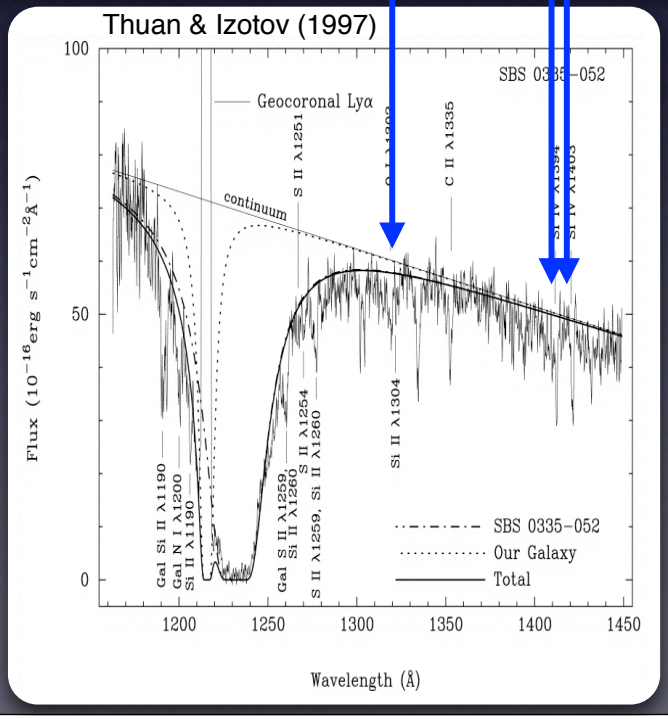

Rau et al. (2010)



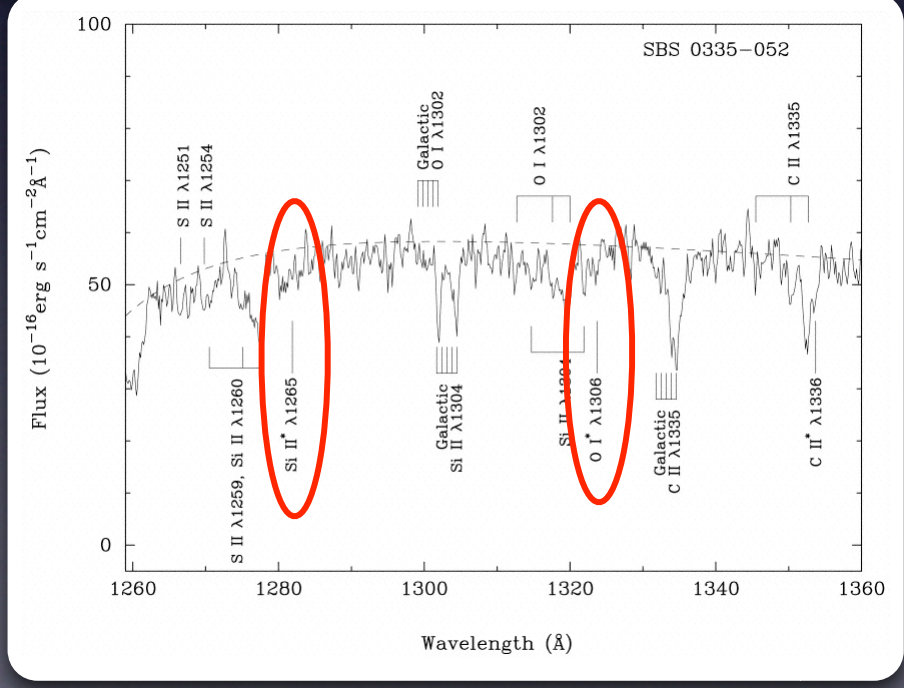
# Is there a typical GRB host?




Thuan & Izotov (1997)




**Local dwarf galaxy**
**SBS 0335-052**
**z = 0.0125**



# Is there a typical GRB host?

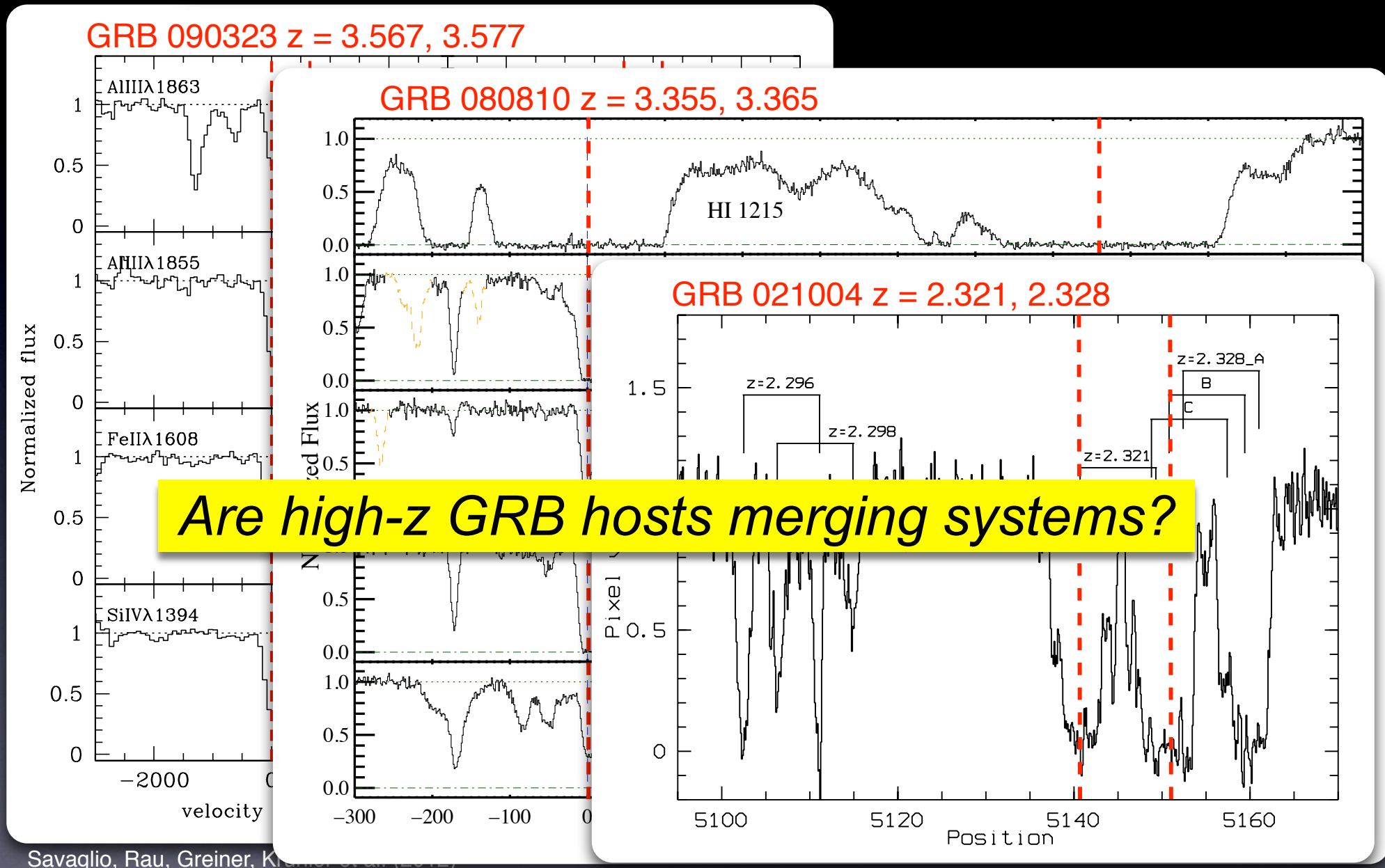
Local dwarf galaxy

Low-z GRB host

High-z GRB host

| | SBS 0335-052 | GRB 980425 host | GRB 090323 host |
|---|---|---|---|
| $z$ | 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$^8$ $M_\odot$ | – | – |
| $M$(stars) | ~ 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 |

# Double absorbers in high-z GRB afterglows



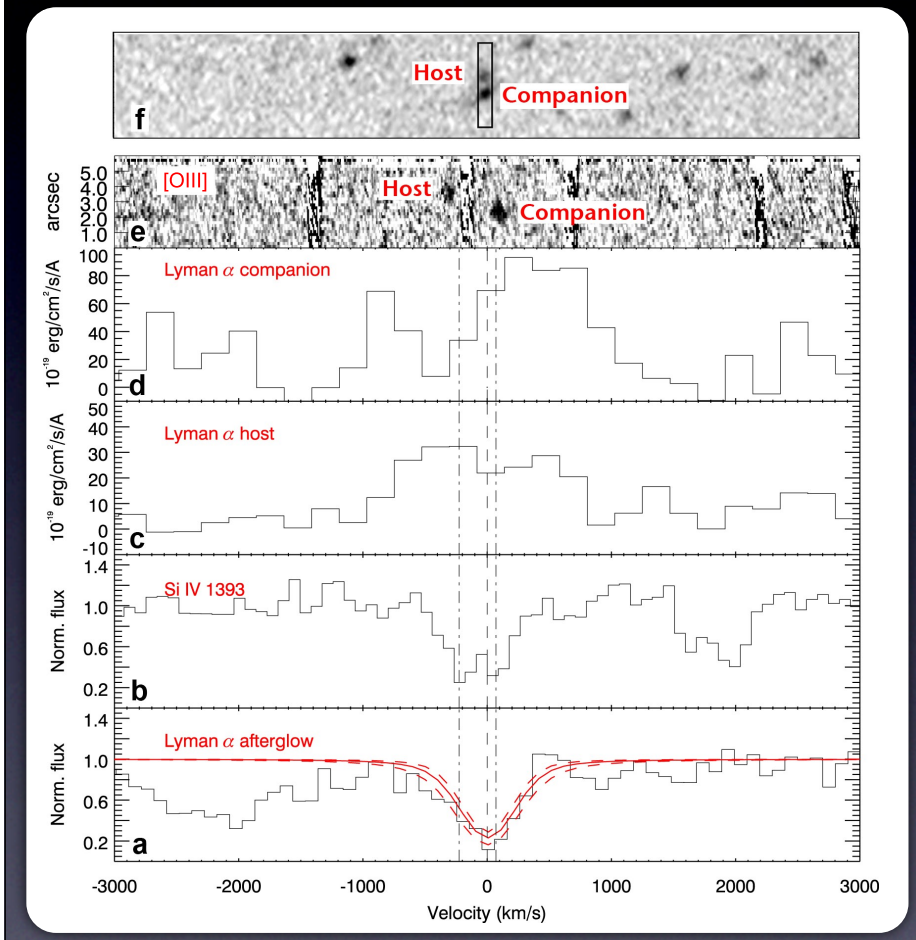

*Are high-z GRB hosts merging systems?*

Savaglio, Rau, Greiner, K[illegible]

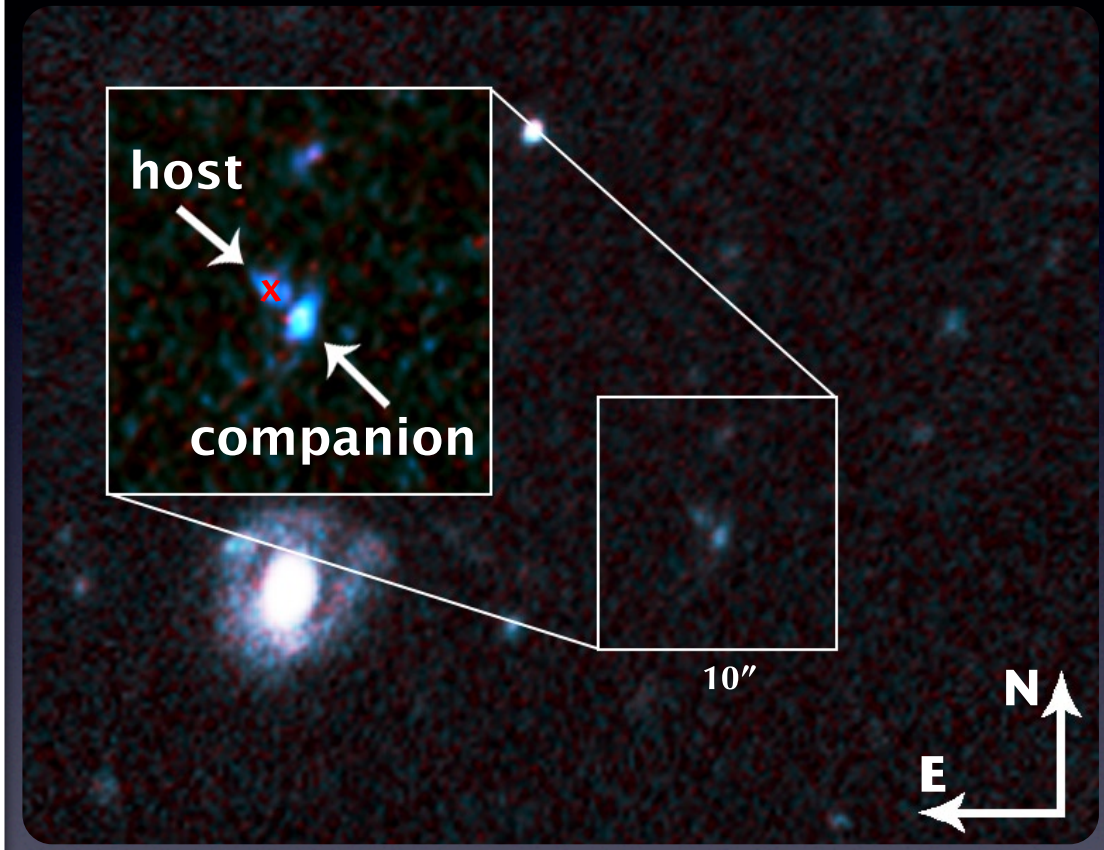
Page et al. (2009)

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

# The interacting-galaxies idea




GRB 090426 z = 2.609




$M_\star = 6.5\times10^{10}\ M_\odot$

$\log N_{HI} = 18.7\pm0.1$

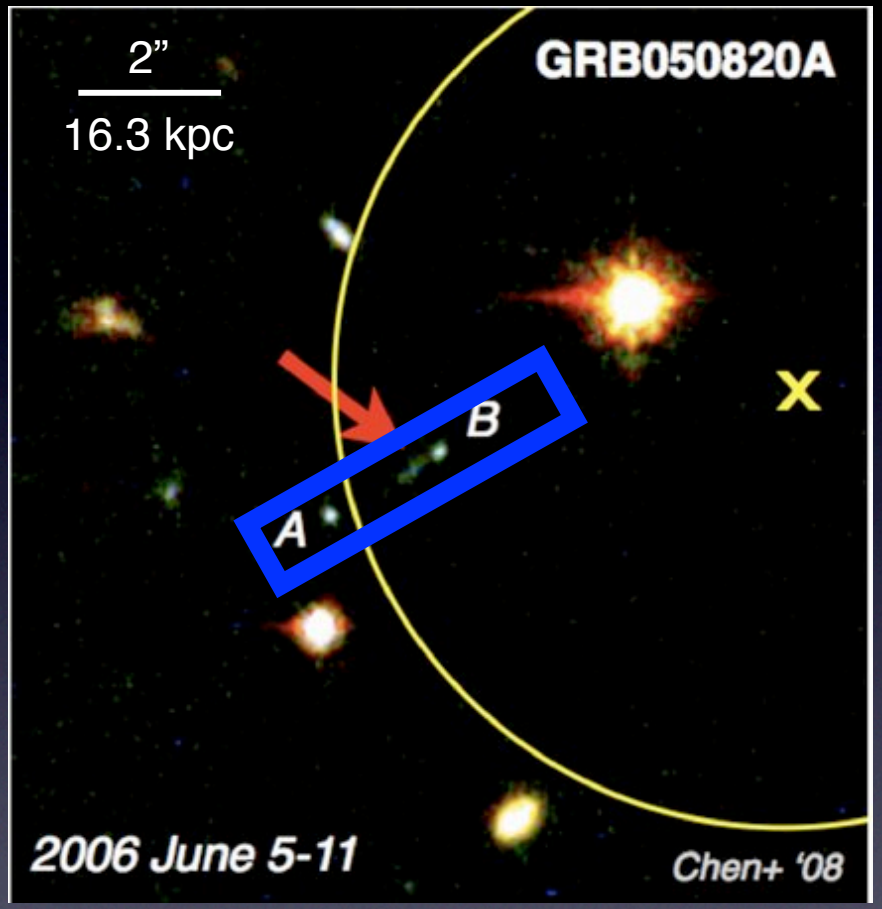
SFR ~ 1.7 $M_\odot\ yr^{-1}$

Thöne et al. (2011)

Levesque et al. (2010)

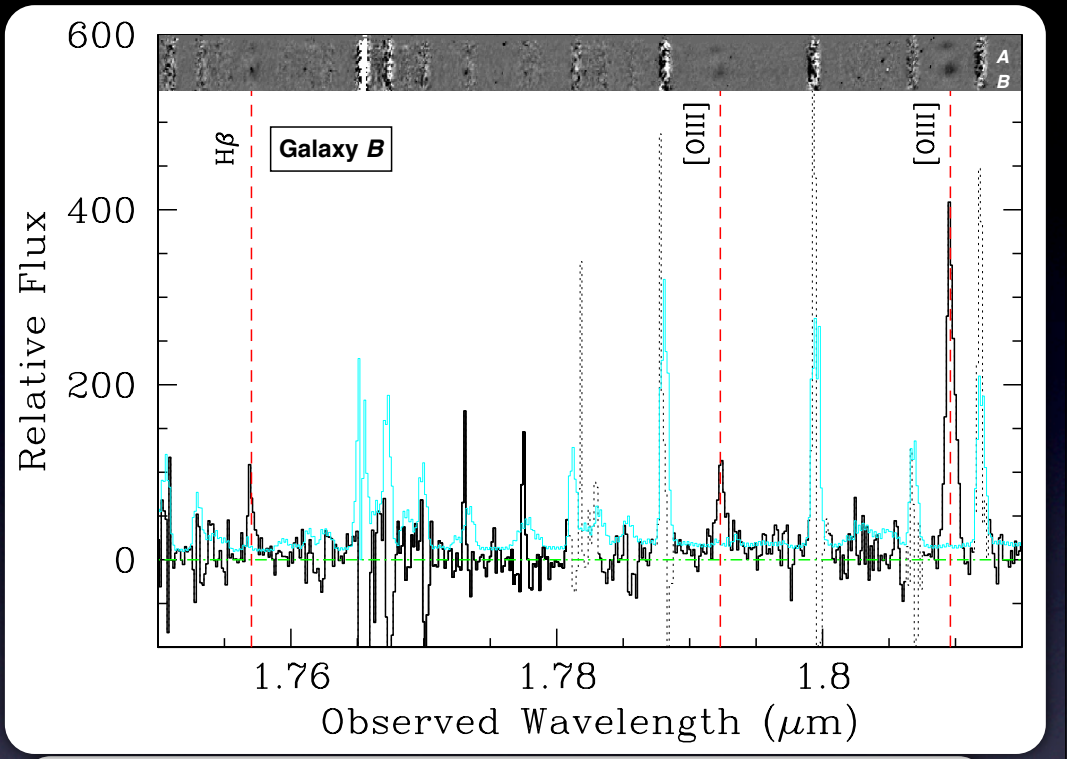
# The interacting-galaxies idea

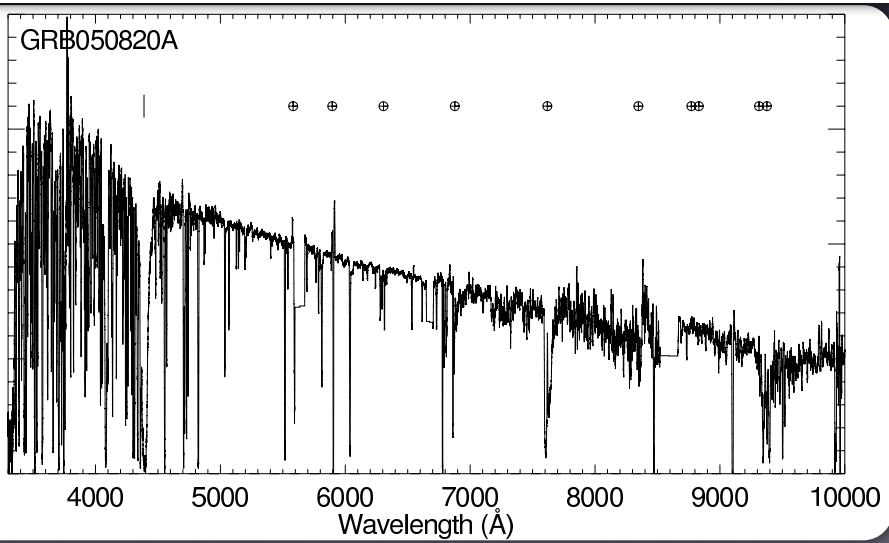
GRB 050820 z = 2.6147




$M_\star = 10^{9.29\pm0.52}\ M_\odot$
$\log N_{HI} = 21.0\pm0.1$
$\log Z/Z_\odot = -0.6\pm0.1$
SFR ~ 0.6 $M_\odot\ yr^{-1}$

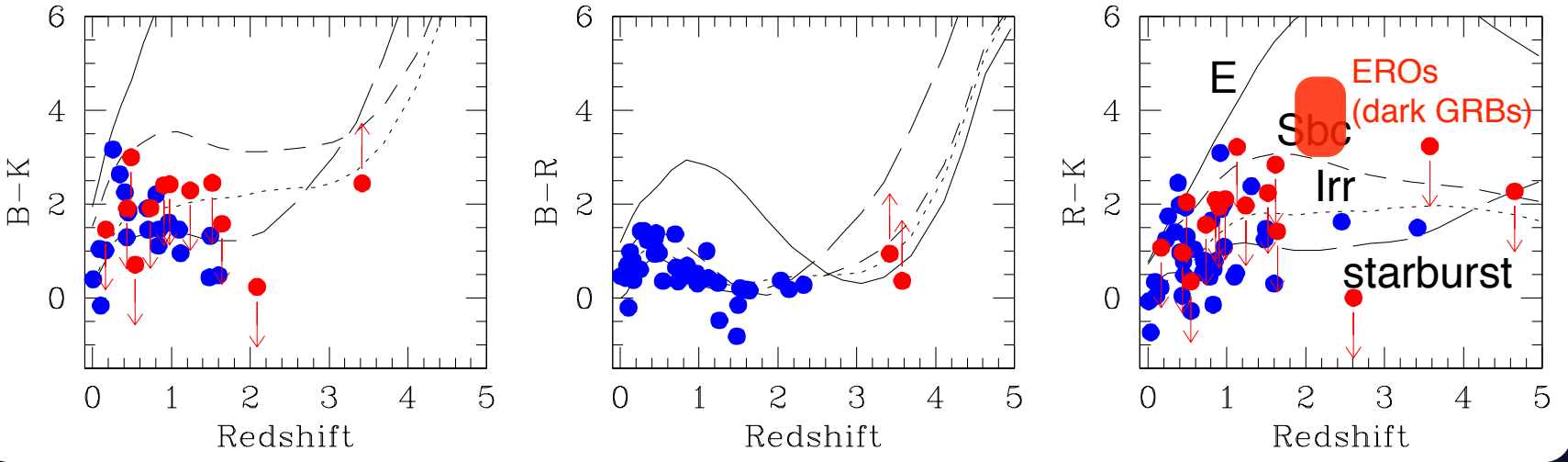
Chen (2012)



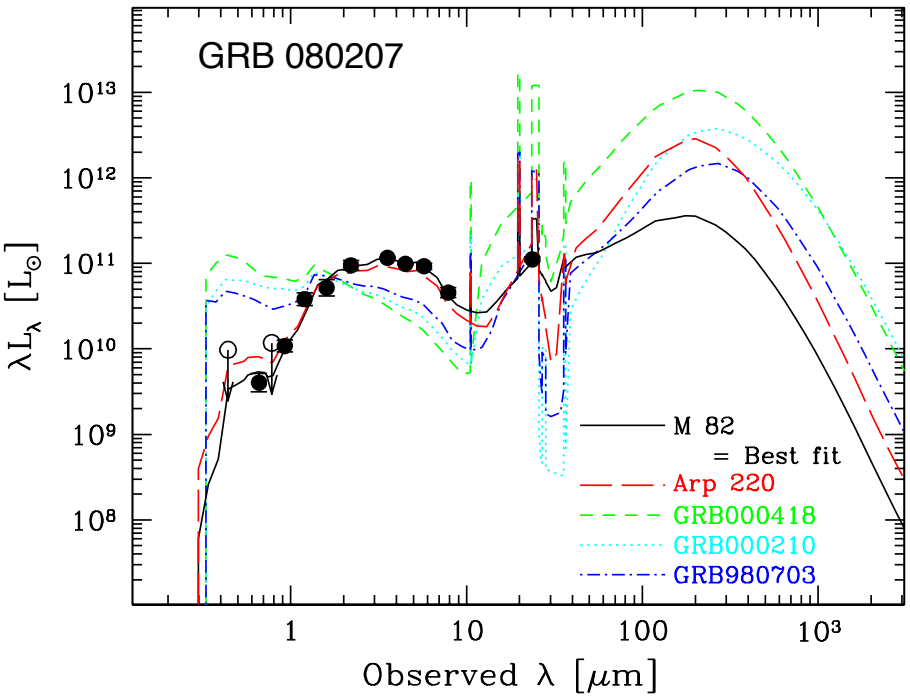




Fynbo et al. (2009)

# GRB host colors



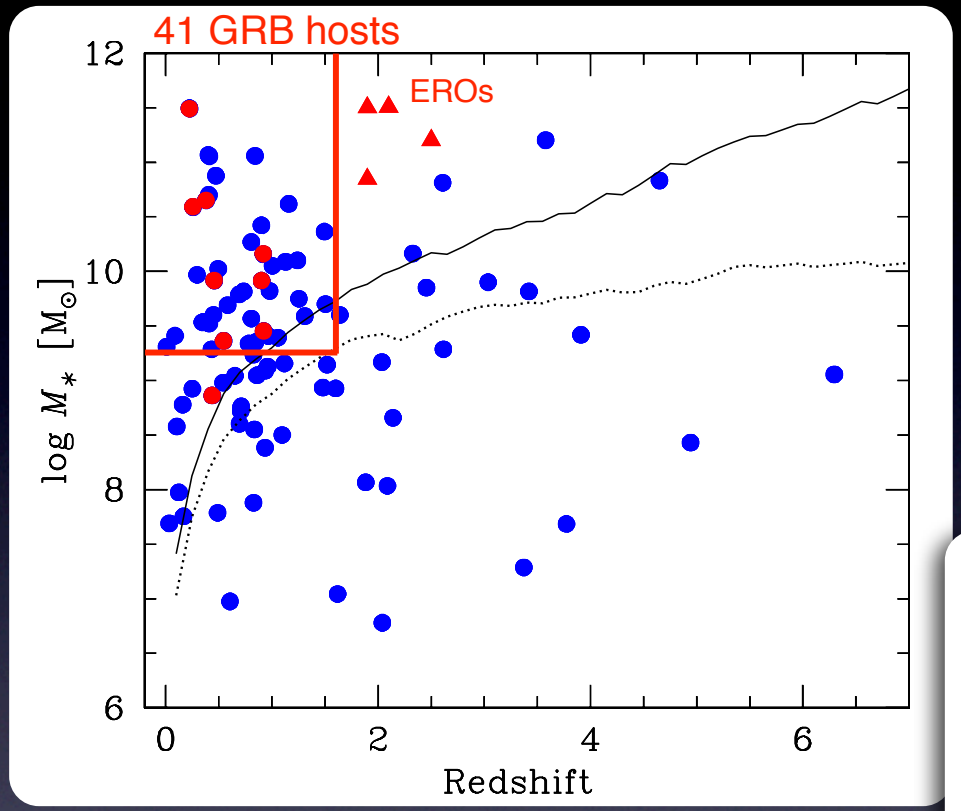

Savaglio, Glazebrook, Le Borgne et al. (in prep.)
Savaglio, Glazebrook, Le Borgne (2009)
Krühler, Greiner, Schady, Savaglio et al. (2011)




$z_{phot}$ = 2.2
$R - K$ (AB) = 4.7
24 μm/$R$-band flux ~ 1000
SFR ~ 120 $M_\odot$ yr$^{-1}$
$M_\star = 3\times10^{11}\ M_\odot$

Hunt, Palazzi, Rossi, Savaglio, Cresci, Klose, Michałowski, Pian (2011)

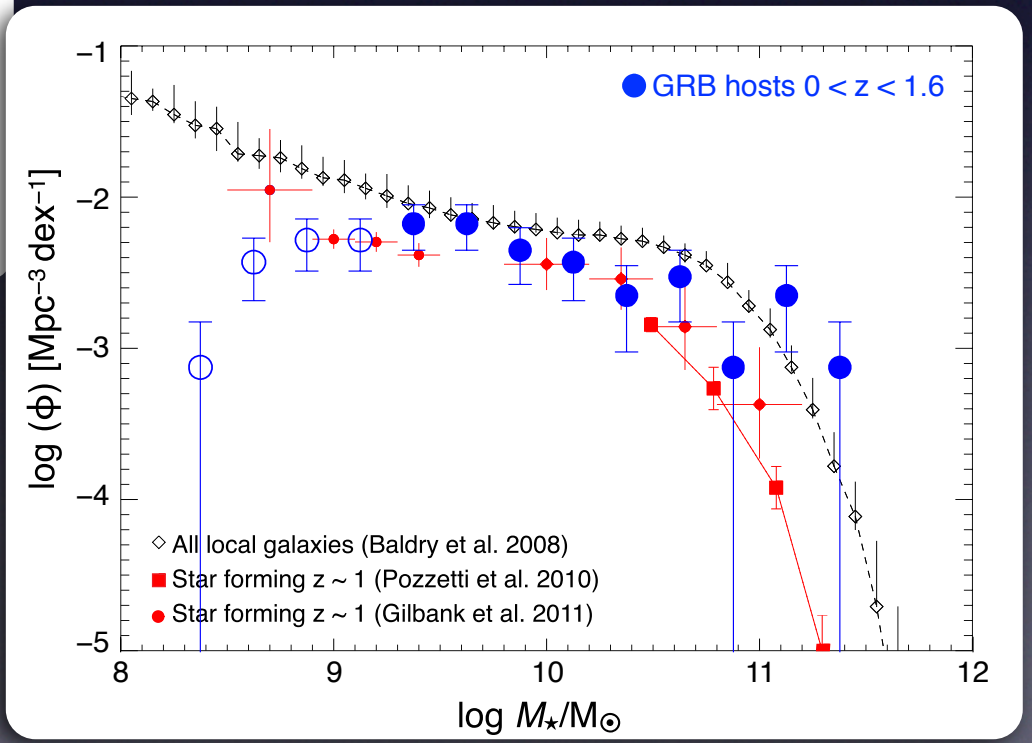
# GRB host galaxies




old stellar population

constant SFR

$m_K = 24.3$

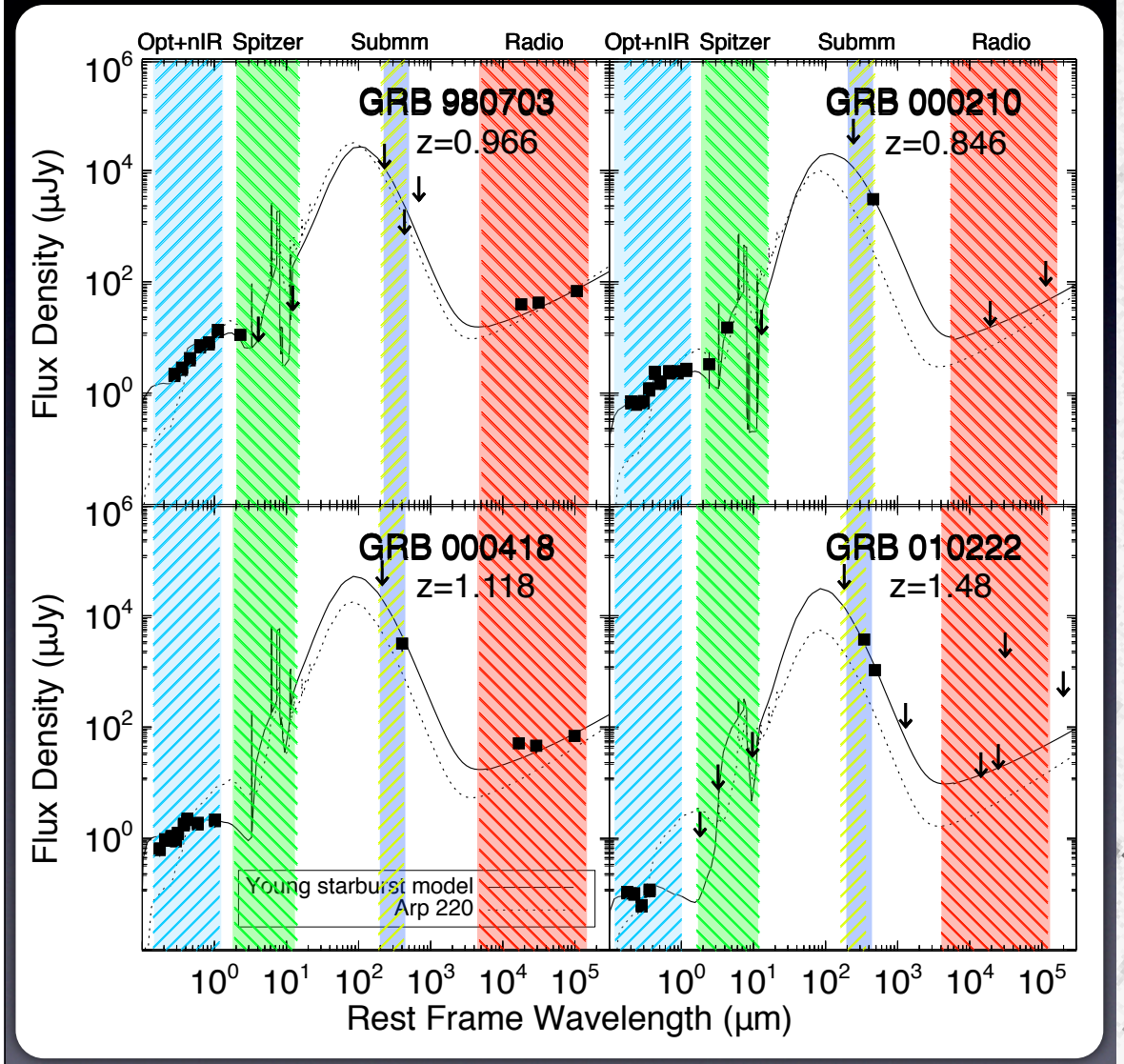


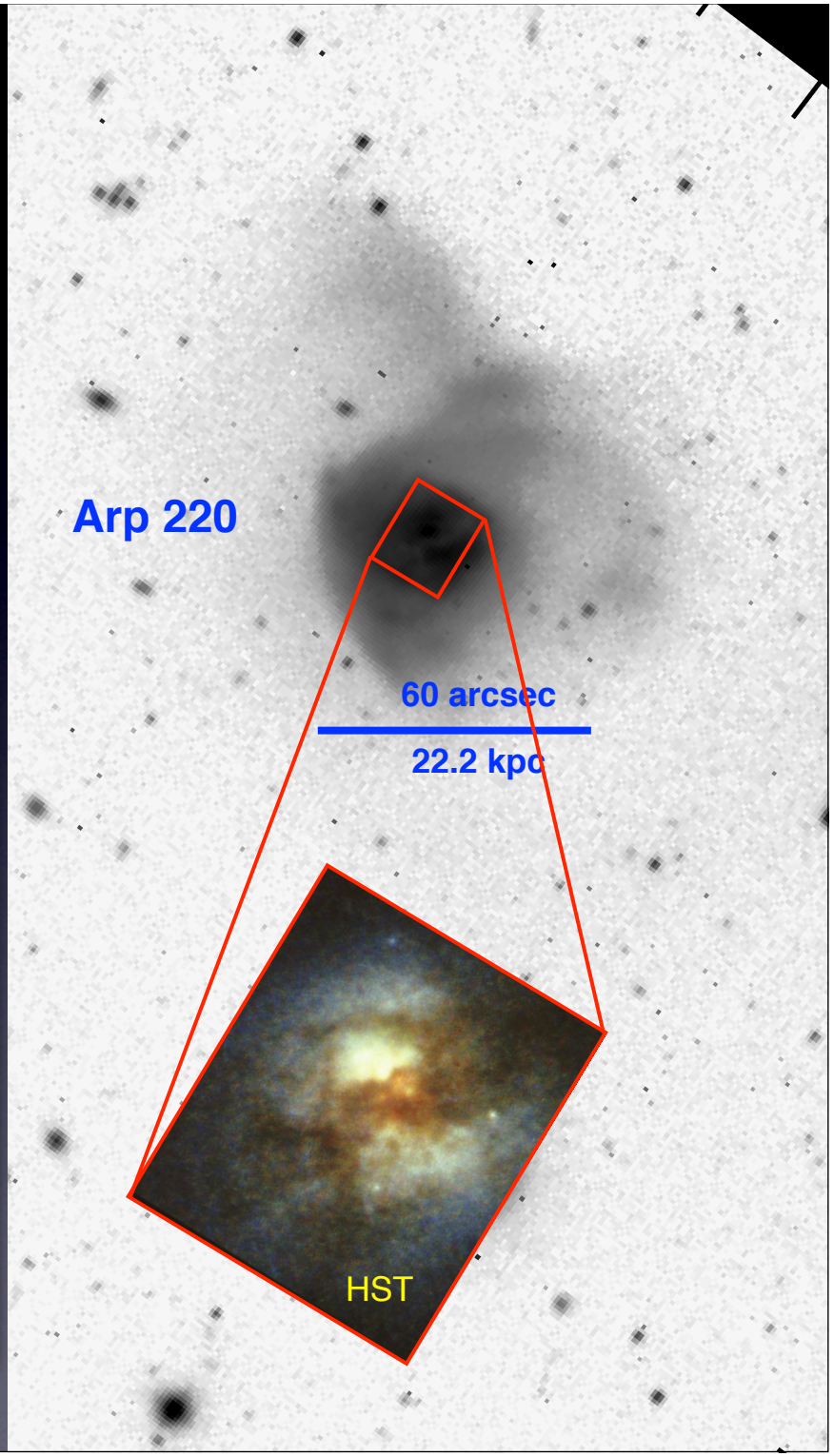

Levan et al. (2006)
Berger et al. (2007)
Hashimoto et al. (2010)
Hunt, Palazzi, Rossi, Savaglio, Cresci, Klose, Michałowski, Pian (2011)


Mystic Mountain with HST


Mystic Mountain with HST

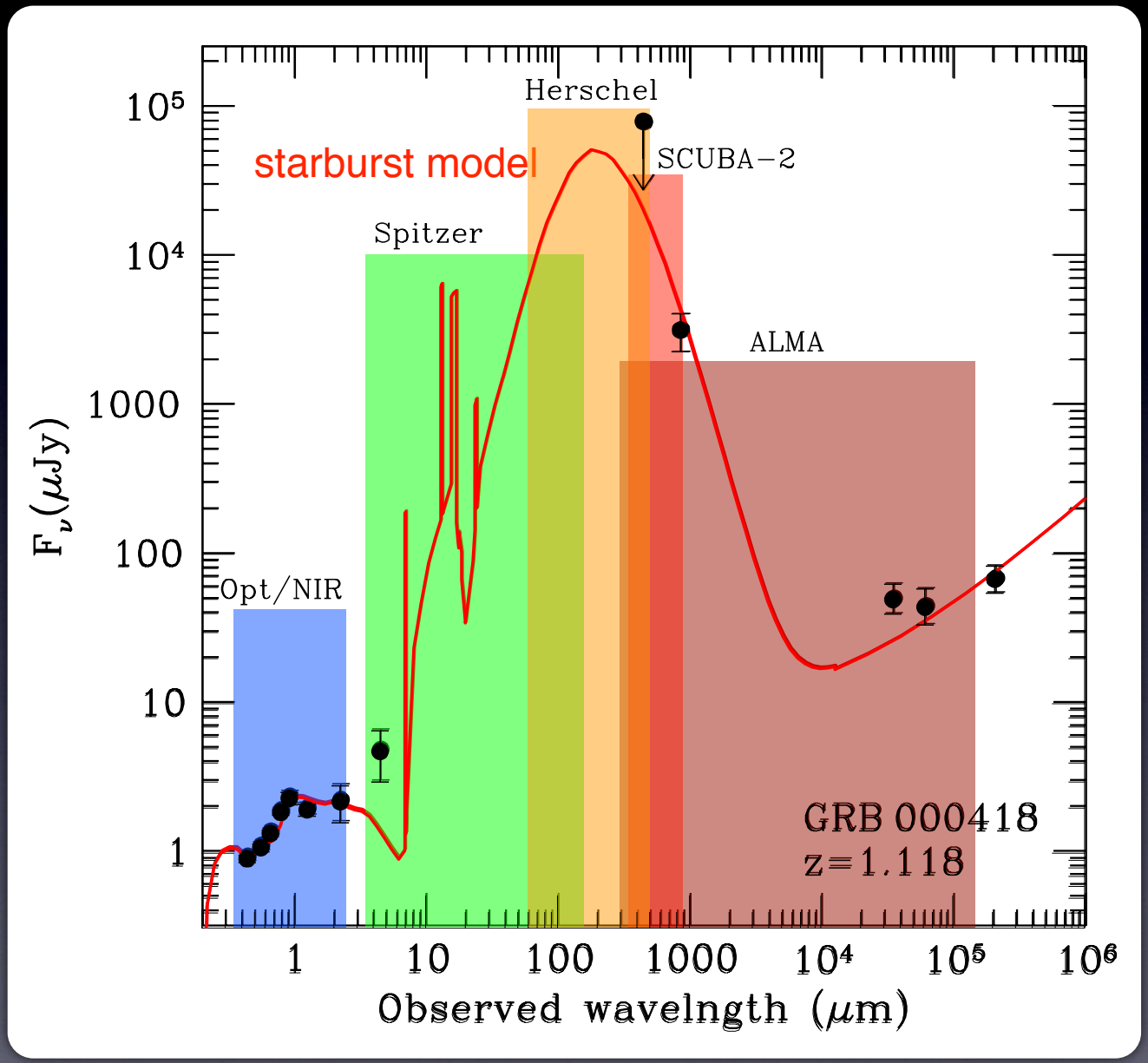
# GRB host SED opt-radio




Michałowski, Hjorth, Castro Cerón & Watson (2008)

# GRB host SED opt-radio




$M_\star = 2\times10^9\ M_\odot$

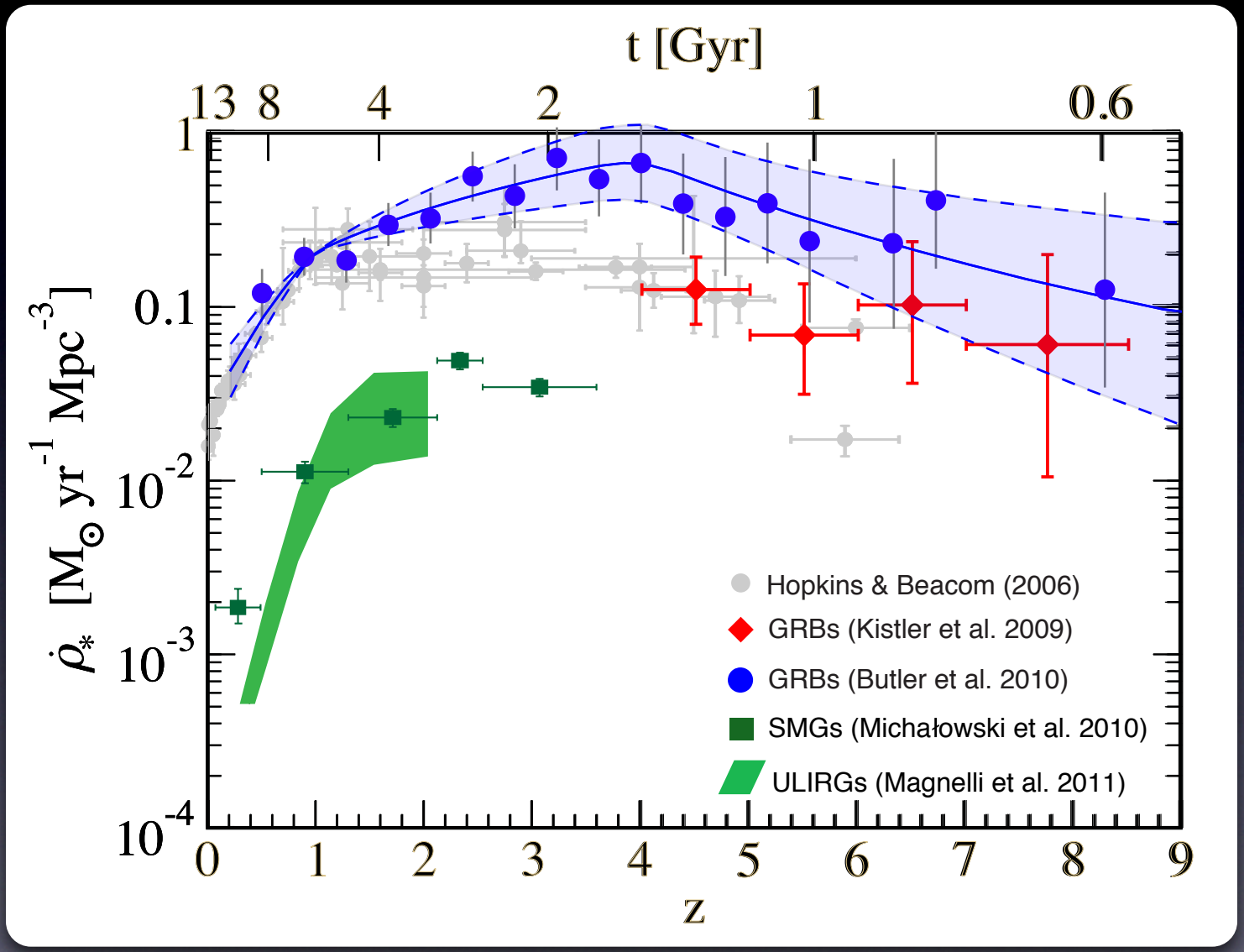
$M_{dust} = 3\times10^8\ M_\odot$

$SFR_{opt} \sim 10\ M_\odot\ yr^{-1}$

$SFR_{radio} \sim 150\ M_\odot\ yr^{-1}$

Michałowski, Hjorth, Castro Cerón & Watson (2008)

# Star Formation Rate Density of the Universe




(see also Elliott et al. 2012)

# Conclusions / Future

❶ Are all GRB hosts small ?

❷ What is their nature at z > 2 ?

❸ Are high-z GRBs triggered by mergers ?

❹ Long-wavelength investigations can answer