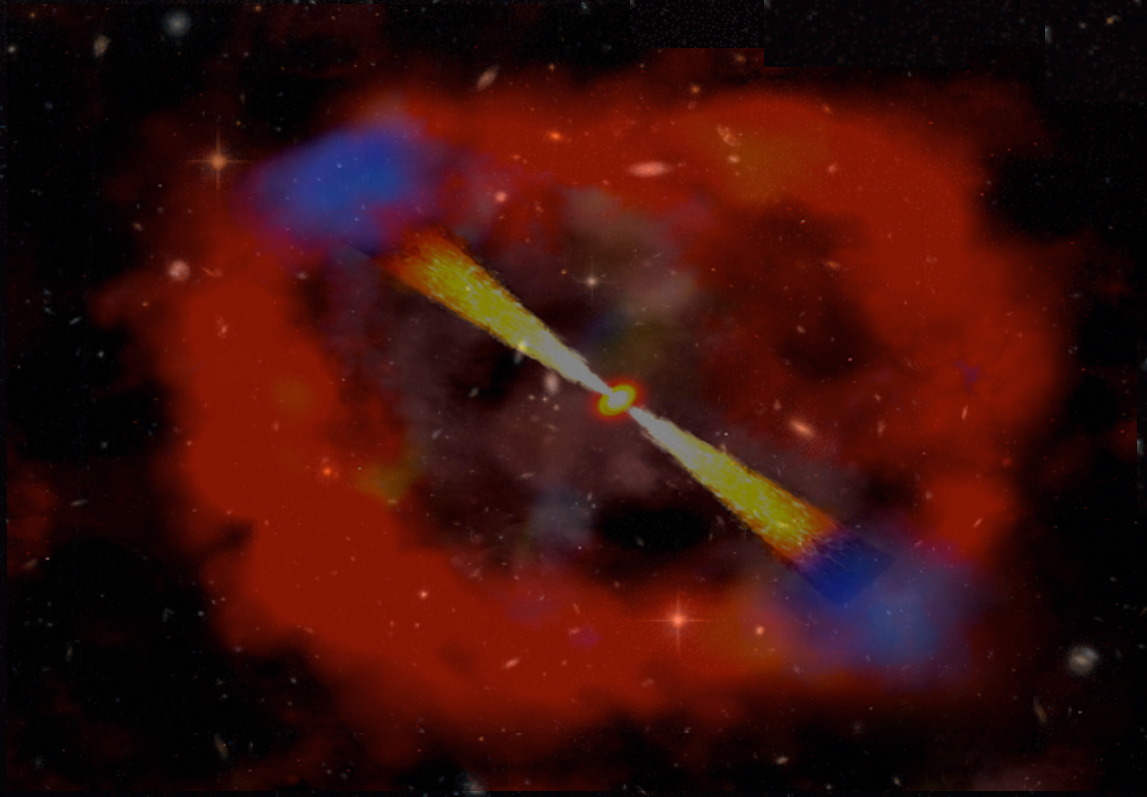
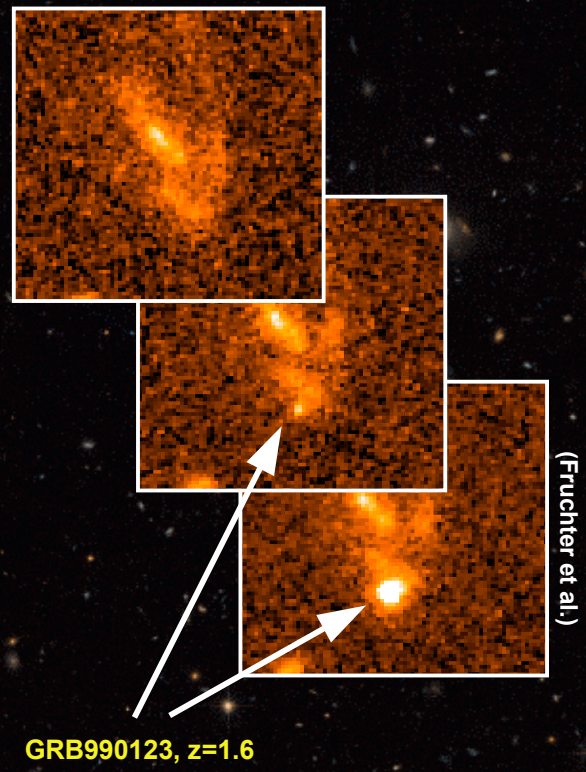
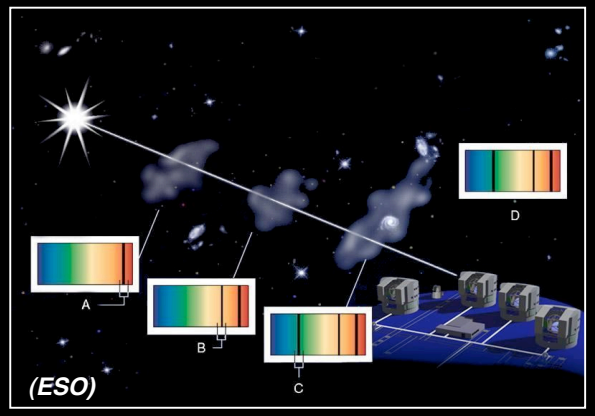
# GRB hosts and their connection with galaxy formation in the early Universe

E. Le Floc'h (CEA, Laboratoire AIM)



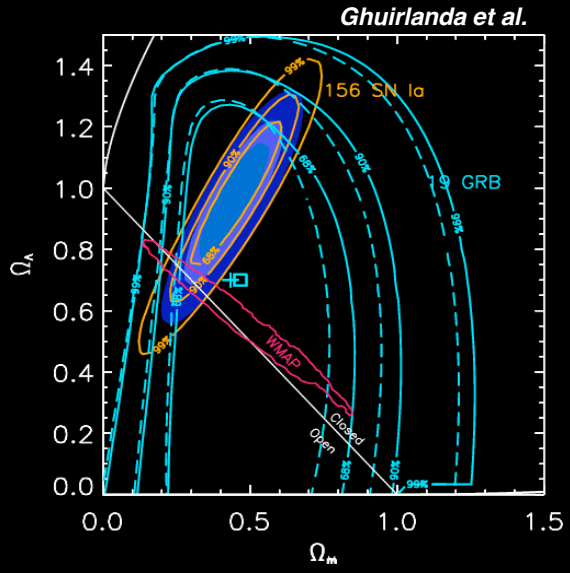


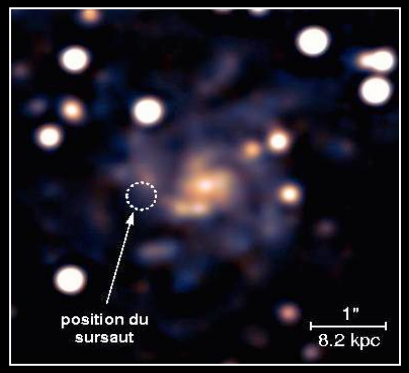
# GRBs as cosmological tools




* GRBs as background lighthouses probing the IGM/ISM in absorption

* GRBs as distance indicators: e.g., cosmological parameters




* Long GRBs as sign-posters of massive star and galaxy formation
* Short GRBs as tracers of stellar mass

# GRBs as tracers of galaxy evolution ?

- penetrate dust very efficiently: no bias from dust extinction
- visible up to very high redshifts

Long Gamma-Ray Bursts

↕

Collapse of massive stars

↕

Starbursting galaxies

- a pseudo "SFR selection"

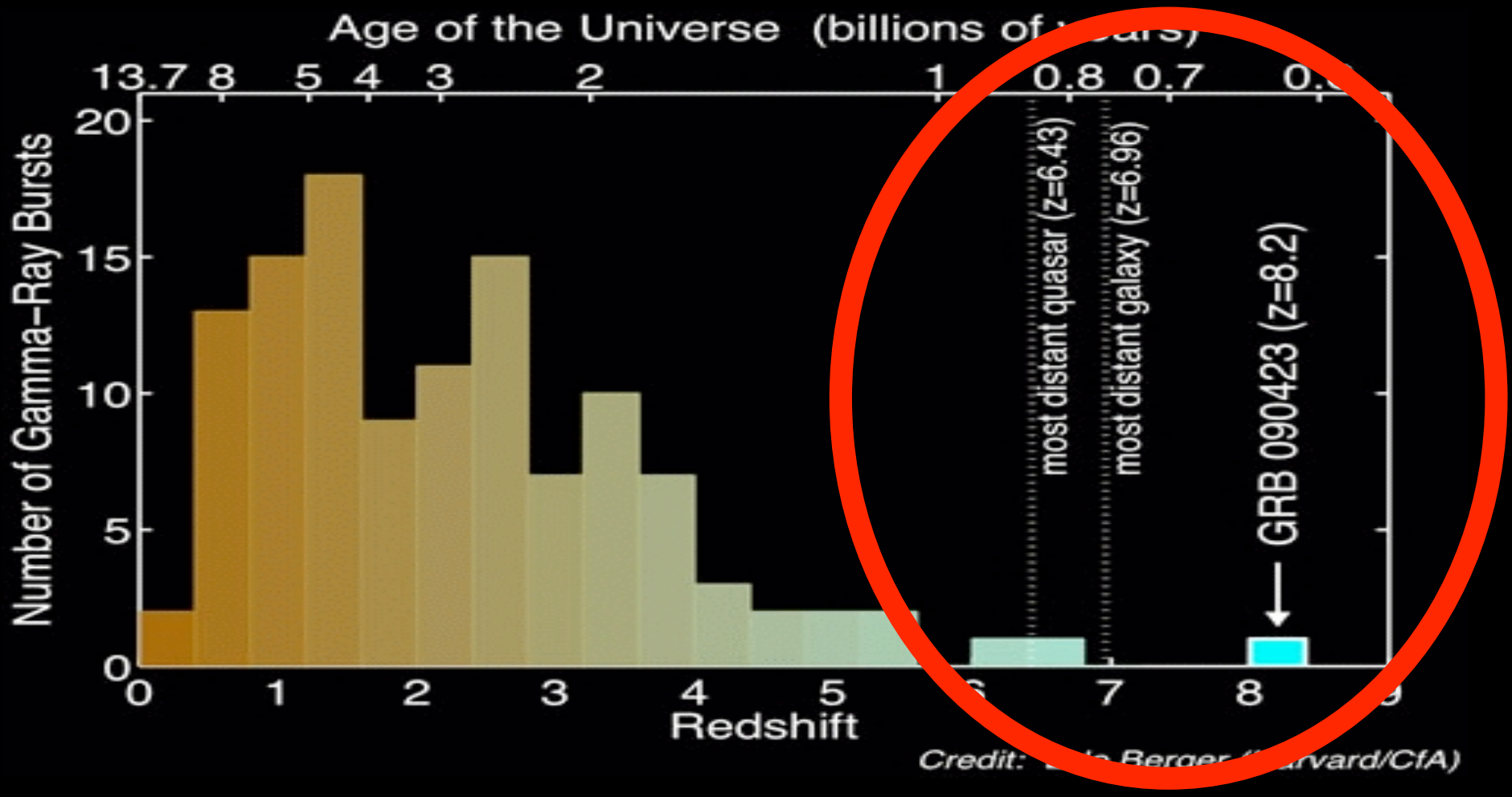
Short GRBs:

progenitors associated with older stellar populations

hosts: Ell + SF

- trace stellar mass assembly ?

# LGRBs as probes of the early Universe




- The "GRB selection" provides the largest fraction of 1<z<6 sources with respect to any mono-wavelength blank field selection

# LGRBs as star formation tracers

* The link between LGRBs and the death of (some sort of) massive stars is now firmly established:

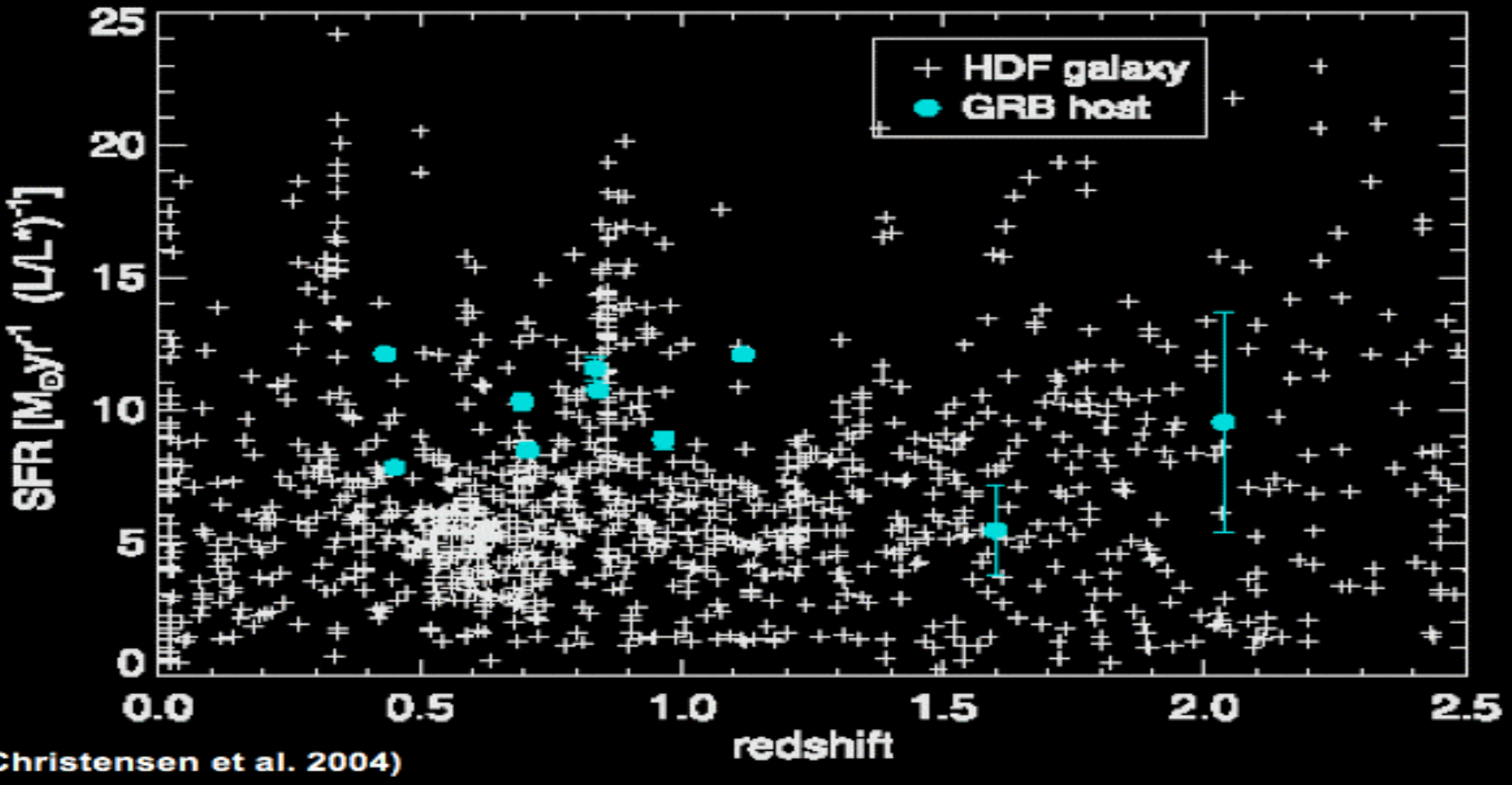
  - accompanying SNe, "star-forming" nature of LGRB hosts, evidence for heavy elements in the outflows …

Yet, the role of key parameters (rotation, binarity, metallicity, mag. fields?, …) may prevent an unbiased relationship between LGRBs and cosmic star formation history

# Specific star-formation rates

* Specific SFR = SFR / (L/L*), measures the star-formation efficiency

➢ GRB host SSFR : larger than averaged in the HDF

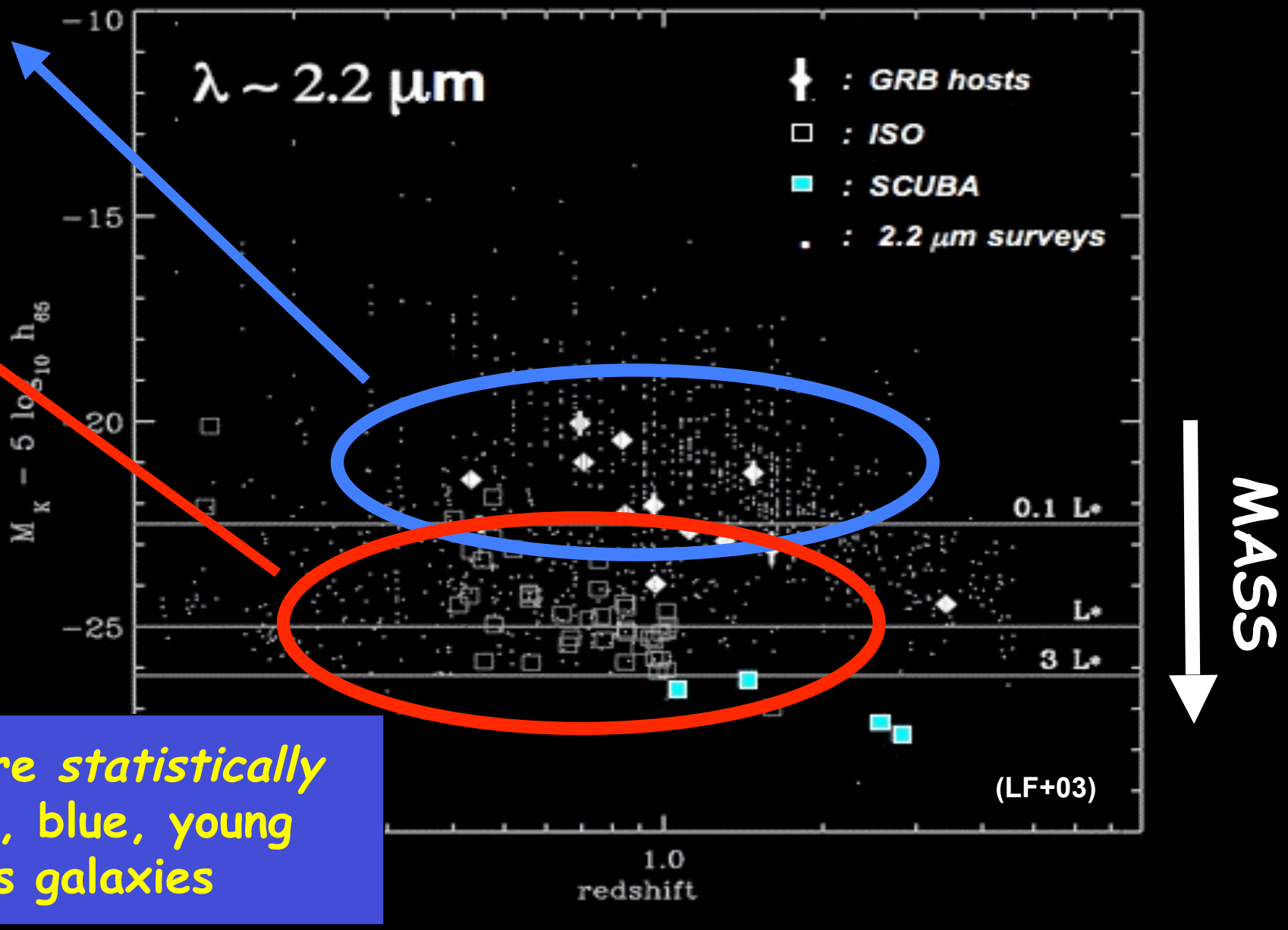



(Christensen et al. 2004)

# GRB hosts: blue and sub-luminous

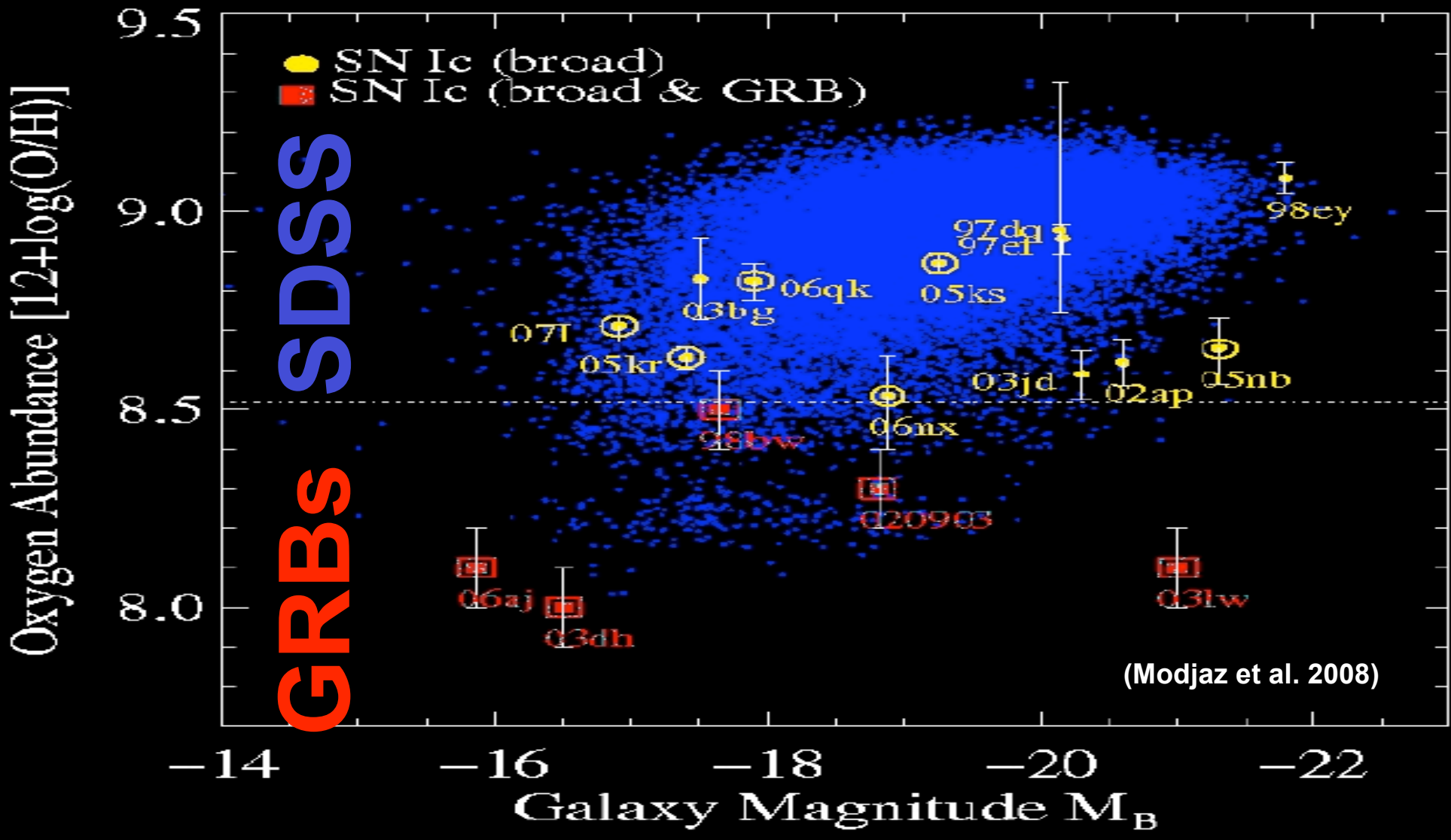
GRB hosts

Luminous dusty starbursts




GRB hosts are *statistically* sub-luminous, blue, young and low-mass galaxies

# Metallicity effects ??




**See also Levesque+09, Han+10 (mass-metallicity relation at intermediate z)**

# Diffuse and irregular morphologies

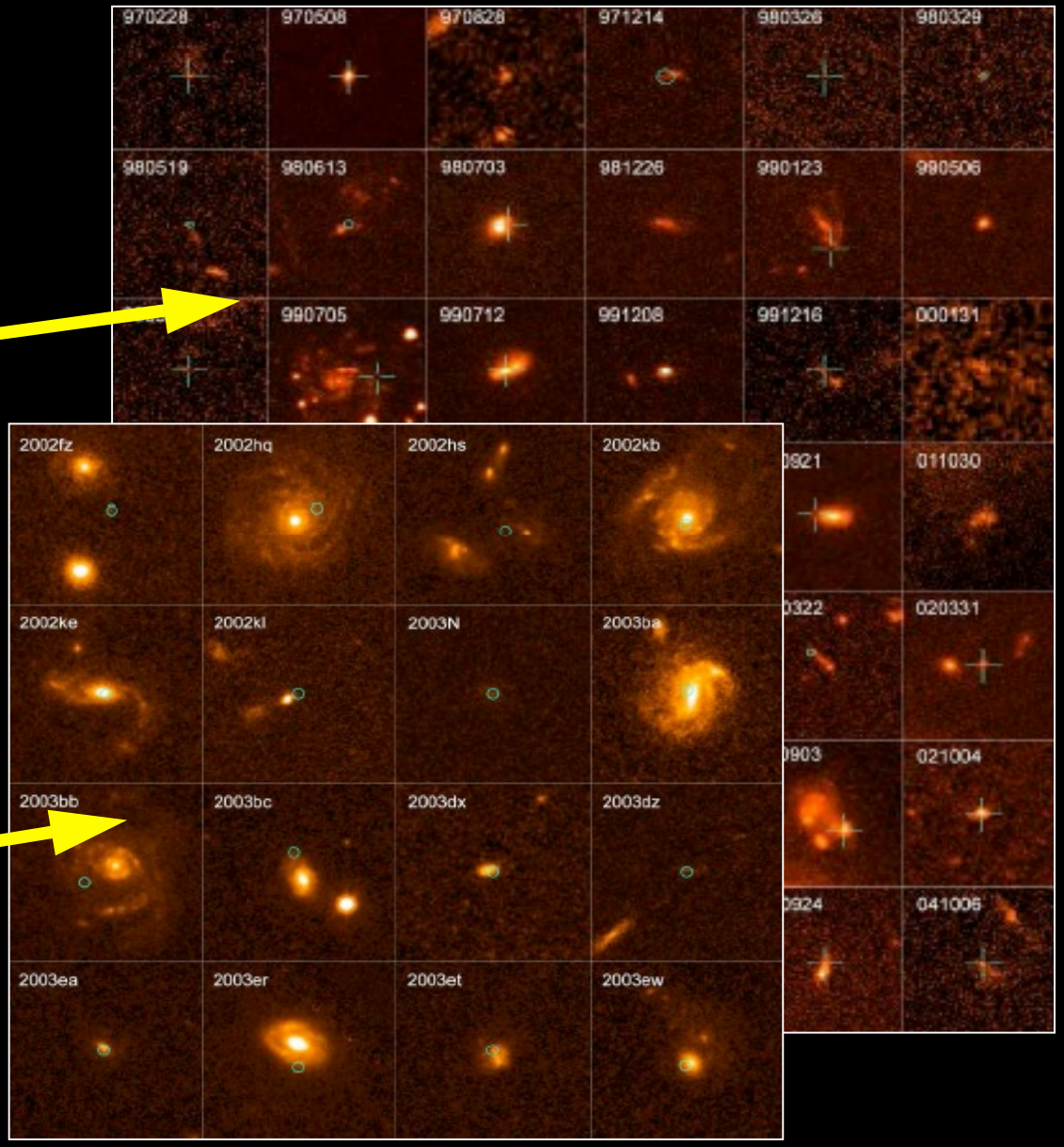
Fruchter et al. 2006

<u>GRB hosts</u>:

- faint, diffuse, compact or irregular
- GRBs more concentrated on the brightest regions

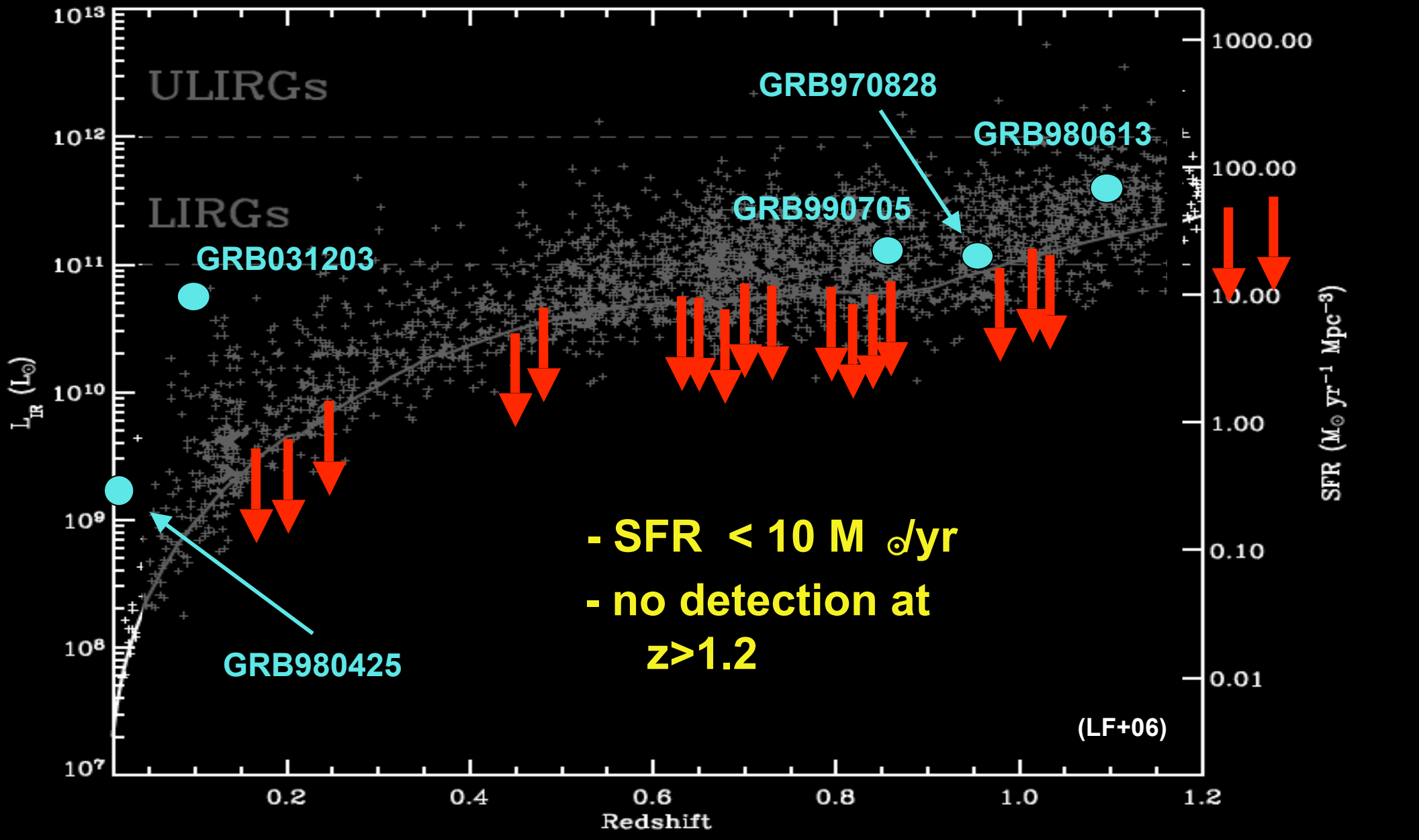
<u>SN II hosts</u>:

- larger, more luminous, grand-design spirals
- SN II more widespread

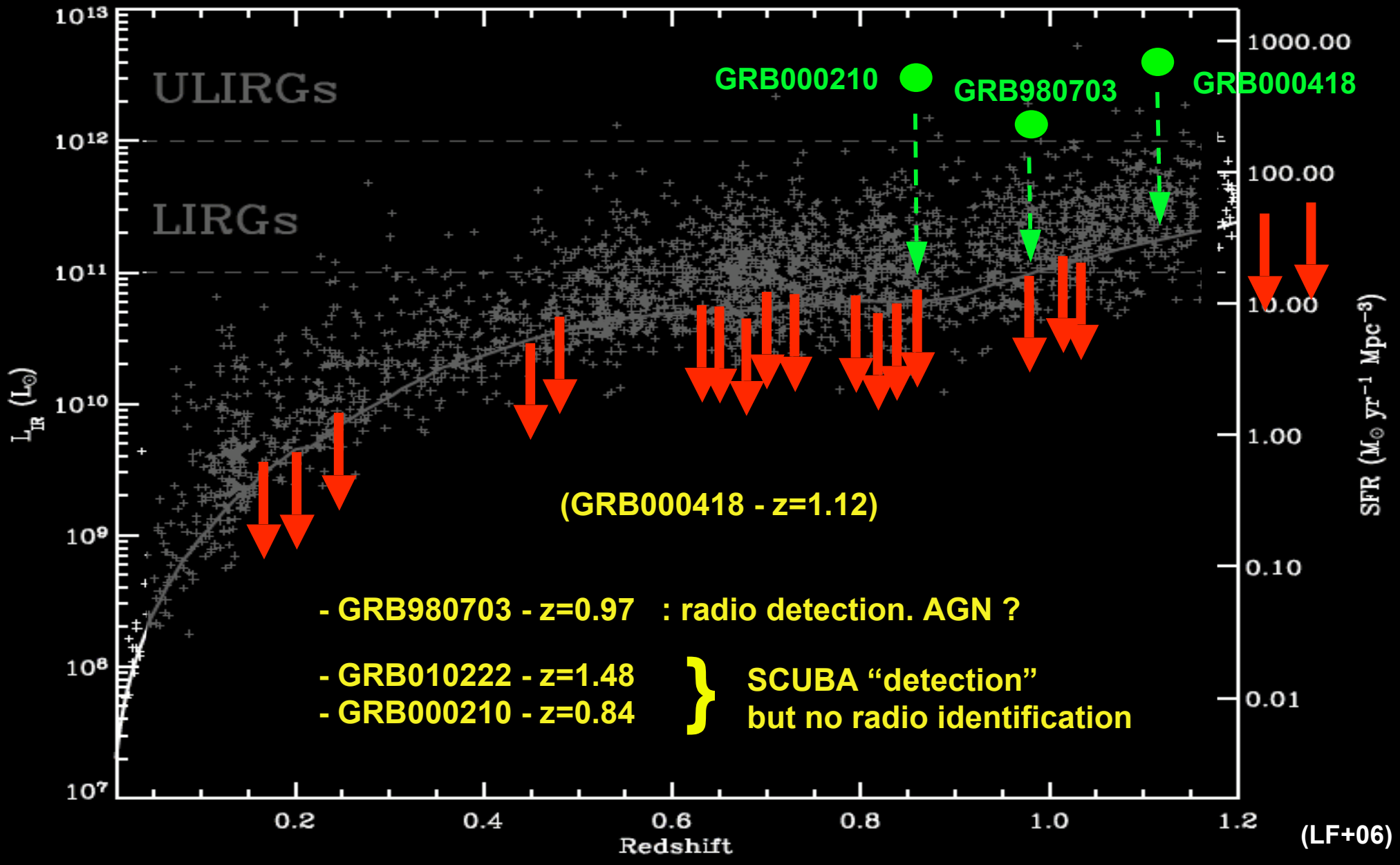



See also Svensson et al. 2010

# Results at 24μm

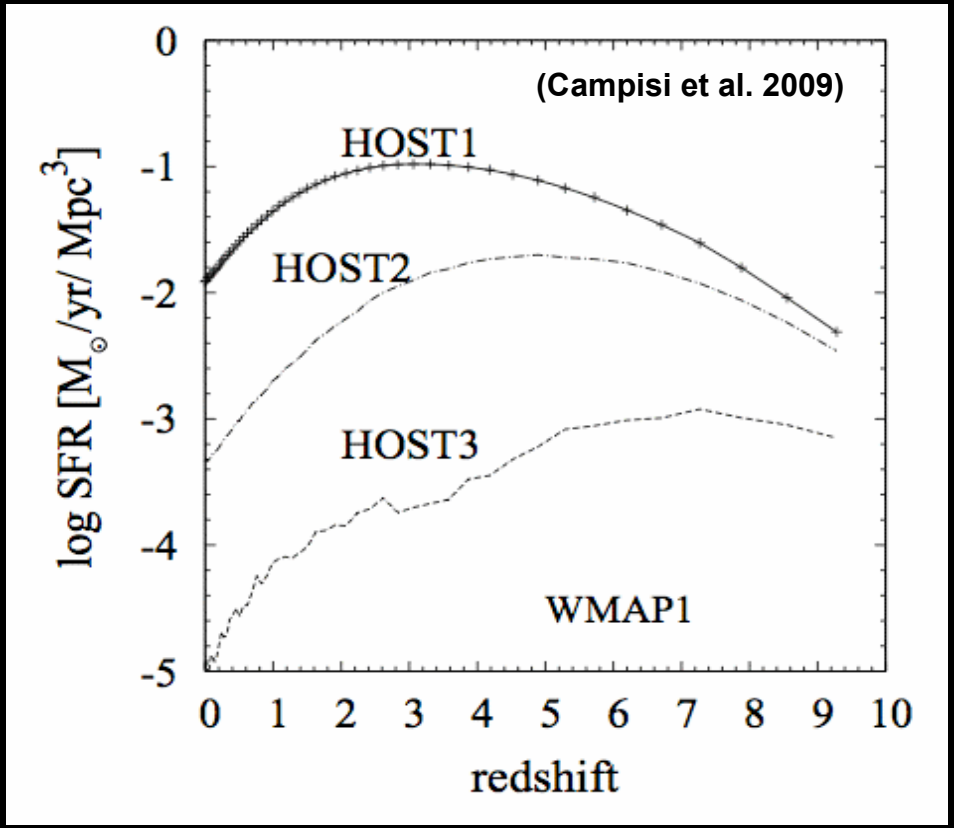


# Results at 24μm



# LGRB hosts in the cosmological simulations

* Courty et al. (2004, 2007), Campisi et al. (2009, 2010), Nuza et al. (2007), Chisari et al. (2010)



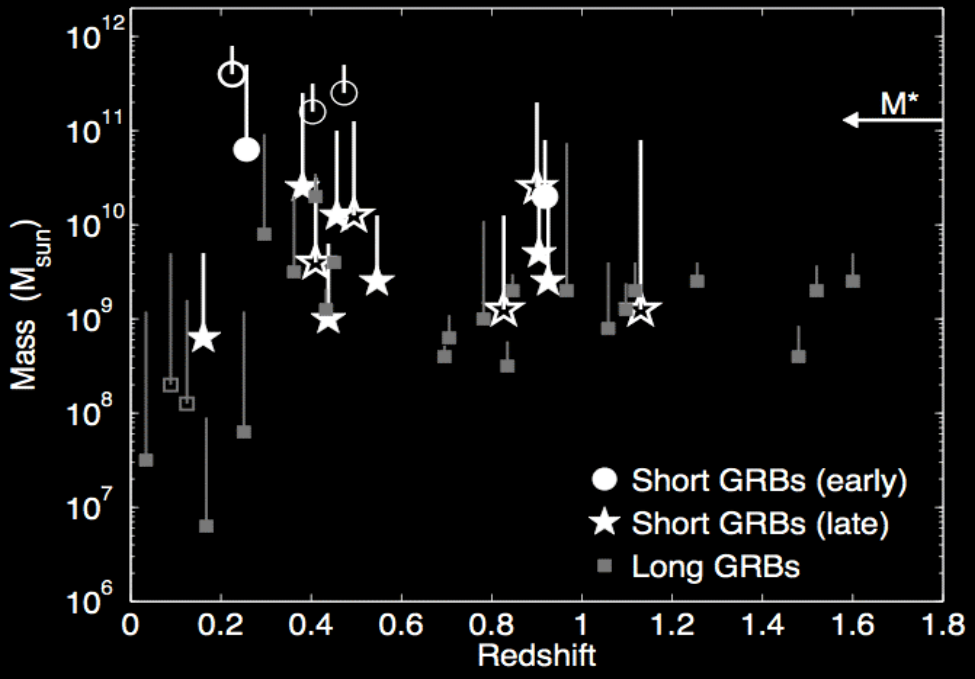

Confirm the observed trends in terms of mass, (blue) colors, modest SFR but high specific rates.

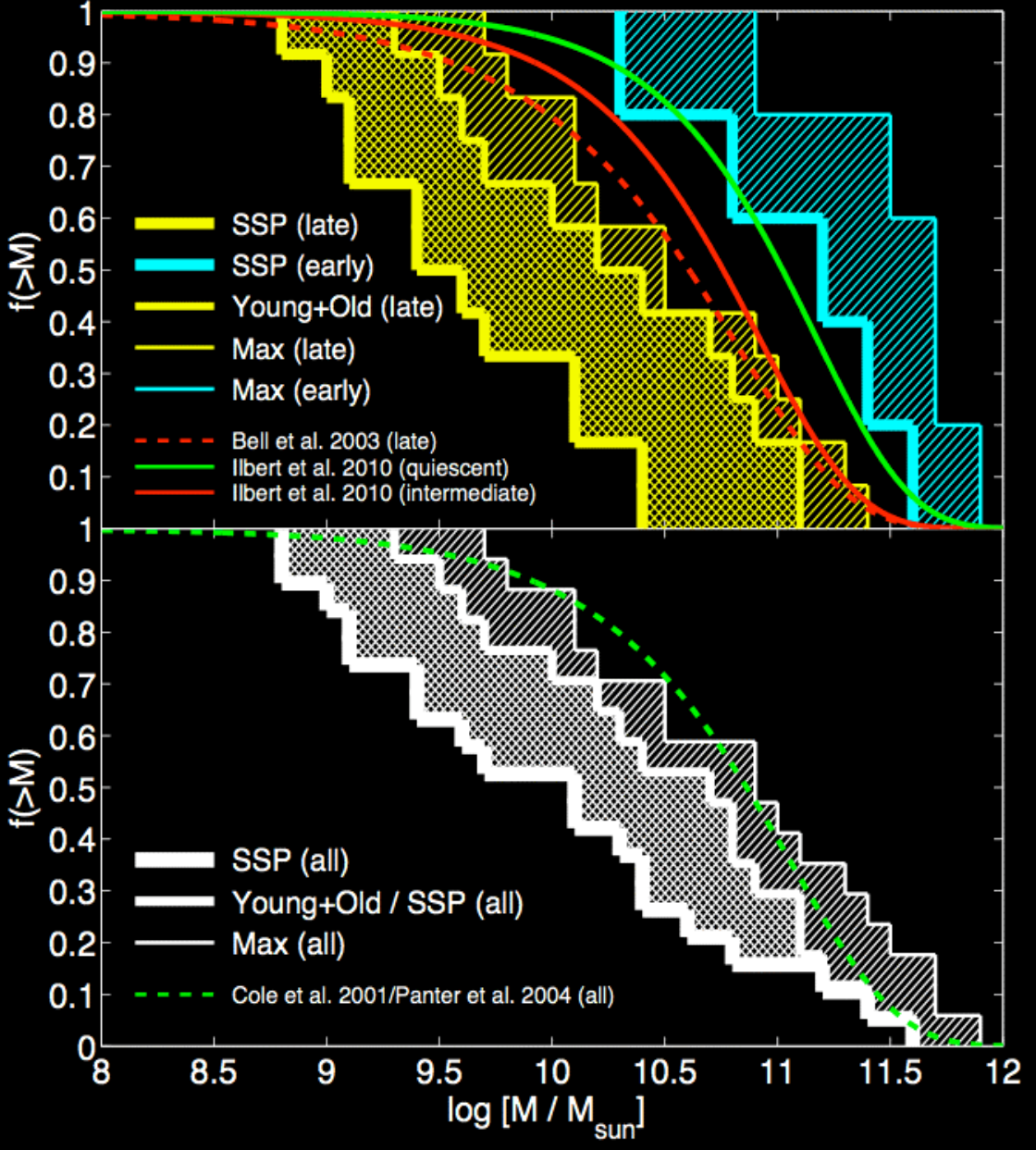
Progenitors with Z<0.3 Zsun give a redshift distribution consistent with the Swift bursts (up to 2009). Only 1% of GRBs at z>6.

# Short-GRB hosts: an update

* Different from the LGRB hosts, even when restricted to late-types
* Larger masses, luminosities, metallicities, and lower SSFR
* Dearth of early-types wrt the stellar mass distrib. of galaxies

(Leibler & Berger, subm., astro-ph)



# Selection effects on the hosts ?

Are we dealing with different sub-populations of GRB hosts depending on the experiment responsible for the GRB detection ???

(e.g., Swift bursts extending to higher-z compared with BATSE/BeppoSAX)

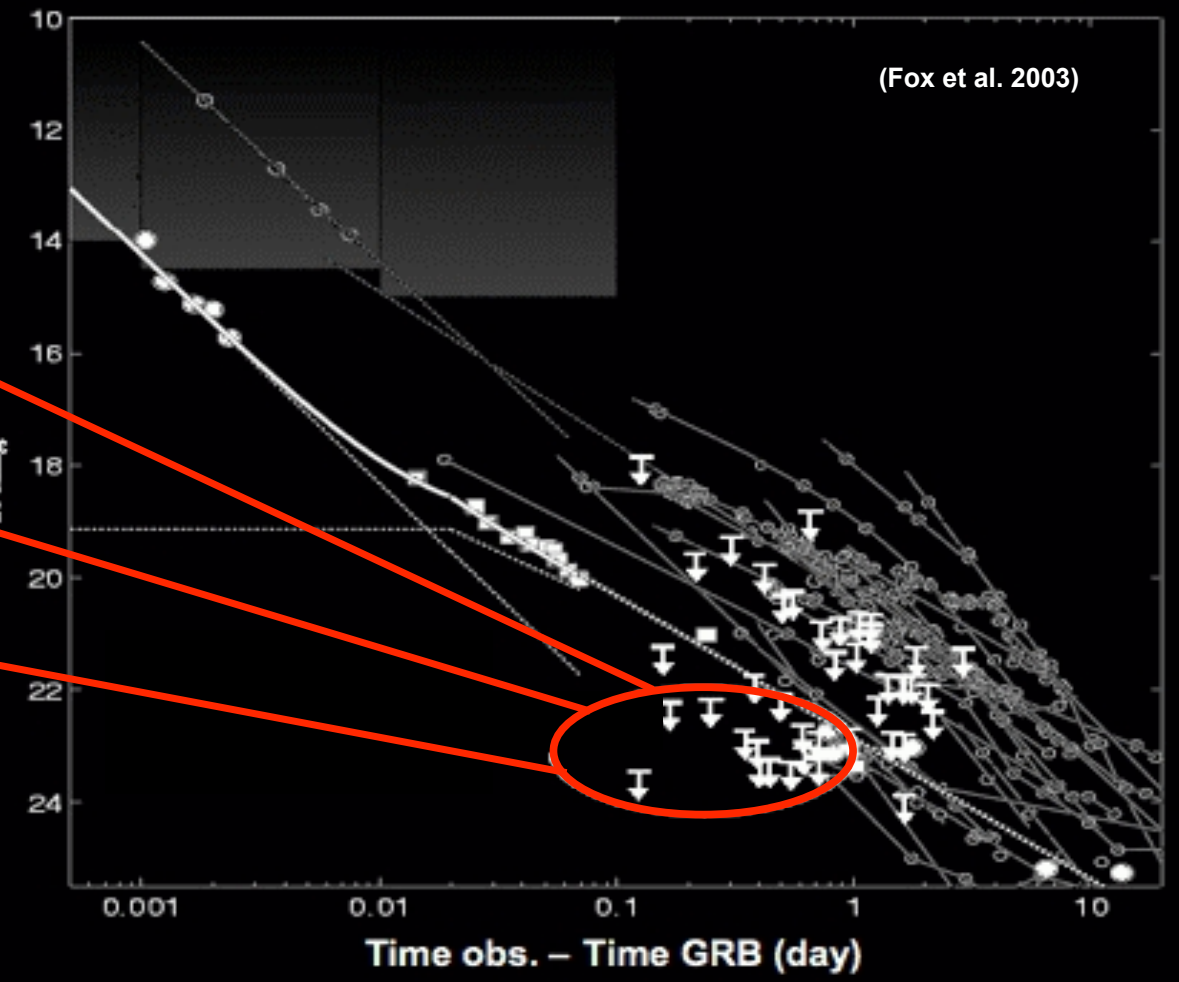
- follow-up of 4 Fermi/LAT GRBs: no difference with previous samples in terms of extinction, SFR, masses (McBreen et al. 2010)

# A bias related to the dark GRBs ?

* GRBs with steep time decays ?

* Lyman absorption of high-z GRBs ?

* dust extinction ?




- optically-*bright* GRBs probe *unobscured* galaxies
- *dusty* galaxies probed by some of the optically-*dark* GRBs

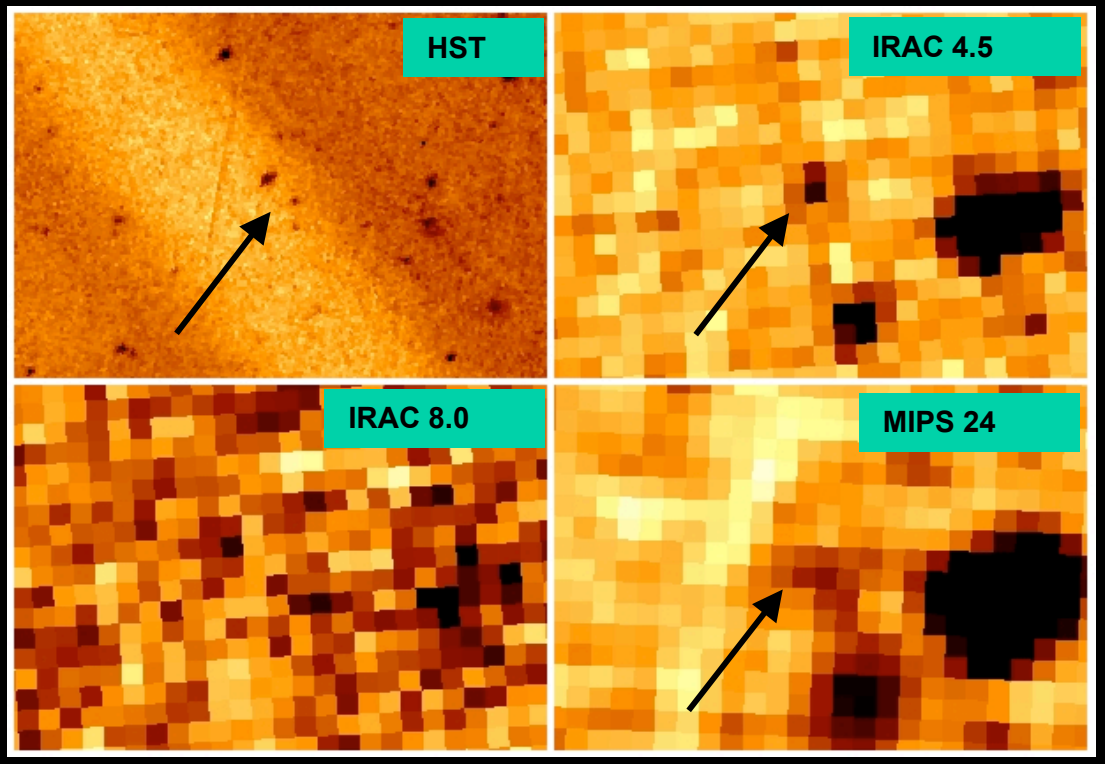
?

# A bias related to the dark GRBs ?

* Dusty dark GRBs do exist !!

GRB970828
(Djorgovski et al. 2001)

- red afterglow
- evidence for extinction
- optically faint host
- detection at 24mic




* Signatures of dust grain destruction by the hard X-ray afterglow

* However, no higher rate of Spitzer detections...

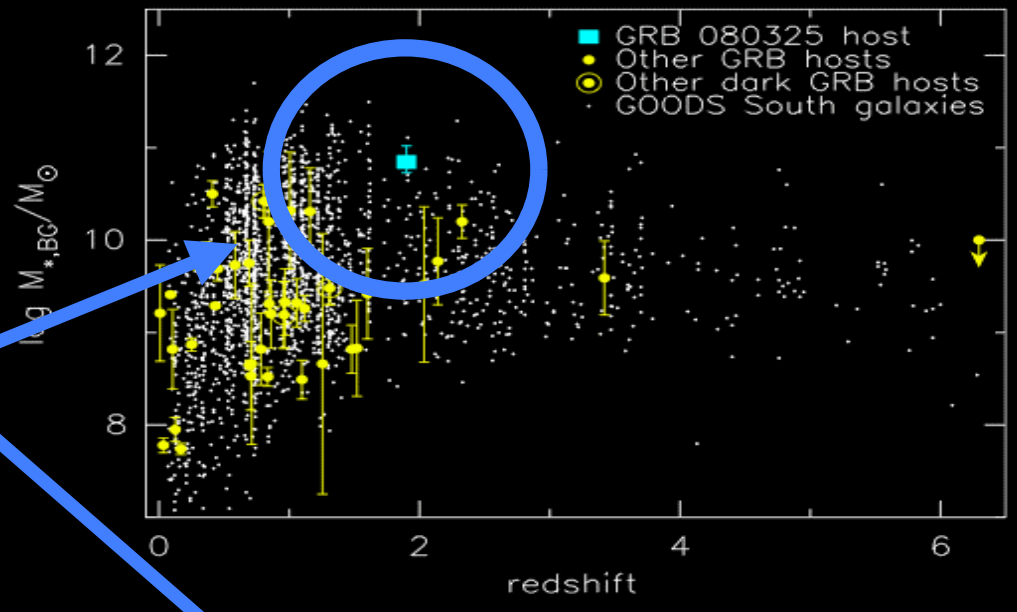
# A bias related to the dark GRBs ?

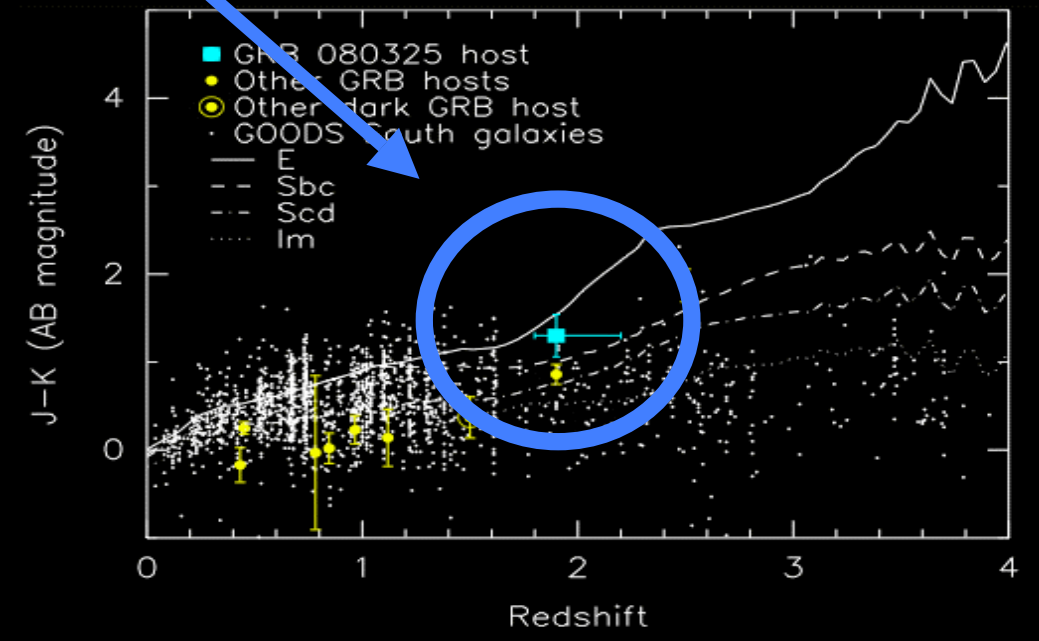
Dark GRBs in massive and dusty galaxies:

* GRB080325 at z~2
  (Hashimoto et al. 2010)

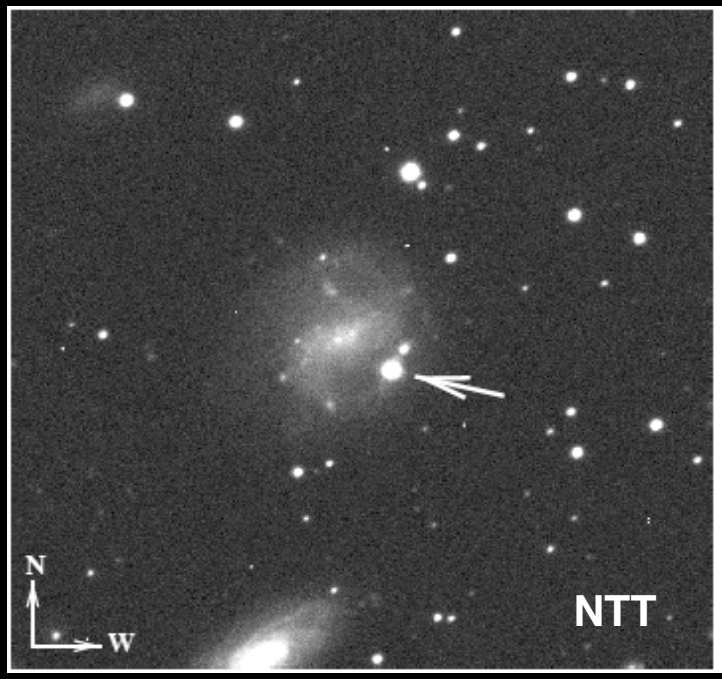
* GRB090417B, z=0.3
  (Holland et al. 2010)
  (Av>12mag,
  SFR:1-100Msol/yr)

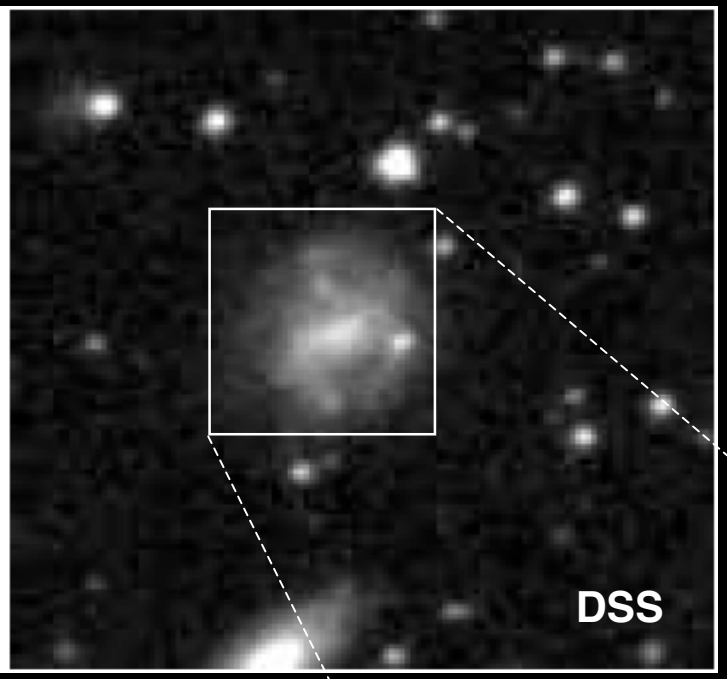
Pellizza et al. 2007:
GRB050223 (z=0.5)



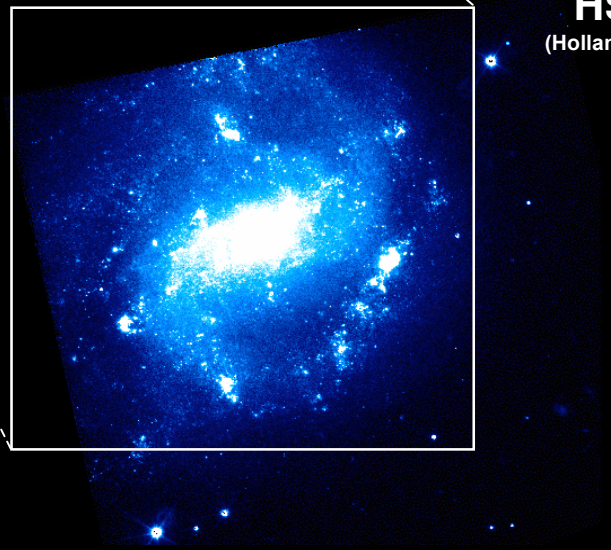



# The host of GRB 980425




(Galama et al. 1998)



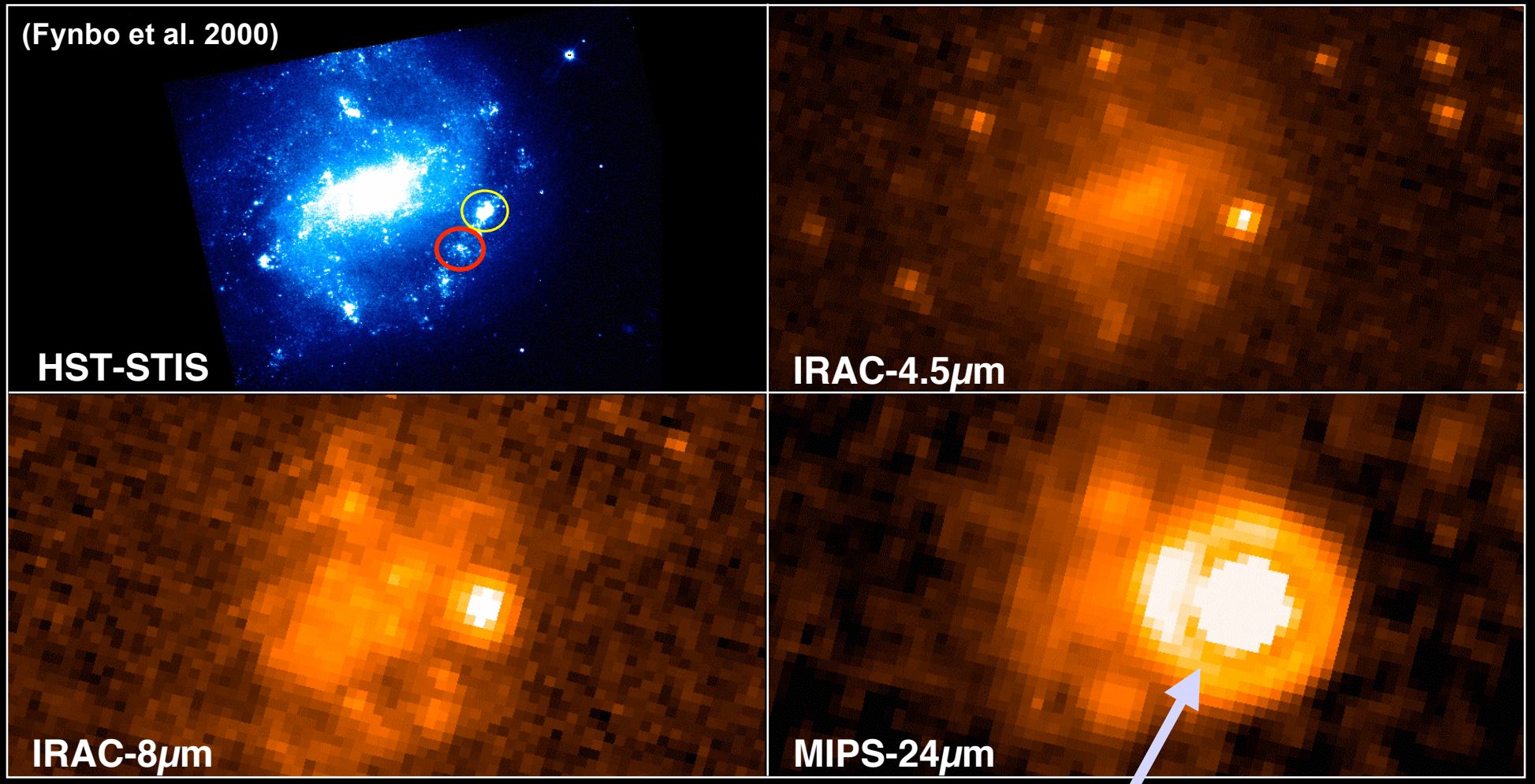
HST
(Holland/Fynbo)

GRB980425 associated with the hypernova SN1998bw at z=0.0085

# The host of GRB 980425

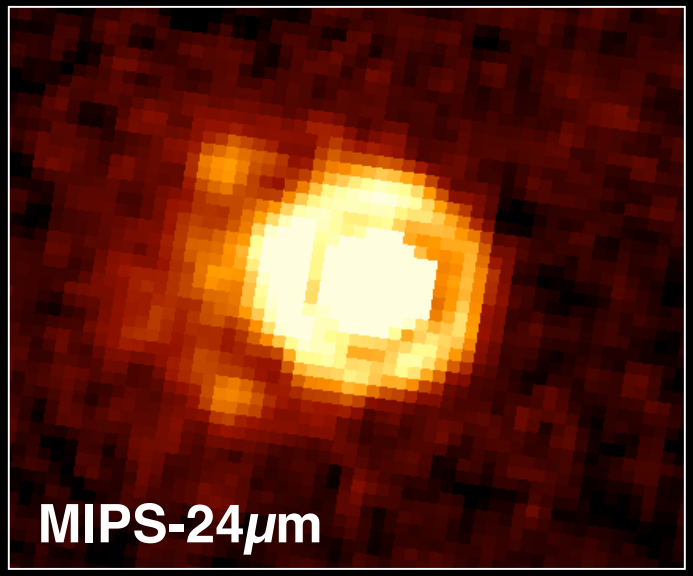
## A multi-wavelength view on the host

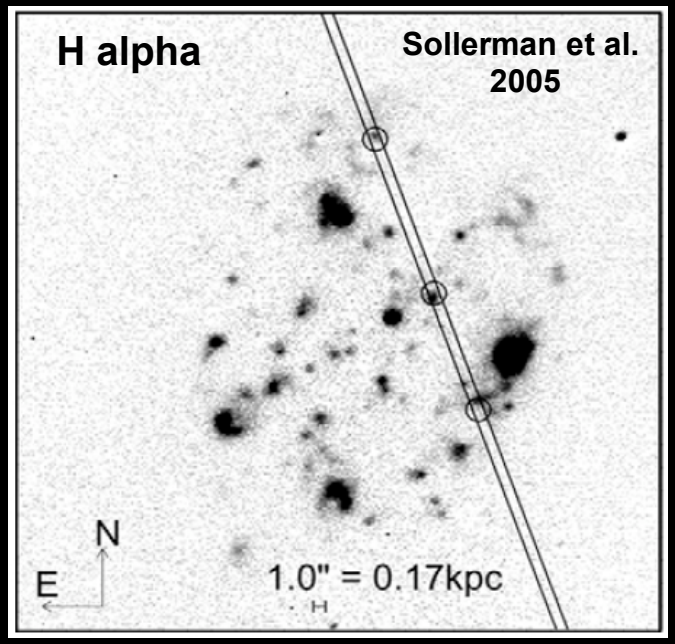
(LF+06)



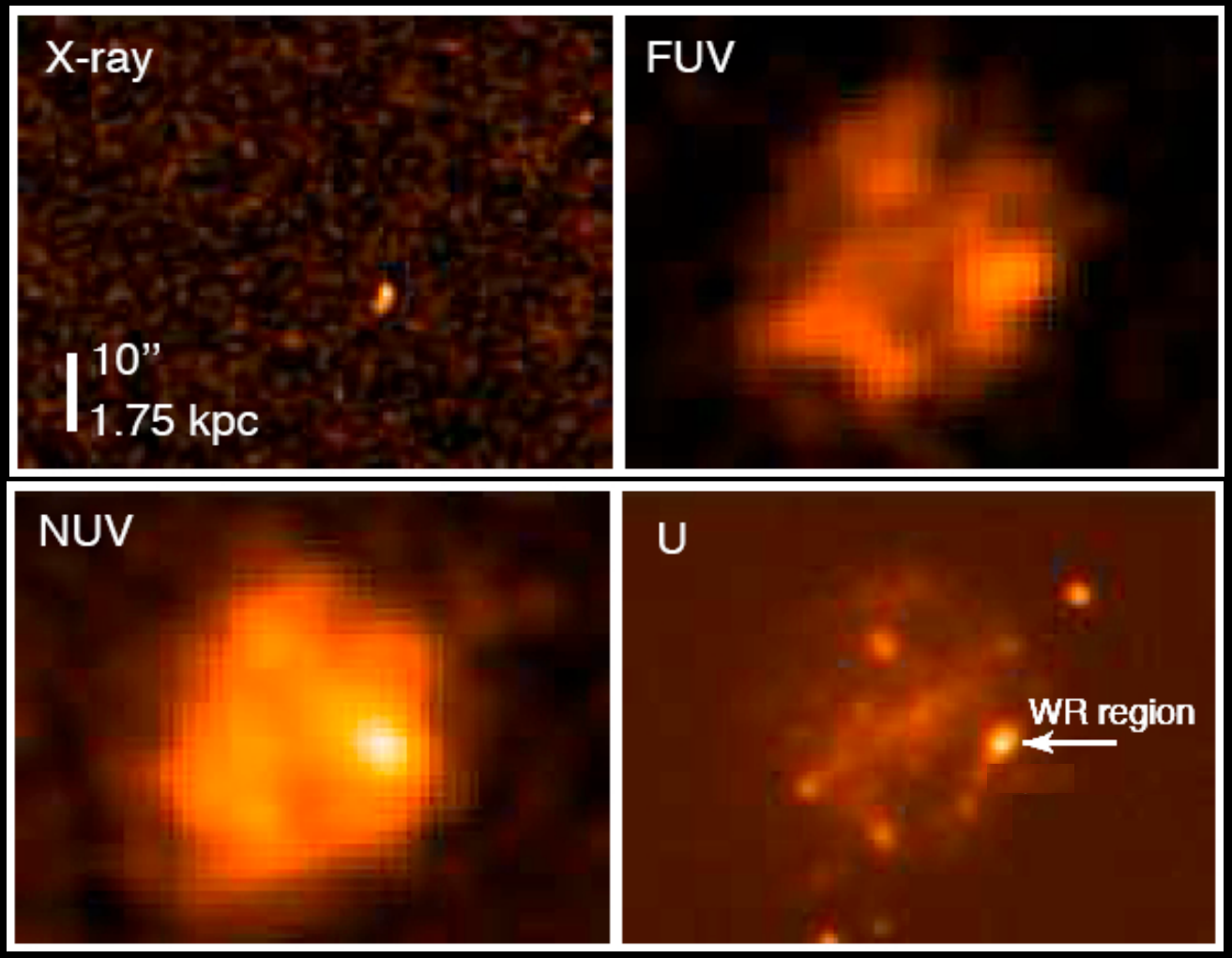

persistent source, SED not consistent with GRB dust heating signature

# X-ray / UV / Halpha imaging



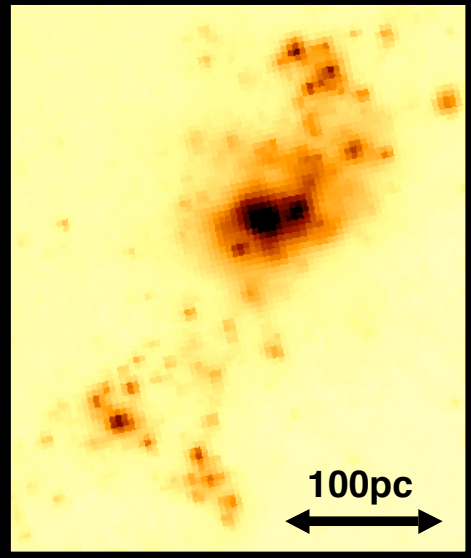



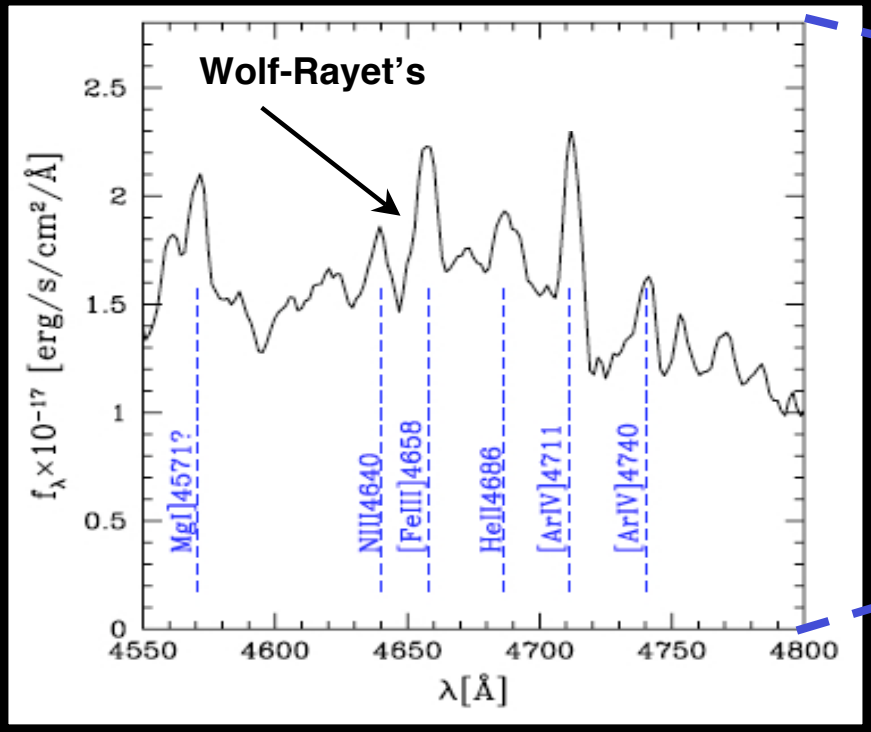

Michalowski et al. 2009



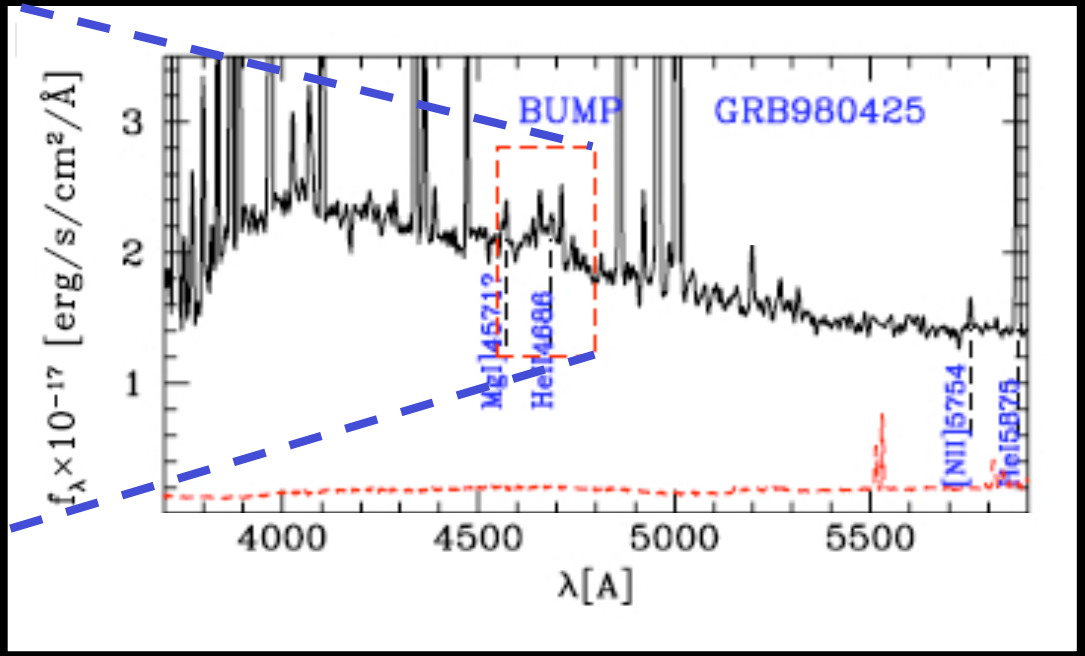
# Probing very young star formation

* Av = 1.5 mag
* 12+log(O/H)=8.4 (~0.5 $Z_\odot$)
* Te ~ 11500K
* EW (Hα) = 1400 Å
* EW (Hβ) = 200 Å
* L(Hβ) ~ 2300 O7V stars
* SFR (Hα) = 0.34 $M_\odot$/yr (extinction corrected)
* Wolf-Rayet's : ~50-100 WN stars

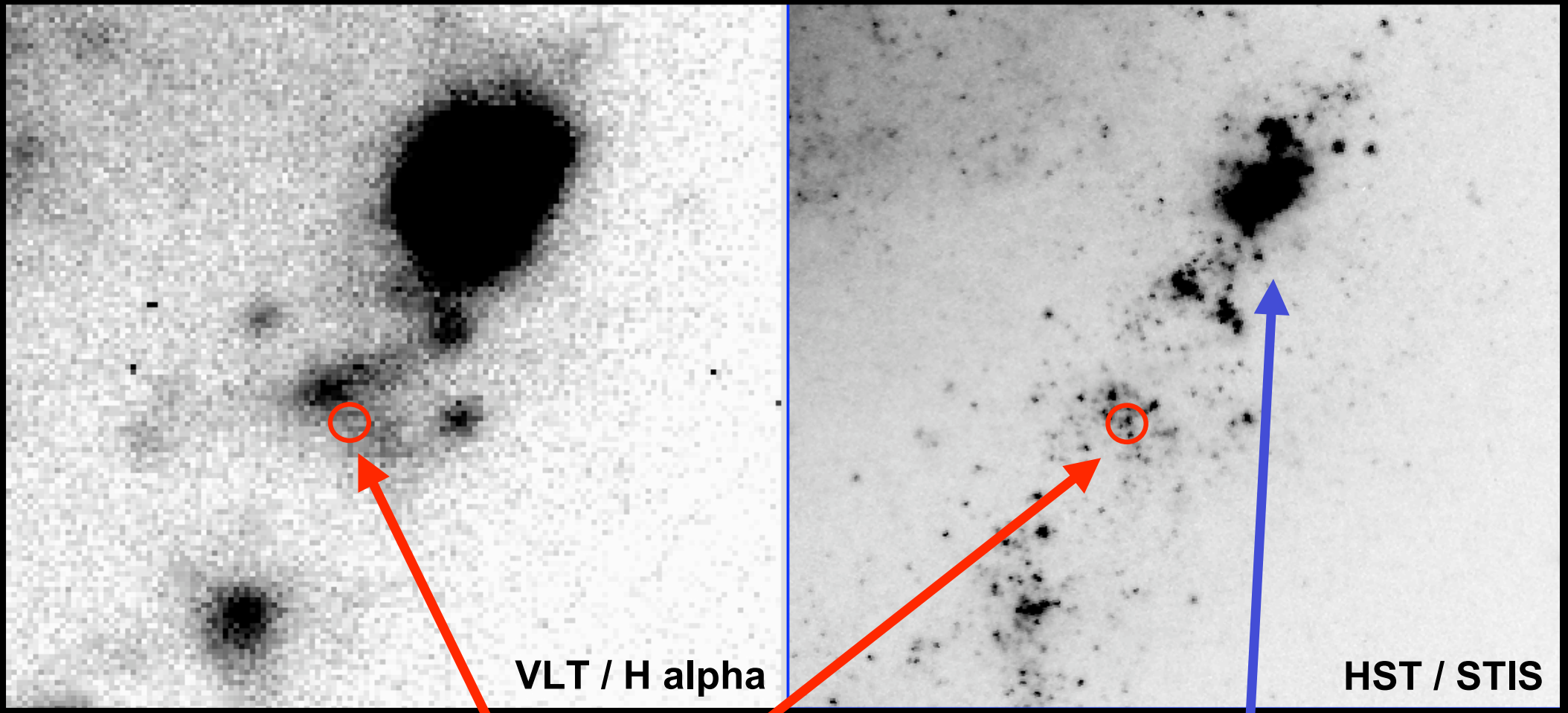



Hammer et al. 2006

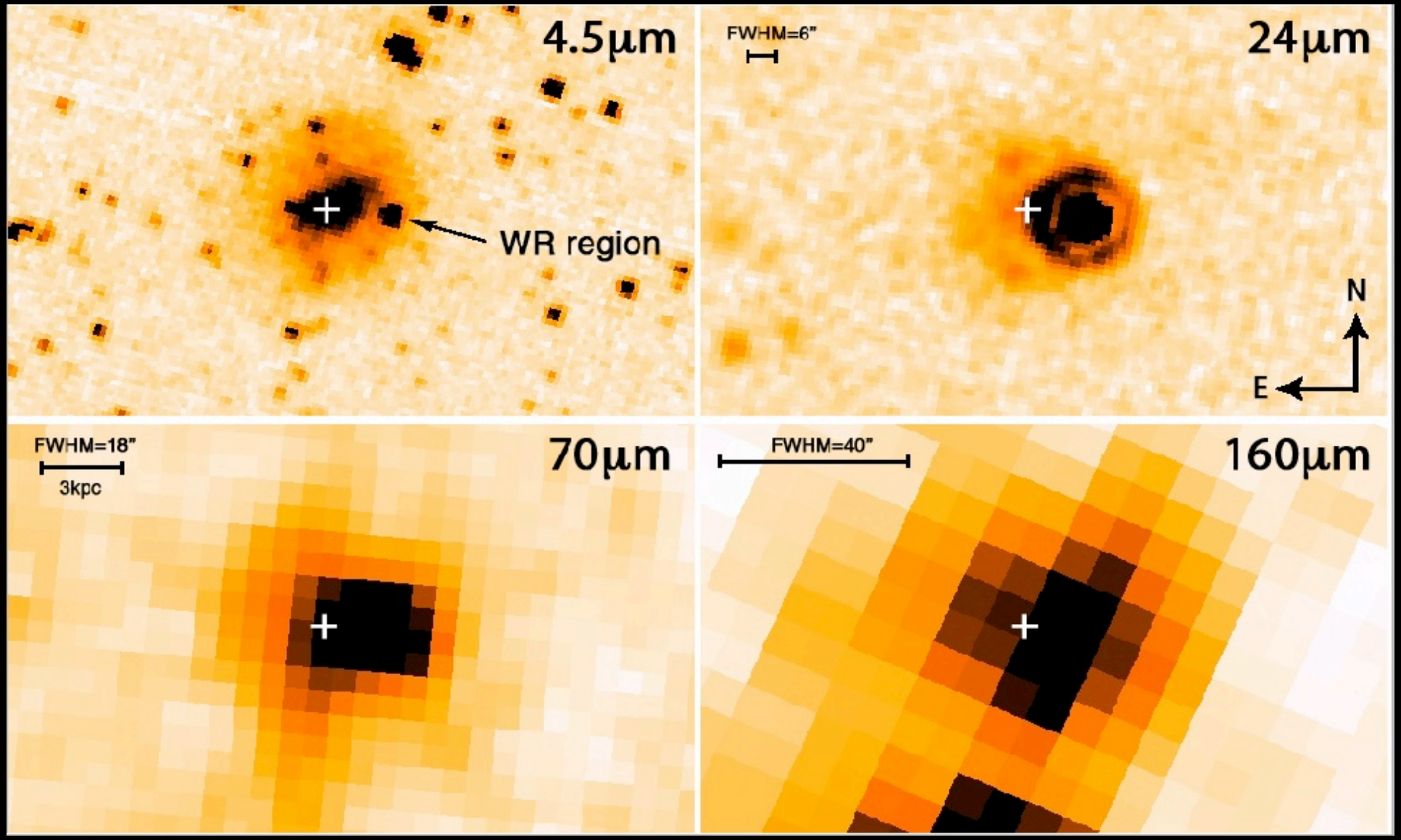


# Optical properties of the HII region



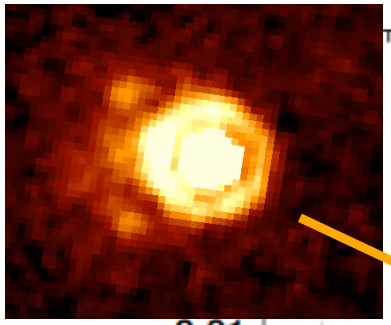

* Run-away scenario (Hammer+06, Cantiello+07) ?????????

# Observations at 70/160mic




⇨ 60% of the emission at 70μm is powered by the SSC

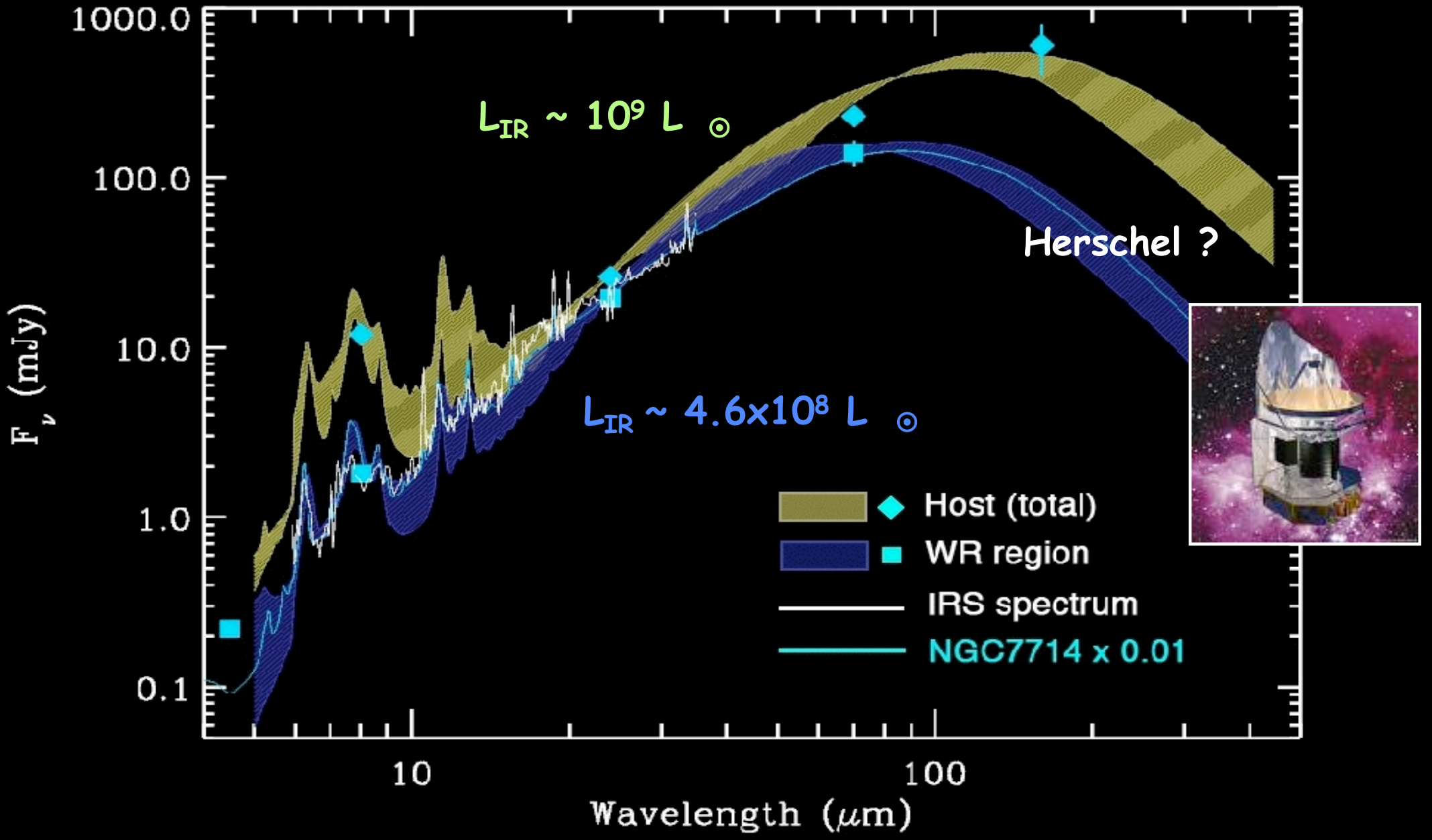
# Probing very young star formation



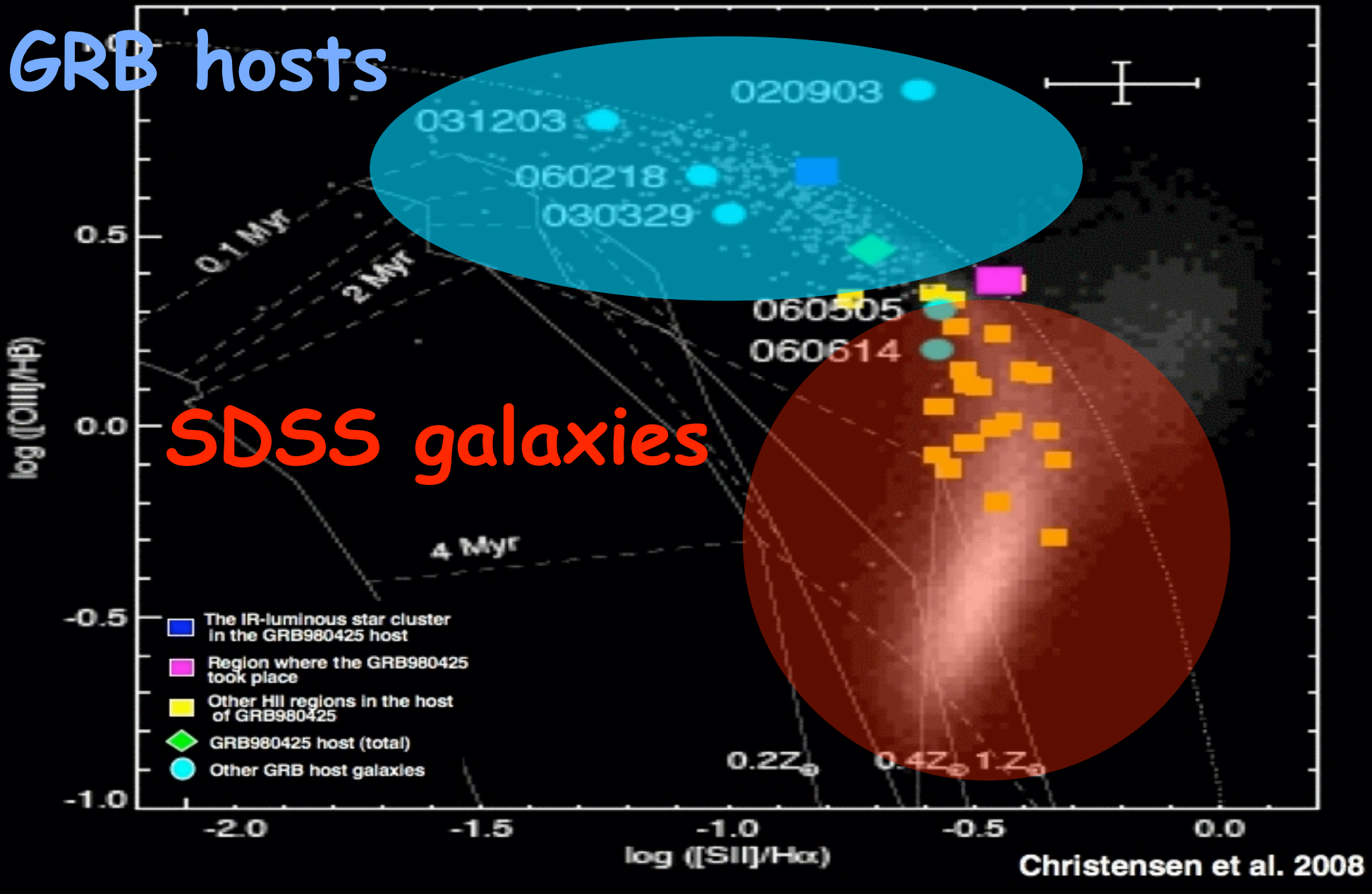



IRS GTO (Charmandaris, Houck et al.)

# Bolometric view



# GRBs as probes of young galaxies



# Caveats

High z GRB hosts are difficult to study and characterize:

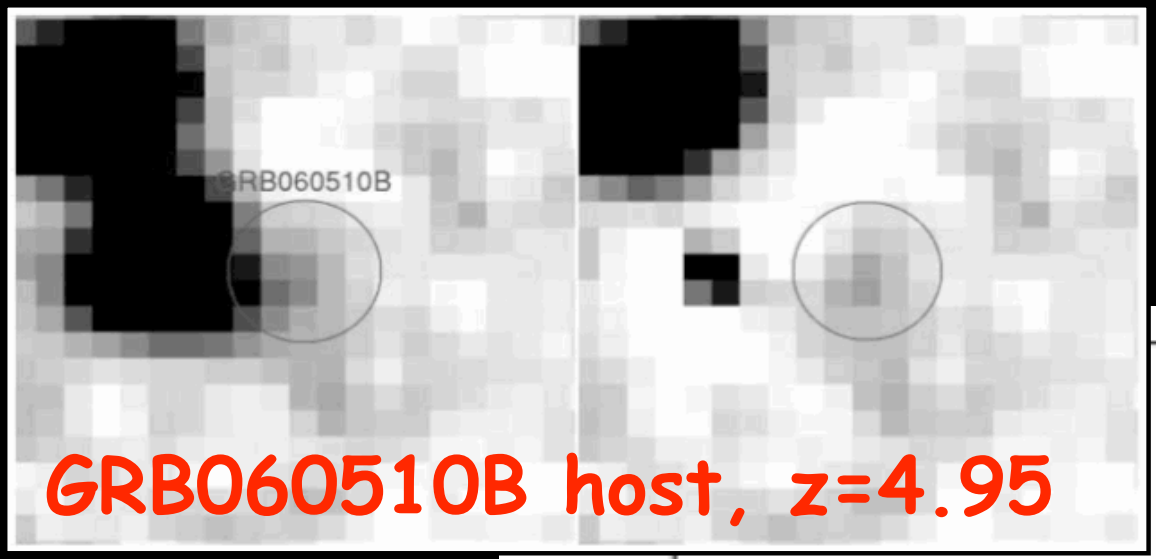
- Intrinsically faint / sub-luminous
- Moderate SFR
- Low extinction

low rate of detections at long wavelengths
(Spitzer, SCUBA, VLA)

* Need for JWST, ALMA, ELTs, …

* Good timing with SVOM

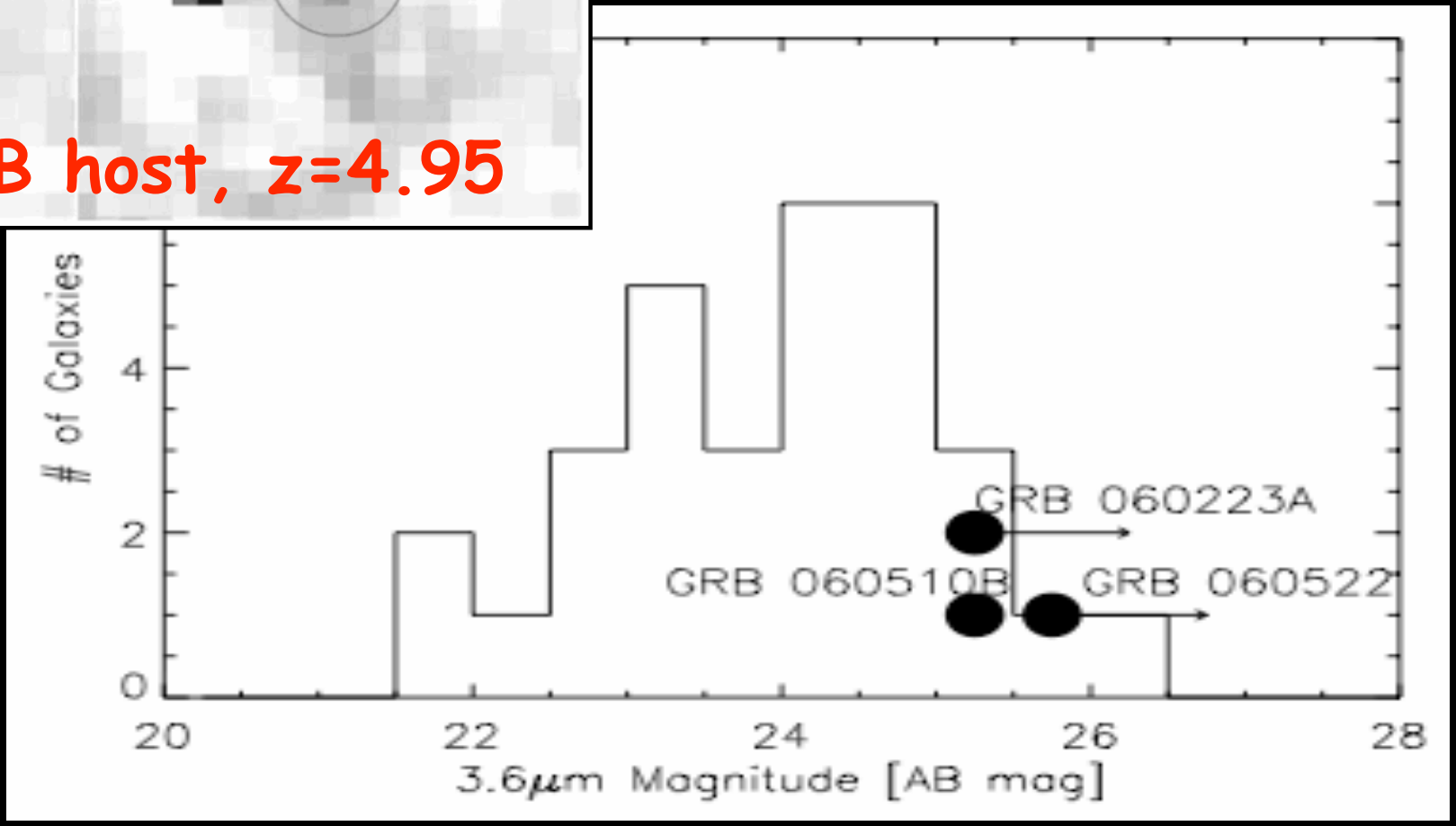
# LGRB hosts at very high z



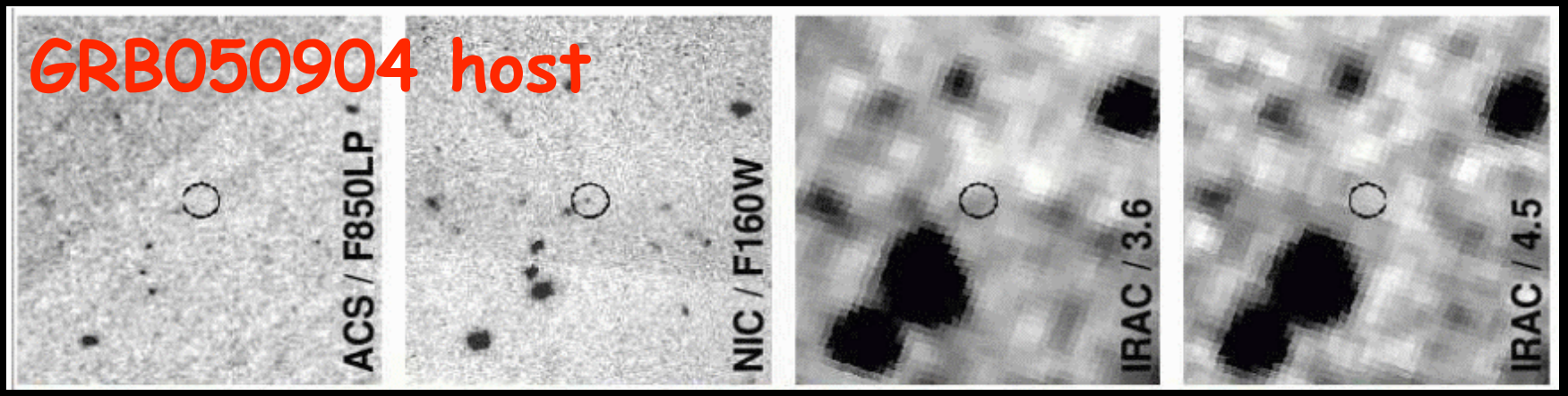

GRB060510B host, z=4.95

(Chary et al. 2007)

* GRB hosts are sub-luminous also at very high redshift

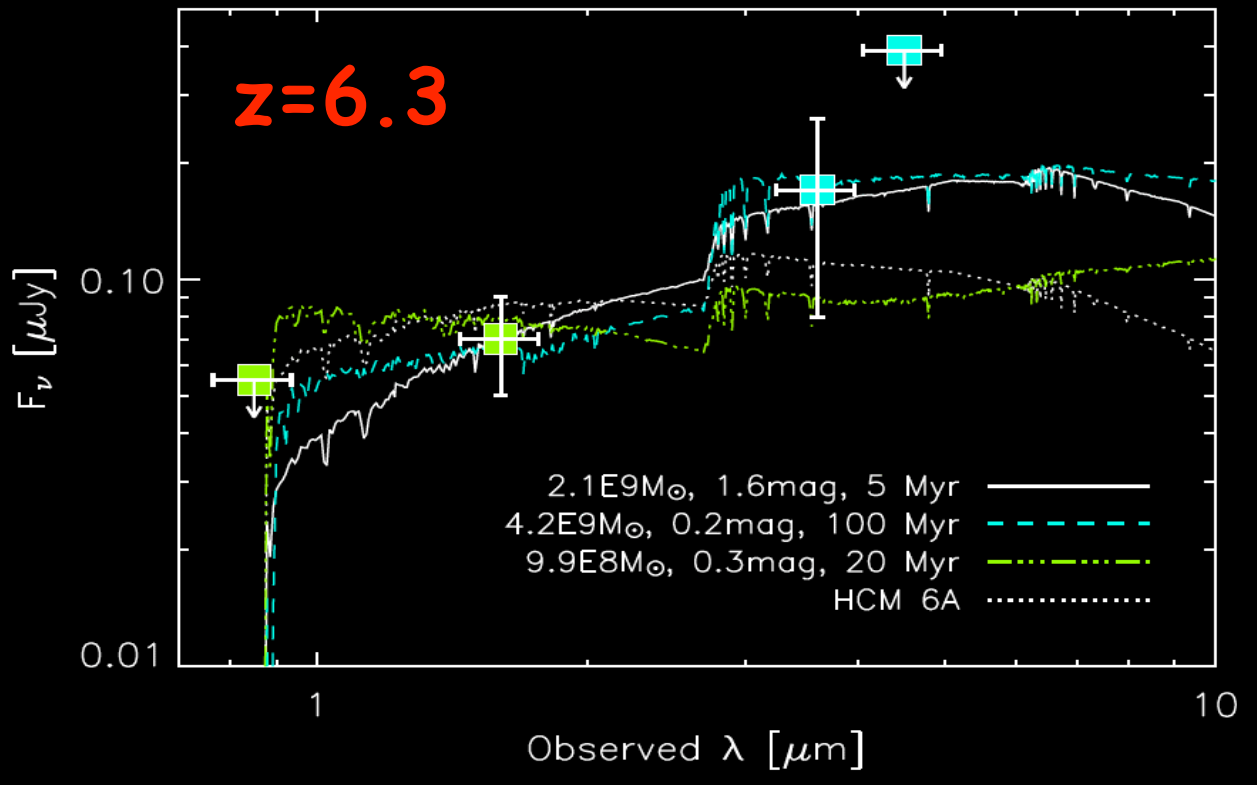


# LGRB hosts at very high z

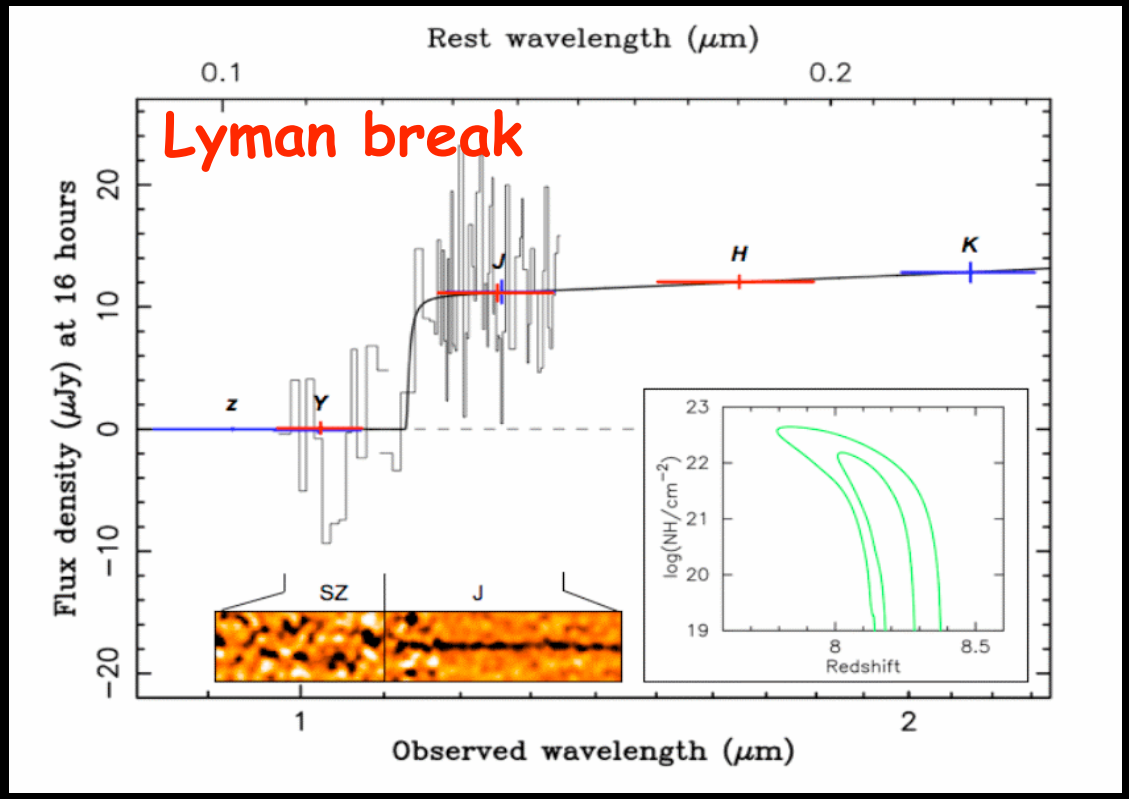



(Berger et al. 2006)

* Not enough constraints to characterize their physical properties in detail



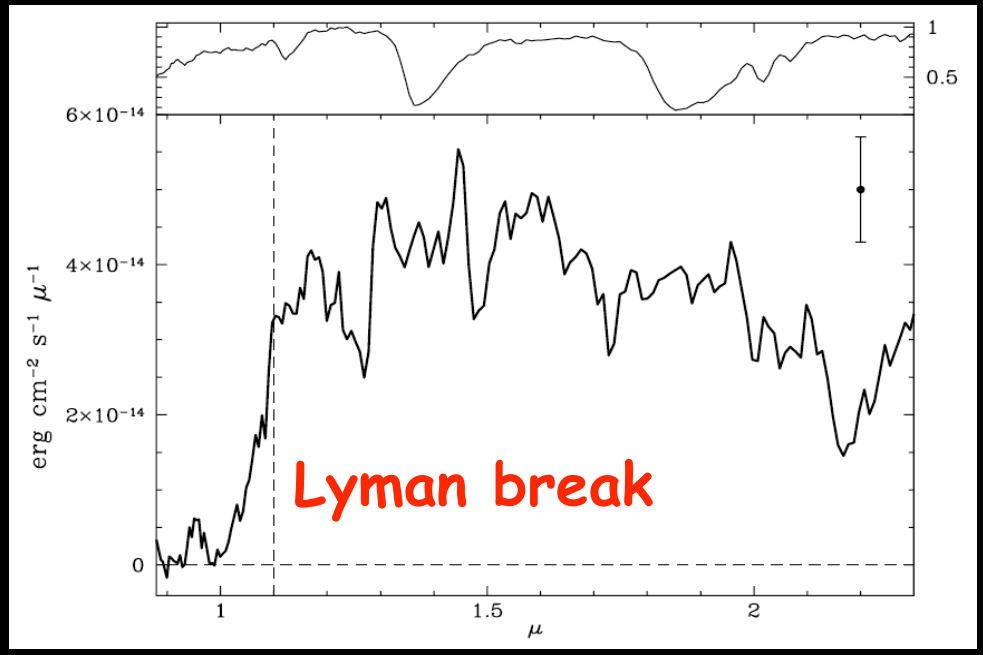
# Pushing to the Dark Ages




(Tanvir et al. 2009)

GRB090423 at z~8,

… albeit with loose constraints…

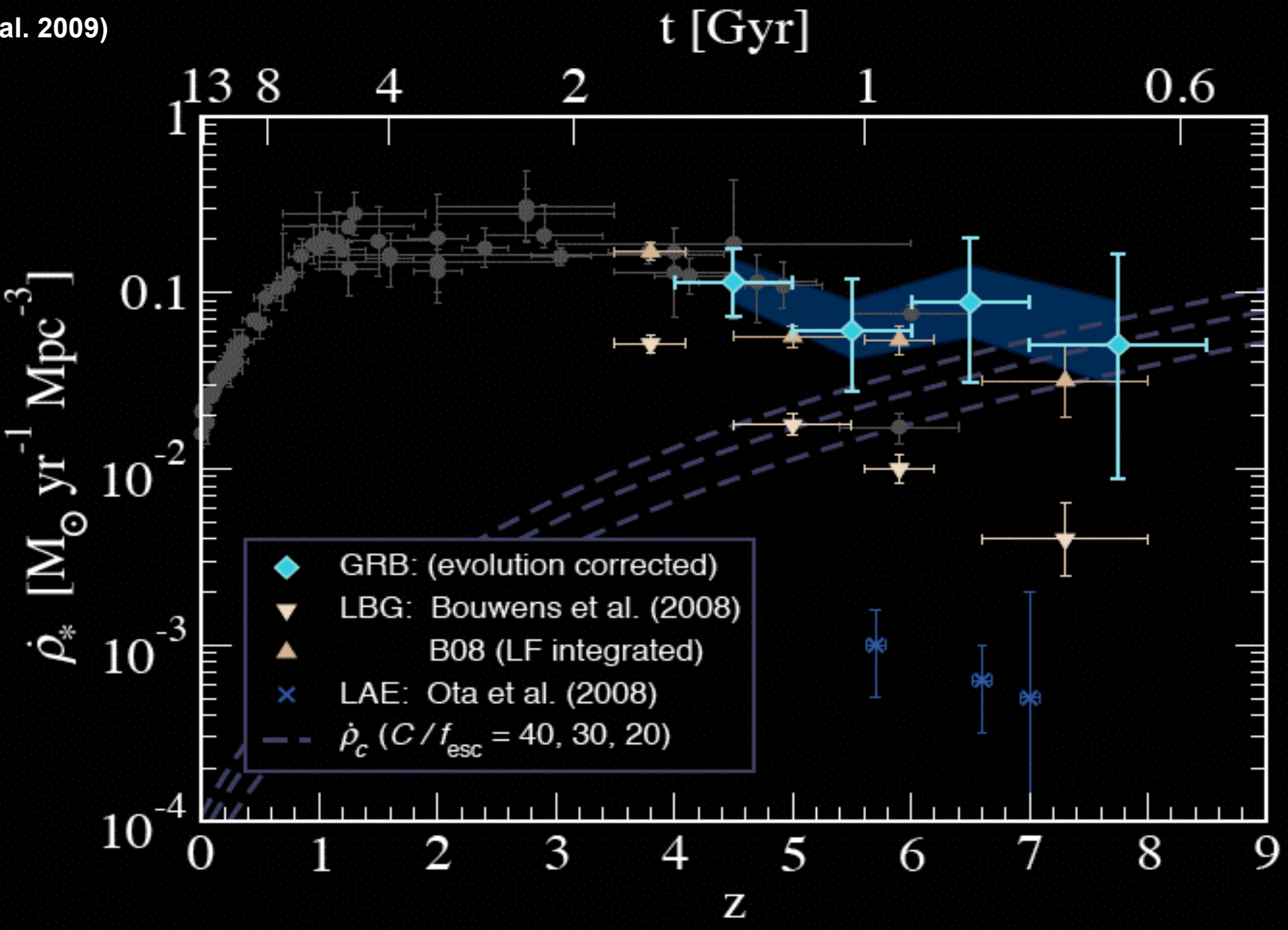



(Salvaterra et al. 2009)

* not a single spec-z at these distances

# Constraints on the star formation history

(Kistler et al. 2009)



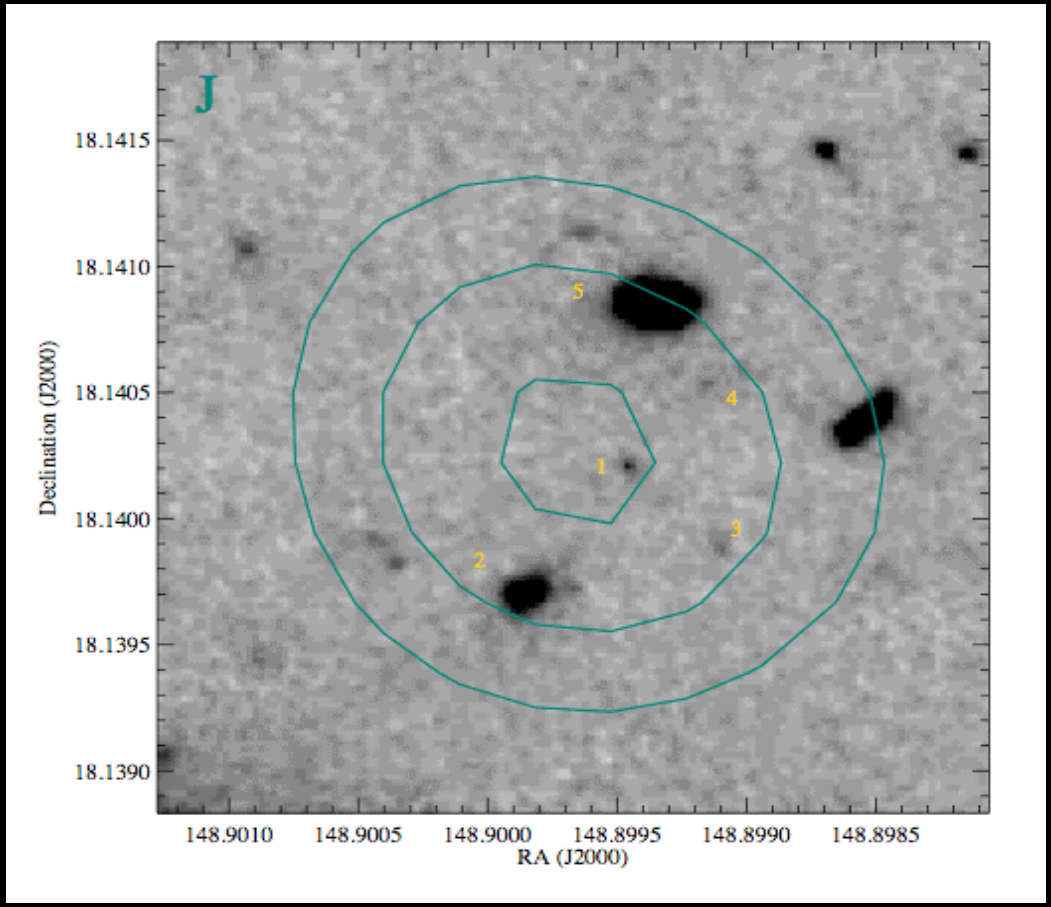
# Molecular gas at very high redshift

Search for CO(3-2) and/or 850mic continuum emission in GRB090423 at z~8

(Stanway et al. 2010)

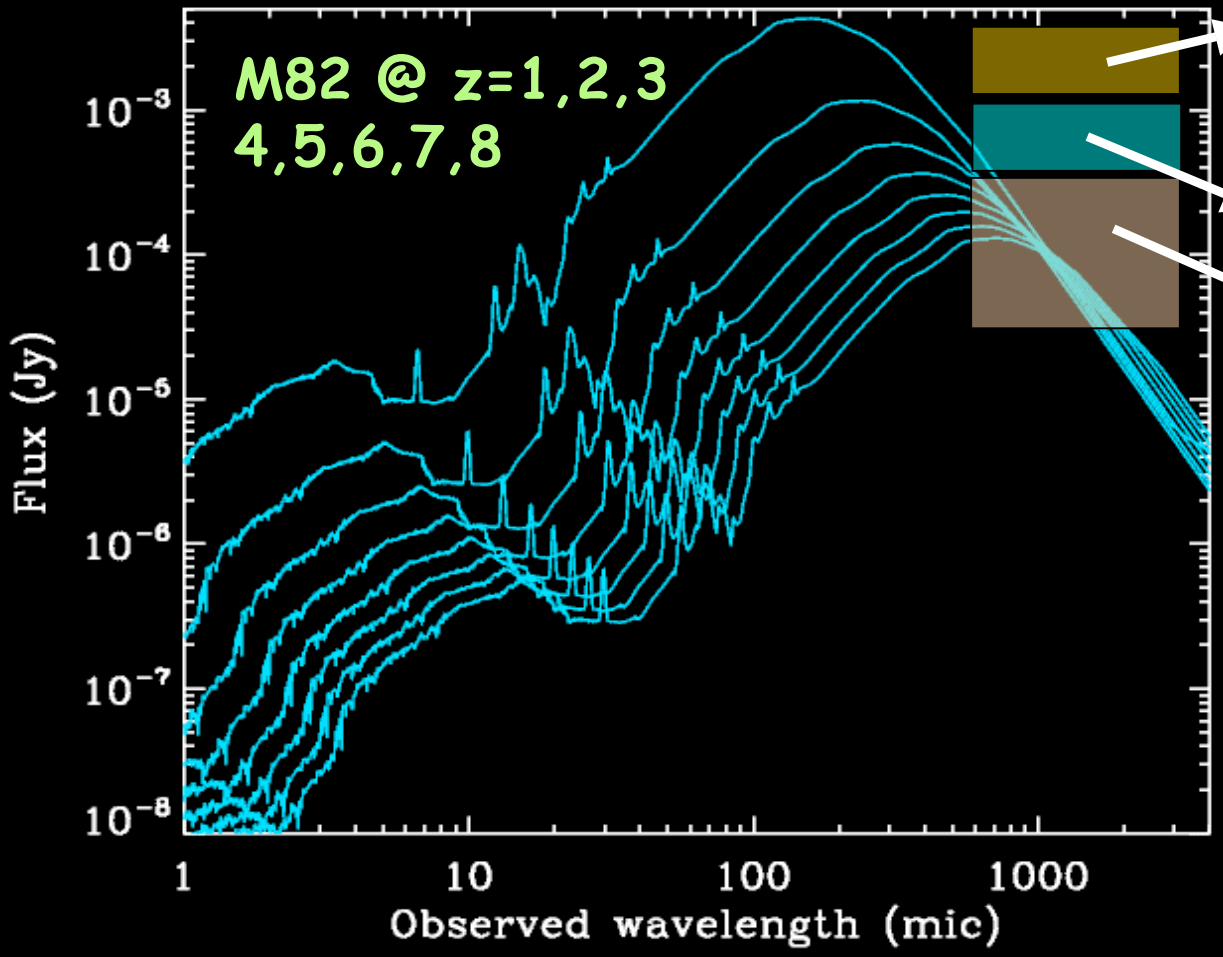
… but no detection

(cf GRB000418 and GRB010222 at IRAM, LeFloc'h+, Carilli+)




Search for [CII] emission (158mic rest-frame): Walter et al. (IRAM). Result not published.

# Dust and cold gas content




Submm/mm surveys (SCUBA, MAMBO, AzTEC)

IRAM, new receivers (PdB)

ALMA, LMT ?

ALMA is designed for follow-up and will not be a "survey machine".

* need high-z targets: e.g., SMGs, LBGs
* LGRBs should be exciting (but difficult) targets

Almost time to think about ALMA ? (first call in 2011)

# Summary

Long GRB hosts:

- blue & sub-luminous star-forming galaxies (moderate SFR, modest extinction, low mass, lower Z for a given mass compared to the field, more diffuse/irregular morphologies, …)
- A biased population compared to field SF galaxies
- The bias might be less significant at high-z

Might still be ideal for SFR constraints at re-ionization, will require follow-up with new generations of large telescopes (ELTs, JWST, ALMA, …)

Short GRB hosts:

- Include both early and late-type galaxies
- Late-type hosts are different from LGRB hosts
- Do not exactly match the stellar mass distribution in the field (might be governed by different parameters, e.g., SFR, mass)