Star Formation and the Metallicity Aversion of Long Duration Gamma Ray Bursts

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Collaborators

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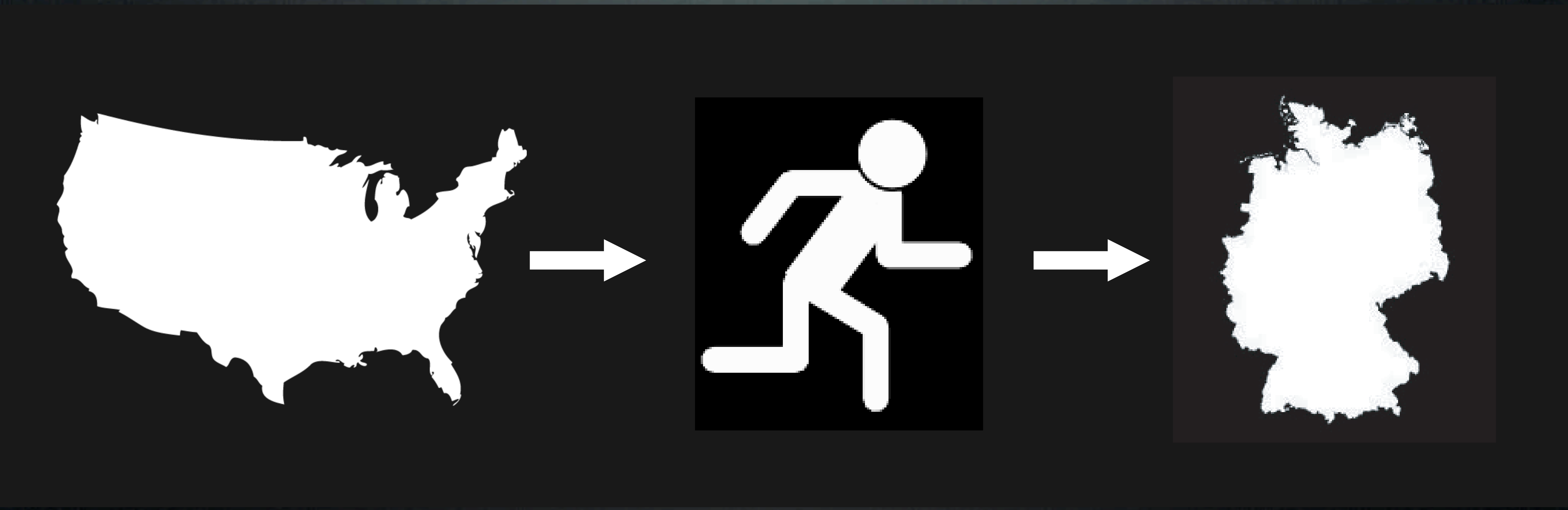
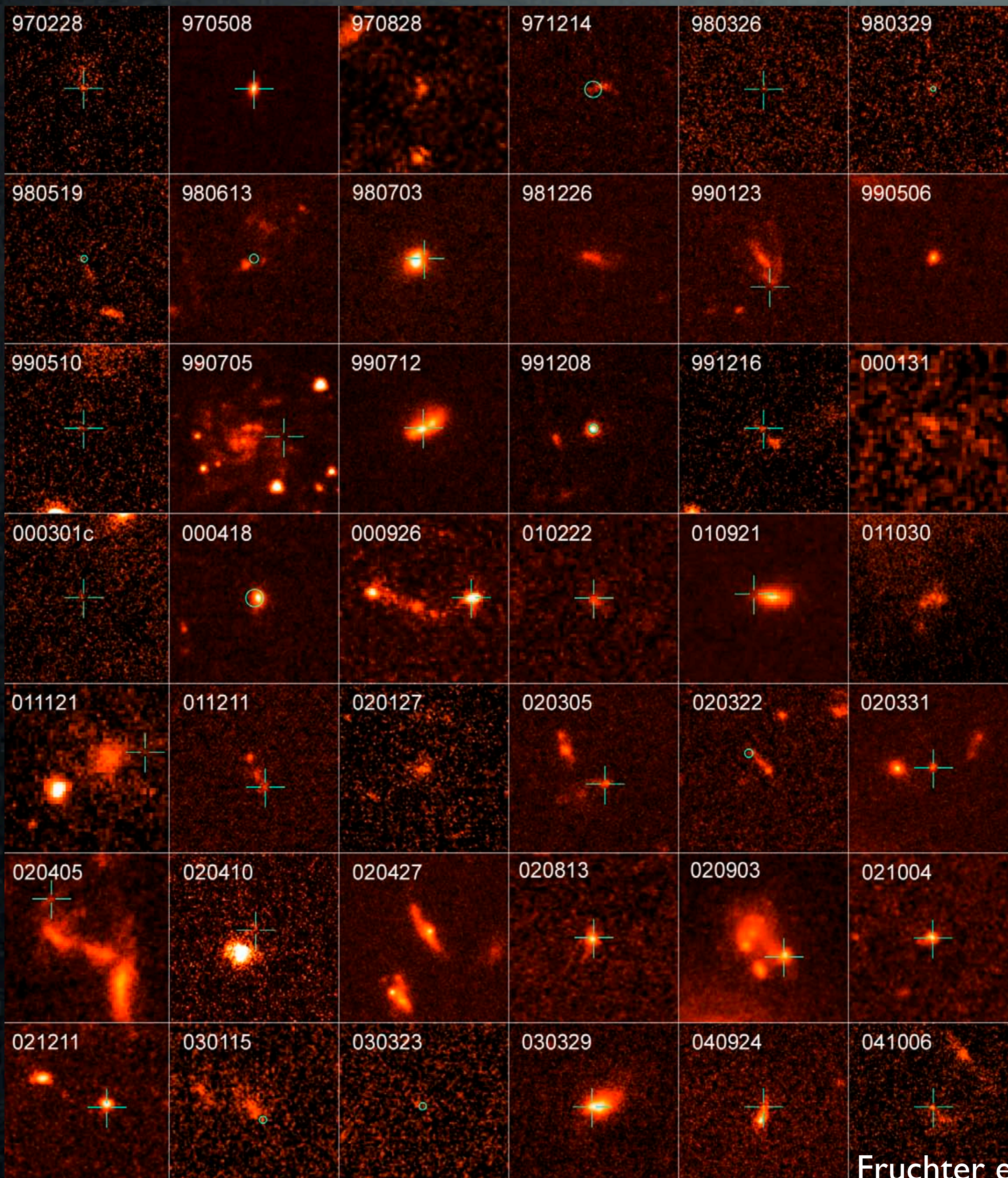
- Greg Aldering
- Saul Perlmutter
- Kuntal Misra
- Kuang-Han Huang
- Dan Reichart
- Melissa Nysewander
- Rebekah Hounsell

About Me: STScI -> MPE

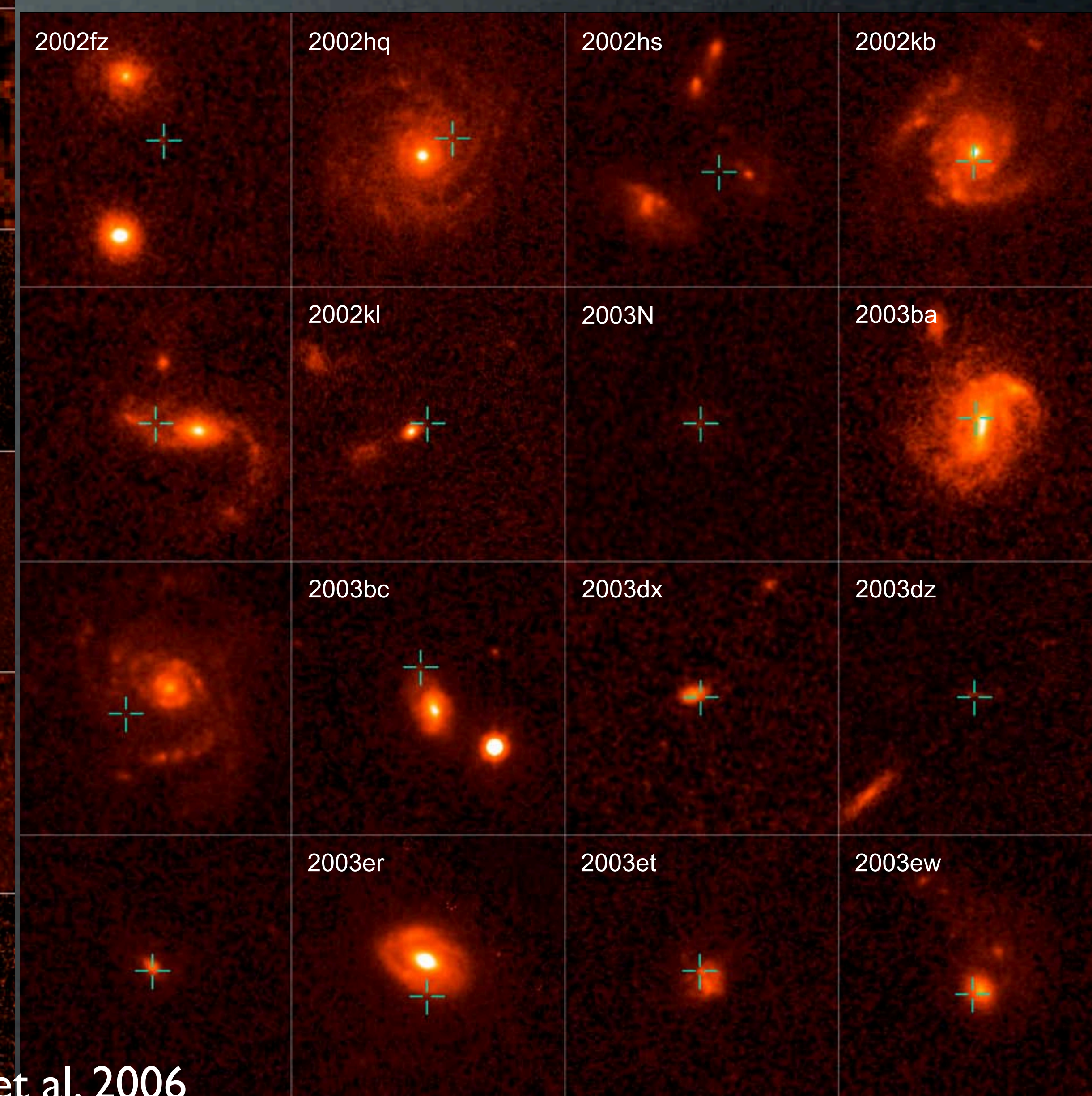


- Finished Ph.D with Andy Fruchter at STScI / JHU
- Starting postdoc with Patricia Schady at MPE

Long Burst Hosts

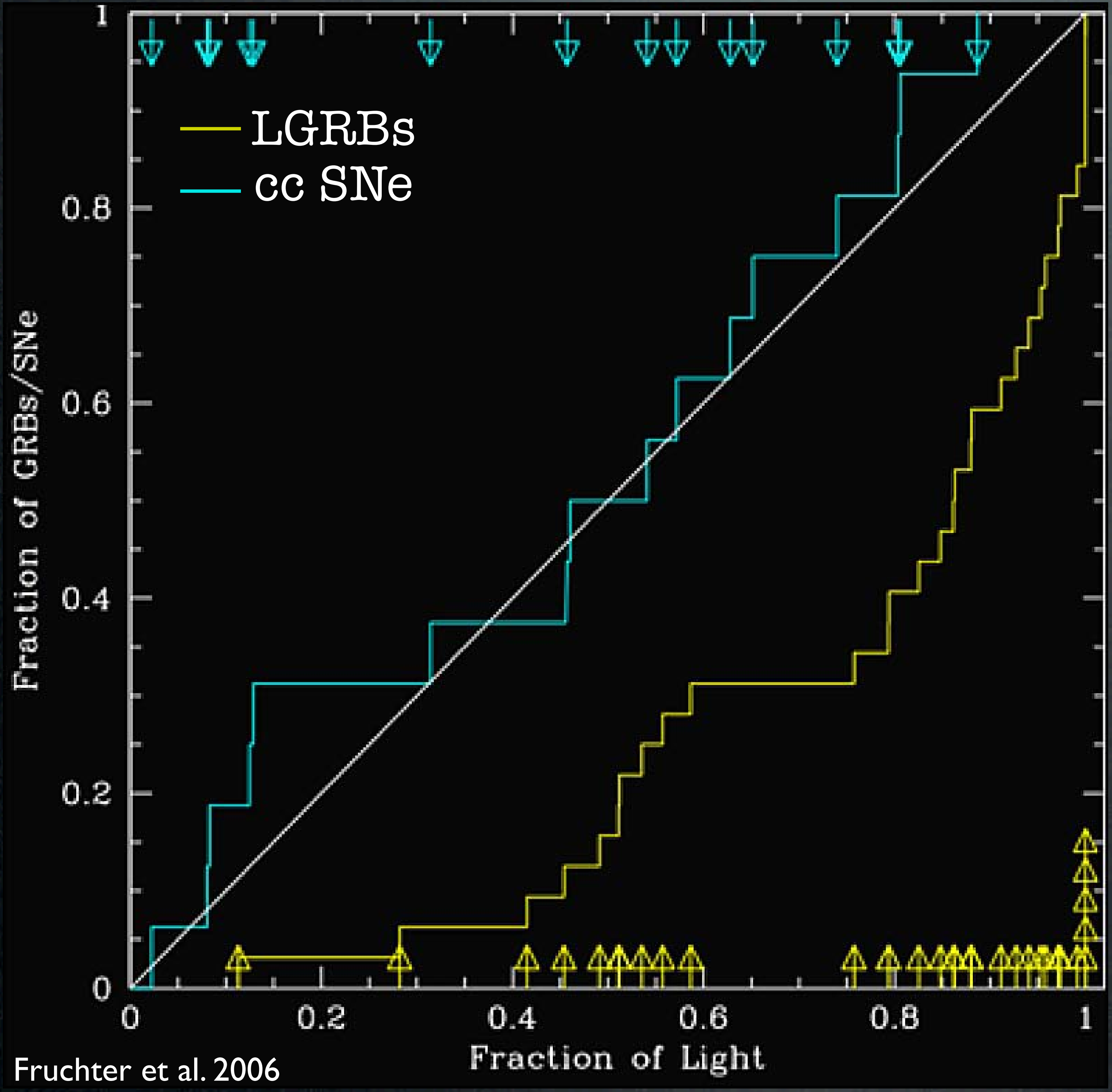


LGRBs (left) favor small blue irregular galaxies. For comparison, core collapse supernovae (below) are much more often found in large spirals.



Fruchter et al. 2006

LGRB Distribution on Hosts

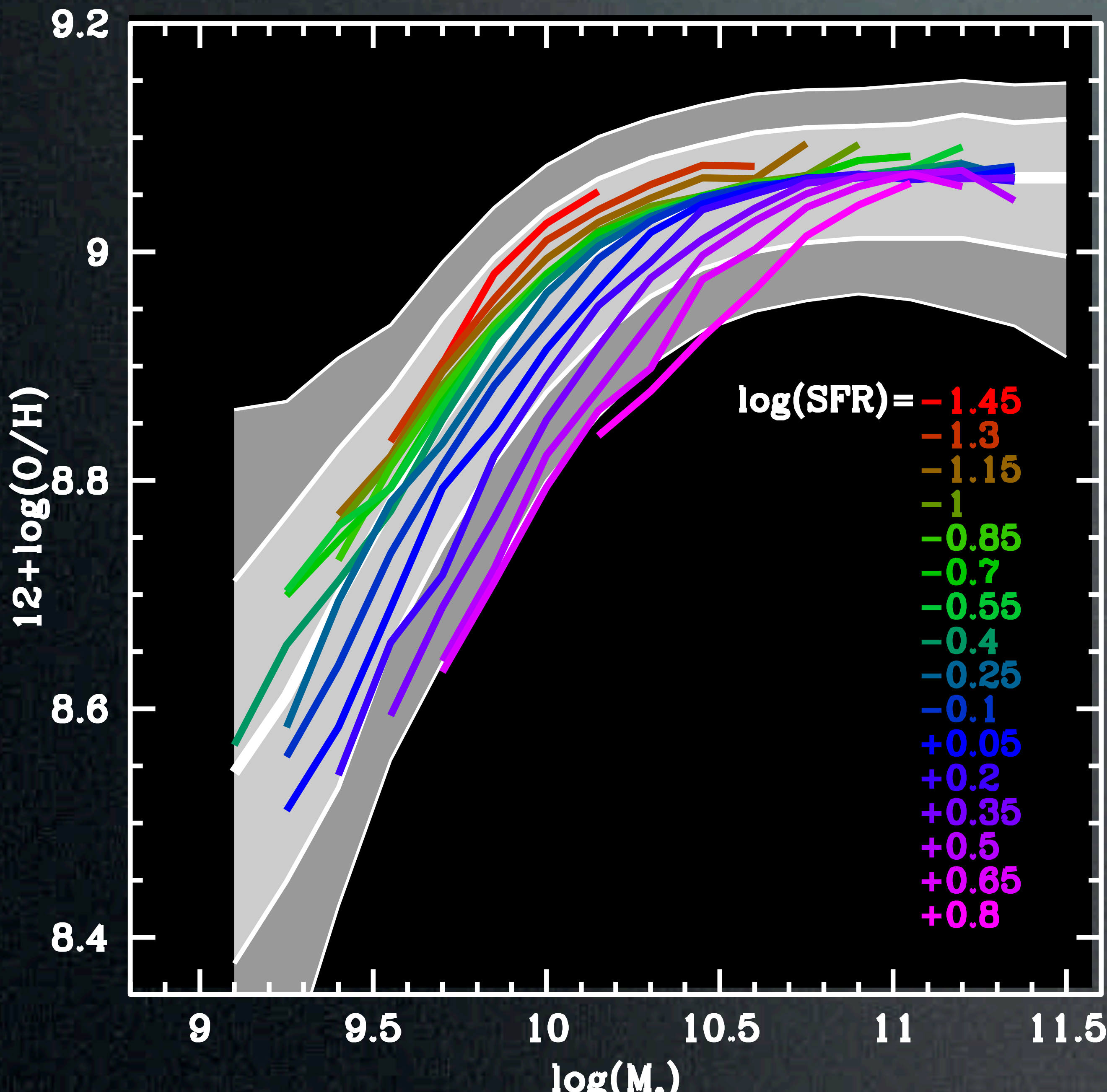


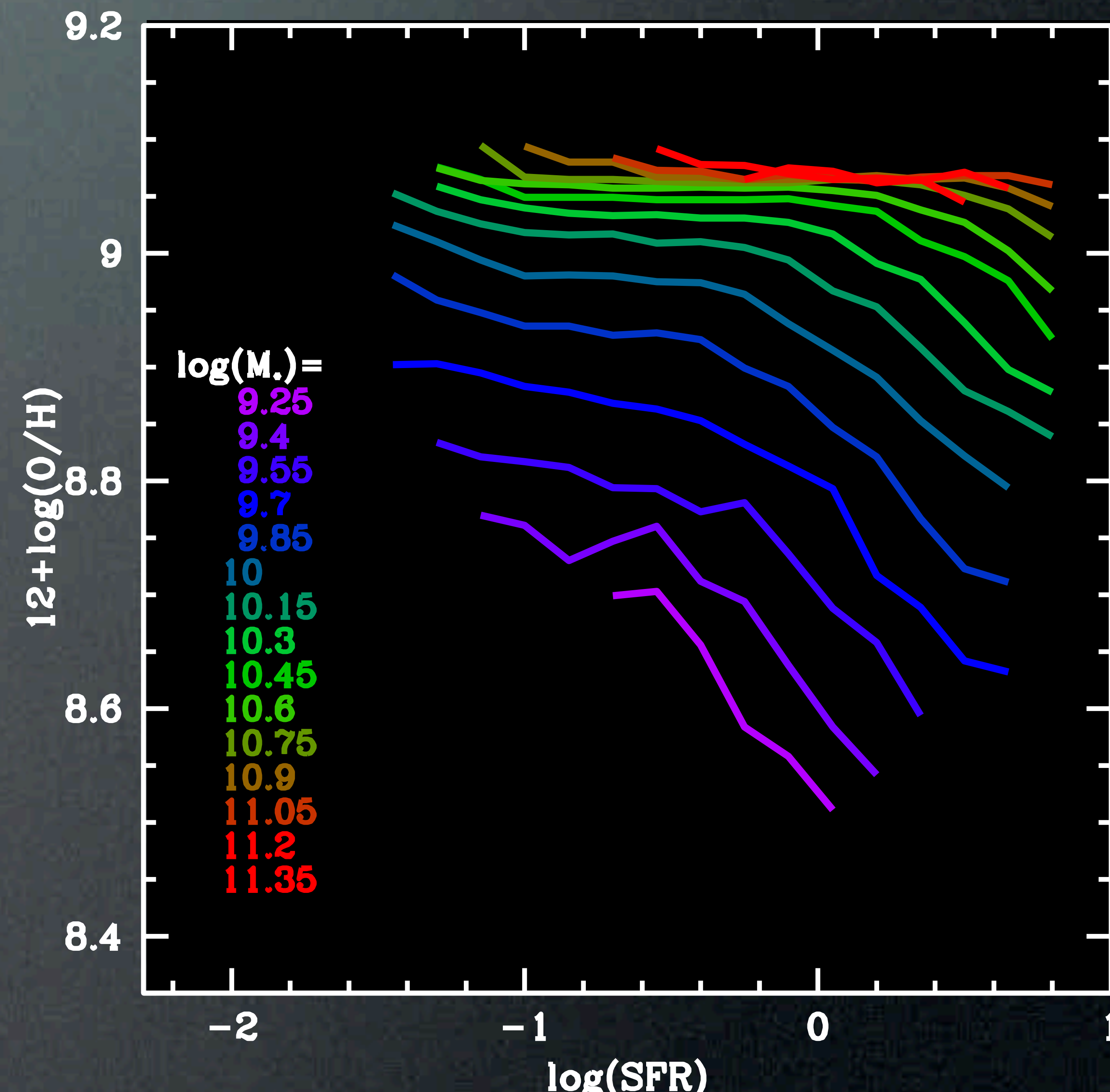
Fruchter plot of LGRBs and core collapse SNe.

Astrometric alignment of LGRB optical transient positions on host HST imaging shows that LGRBs favor the brightest regions of their host galaxies more so then the distribution of light within those galaxies.

Mannucci et al. (2010) Relation

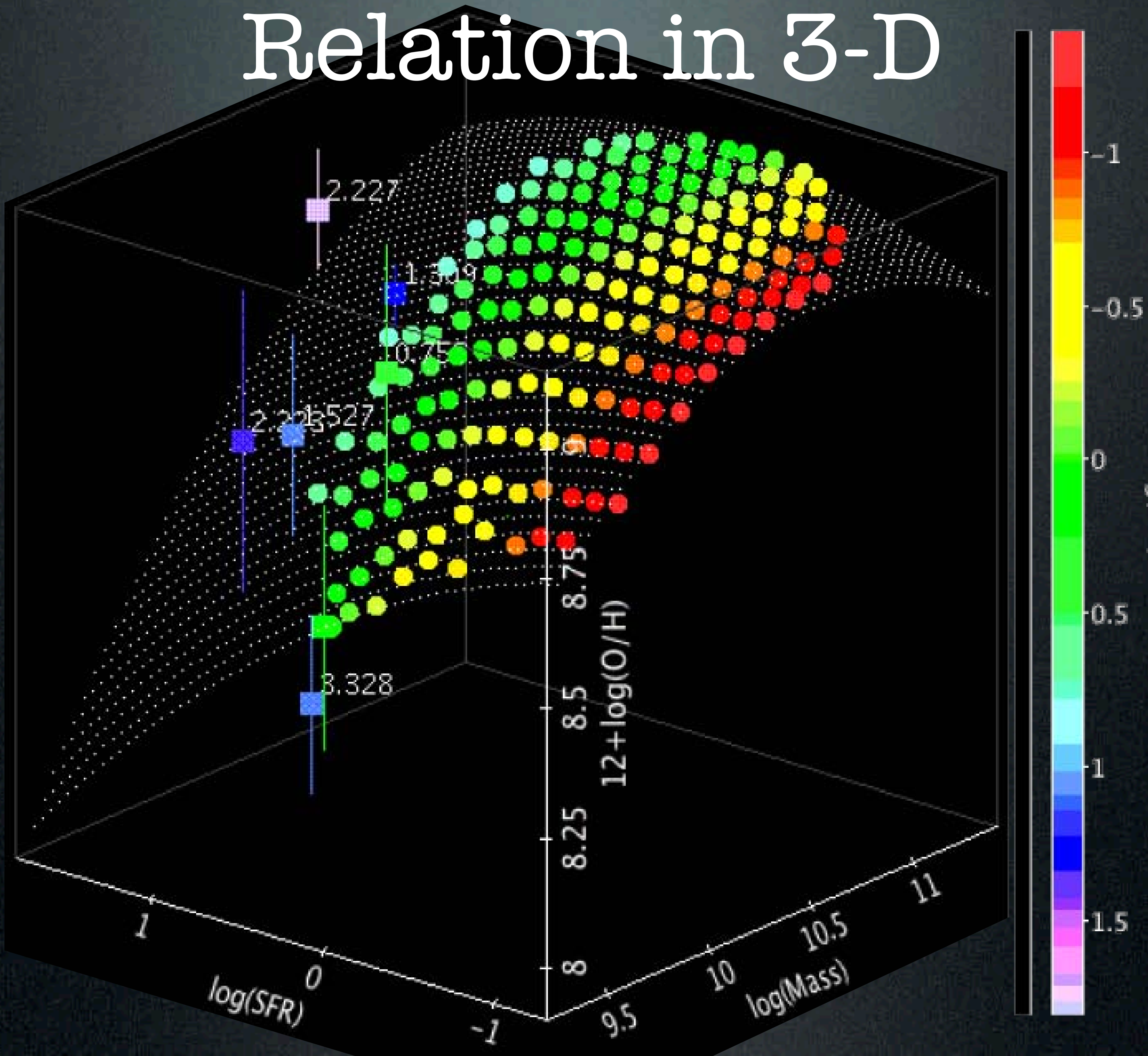
"Fundamental" Relation between Mass, Metallicity, & SFR





Figures from Mannucci et al. (2010)

Relation in 3-D

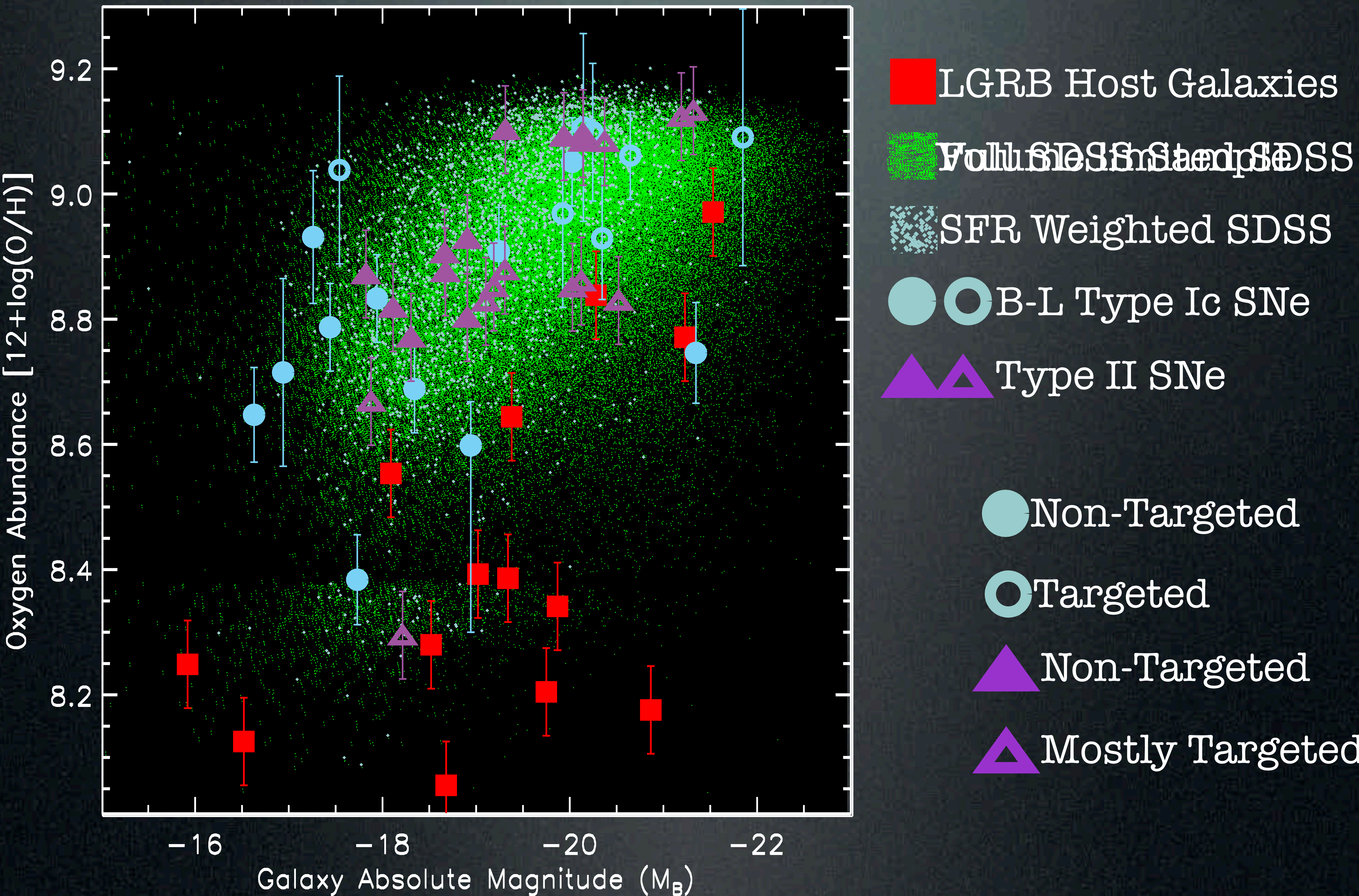


Mannucci et al. (2010)

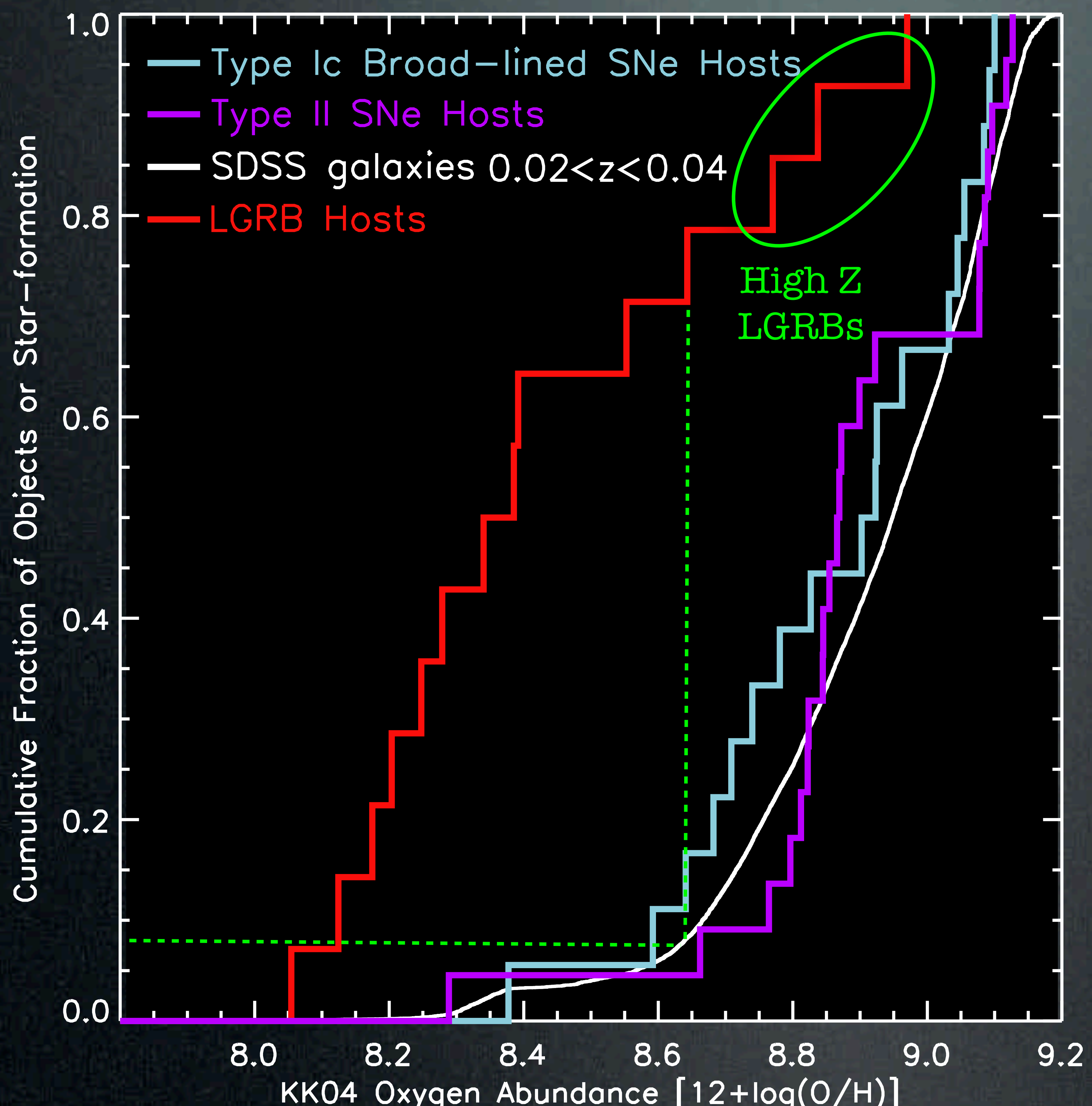
Mannucci et al. (2011) on LGRBs:

- “GRBs with optical afterglows do not preferentially select low-metallicity hosts among the star-forming galaxies.”
- “the difference with the mass-metallicity relation is due to higher than average SFRs [of LGRB hosts]”

Host Metallicity Comparison



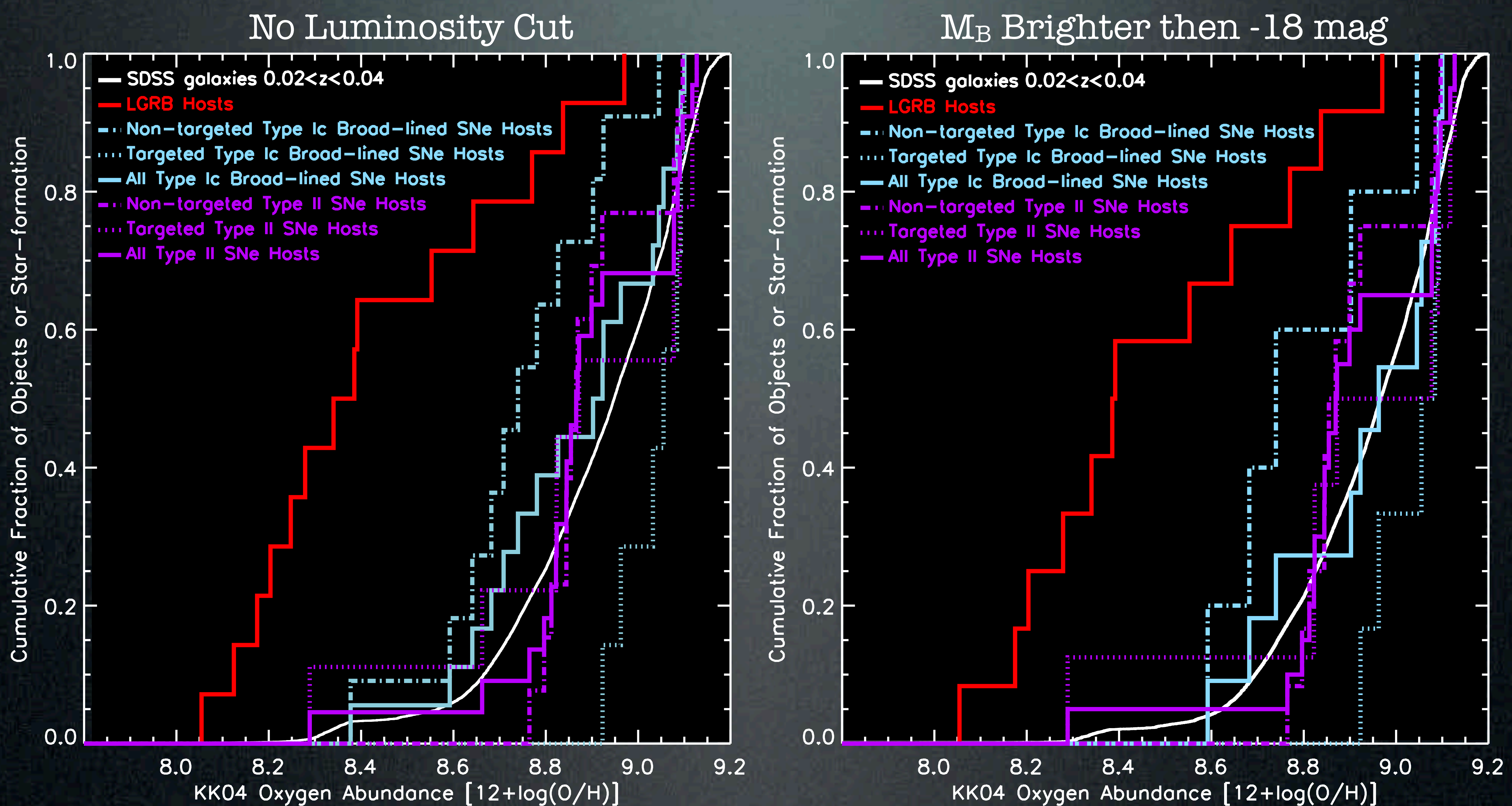
Star-formation fractions



Type II & Ic-BL SNe track star-formation while, for all except the 3 high metallicity cases, LGRBs occur in the lowest metallicity tenth of star-formation.

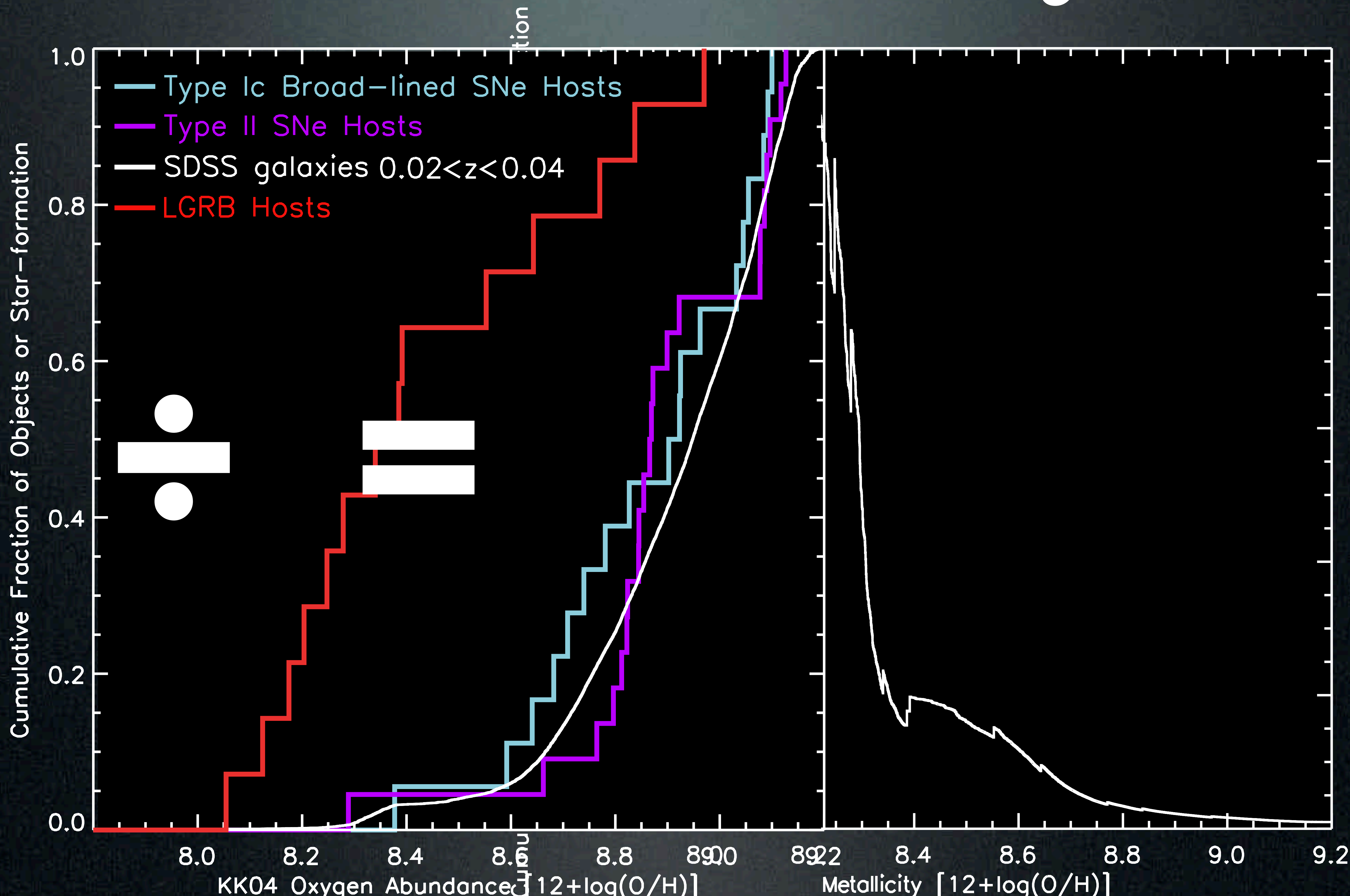
LGRBs and SNe are assumed to trace their own star-formation and are plotted with an even spacing.

Star-formation fraction biases

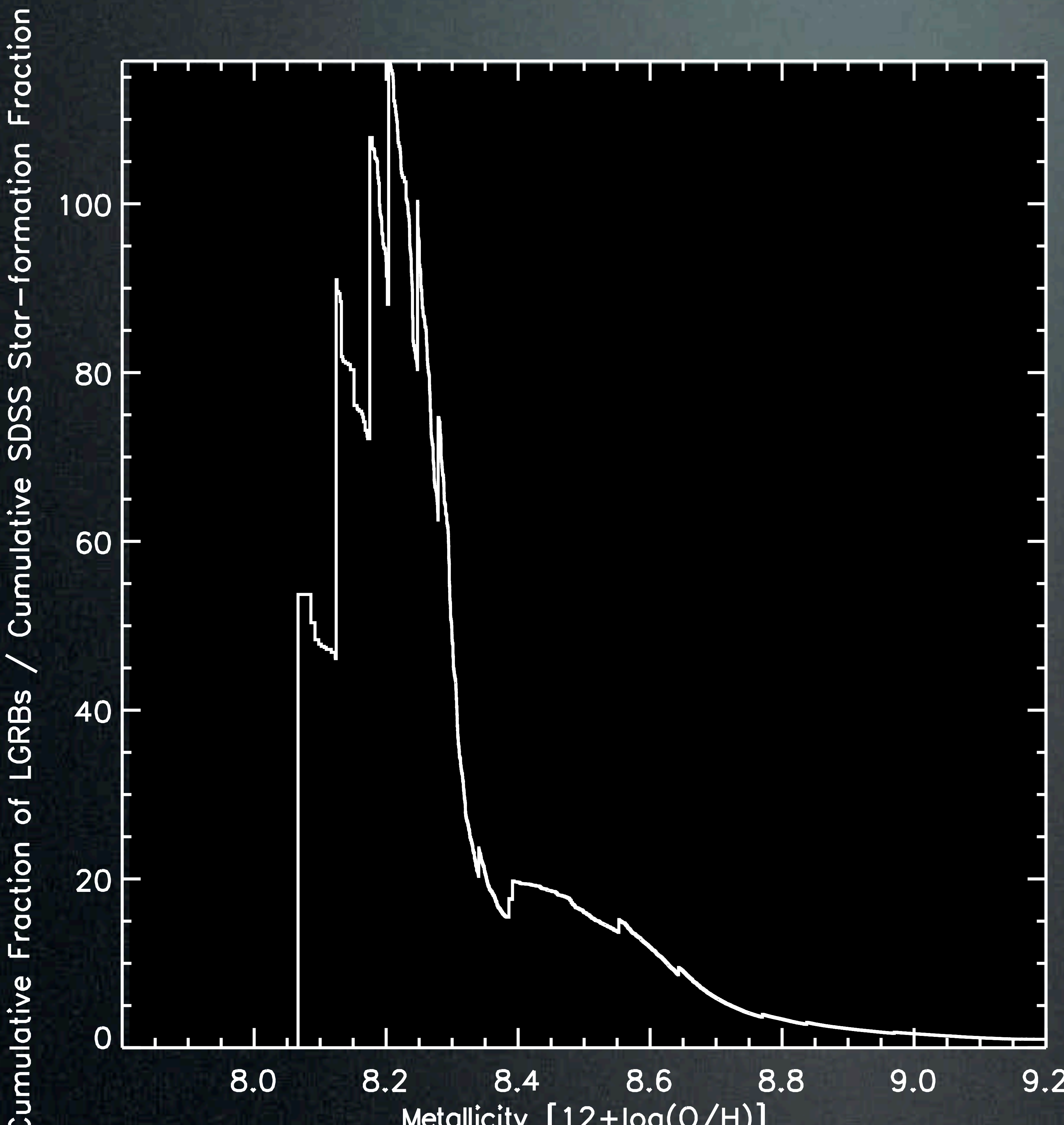


LGRBs remain far outside the SNe populations regardless of how the SNe are selected.

Rate vs. Metallicity

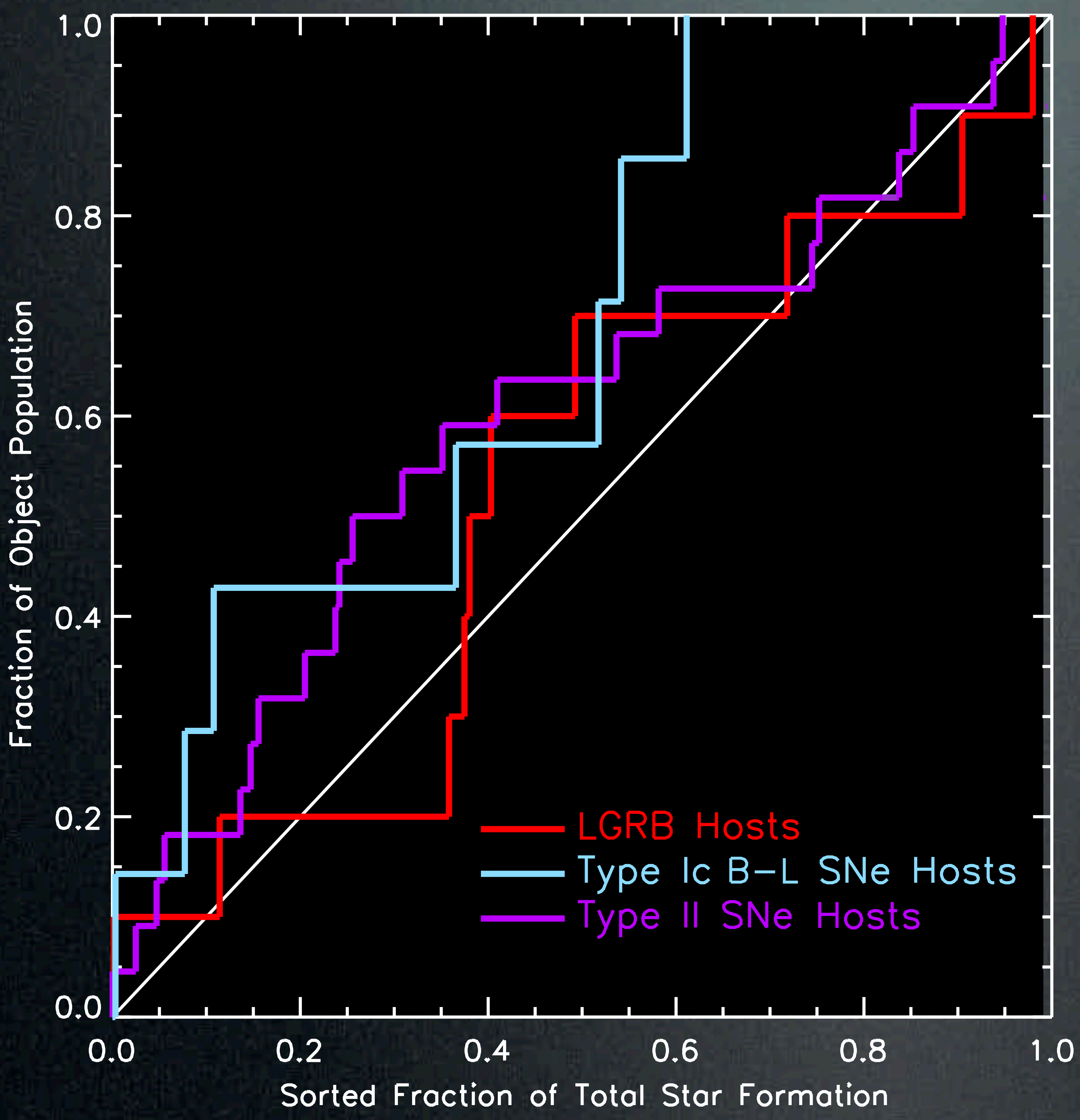


Rate vs. Metallicity



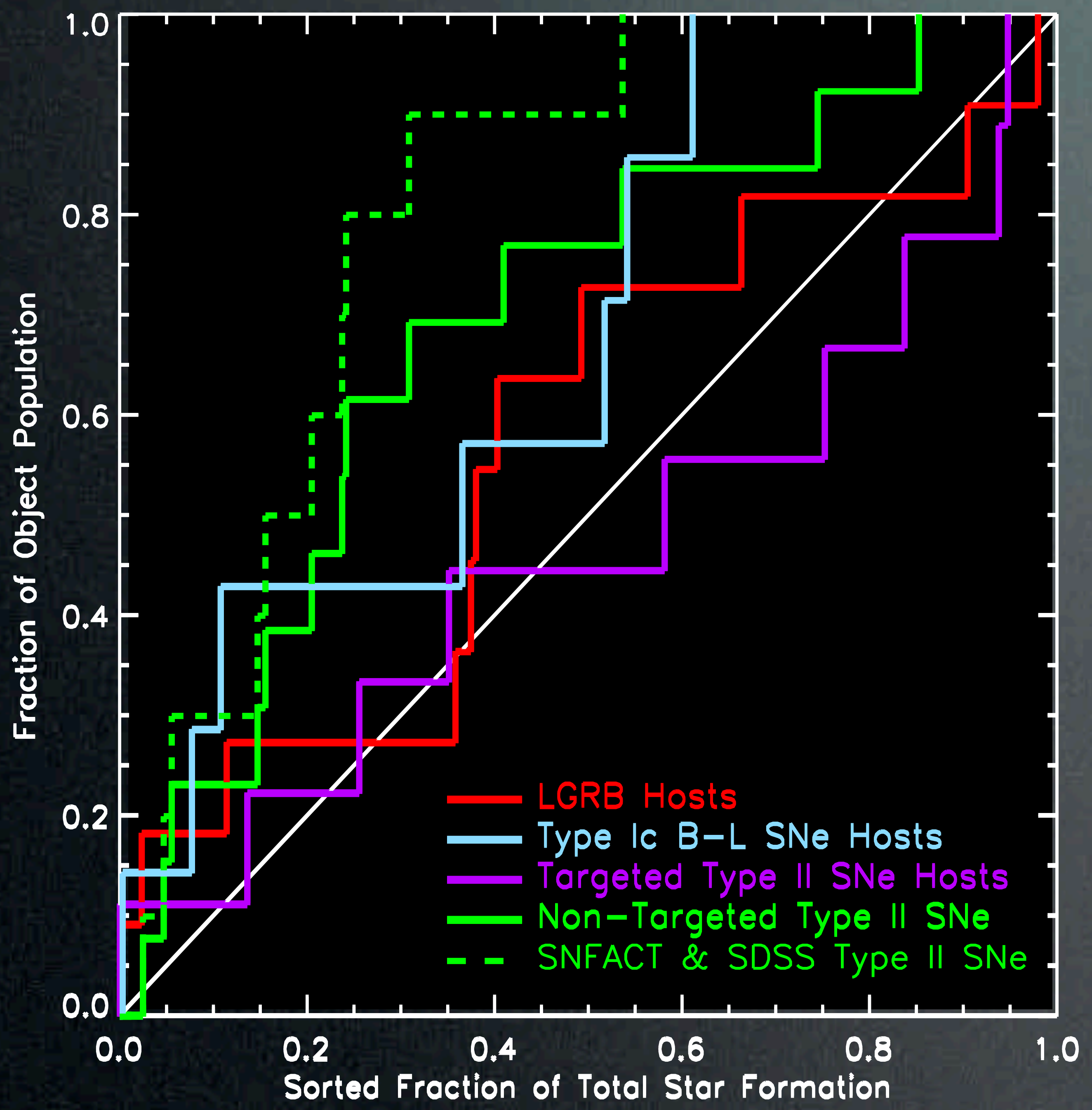
LGRBs have a strong intrinsic preference for low metallicity environments.

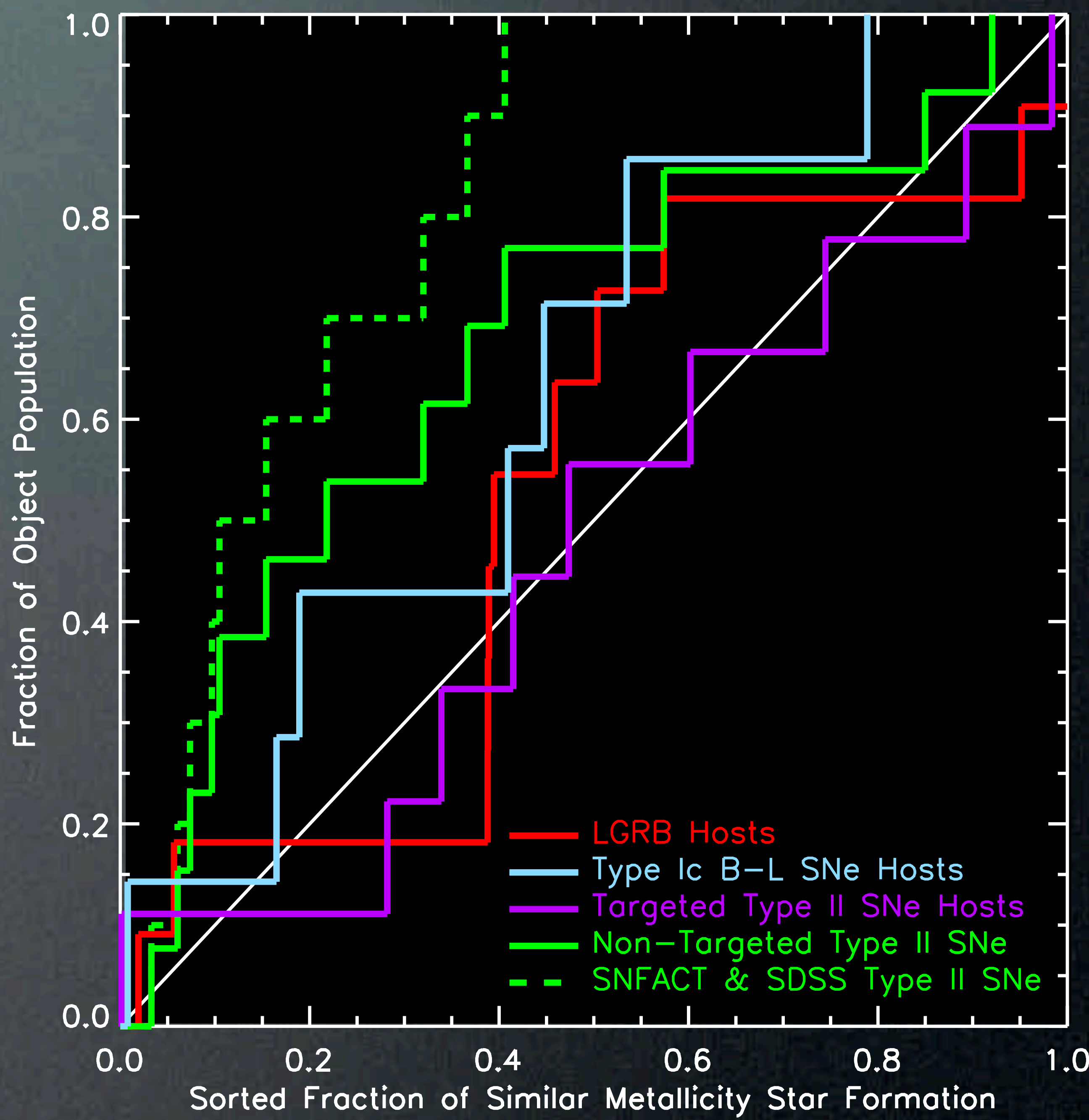
SFR vs. Object Distributions



The LGRB host SFRs tracks the distribution of the entire SDSS star-forming sample while the SNe hosts track the sample after it has been cut to the same redshift range.

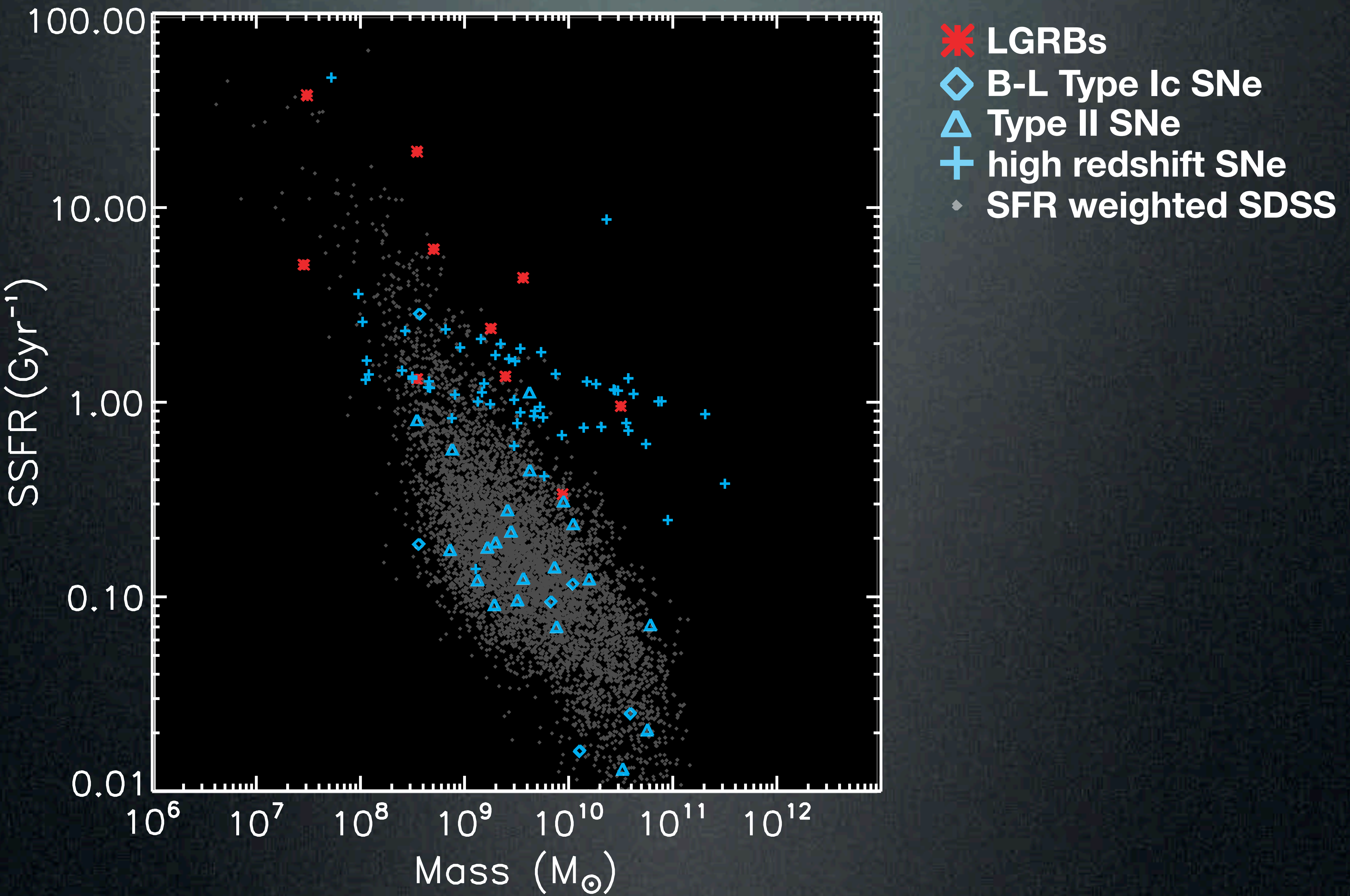
More SFR Distributions





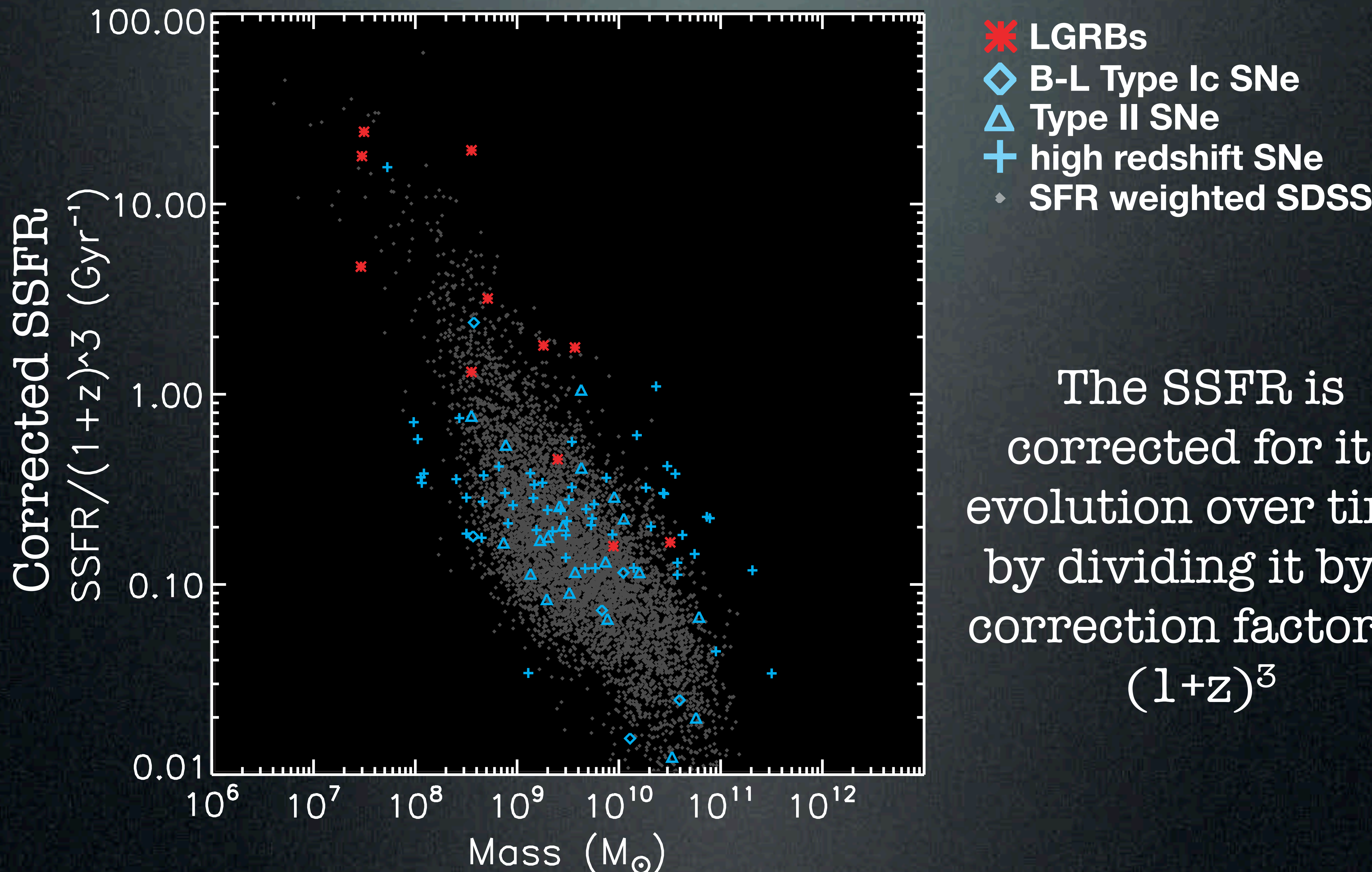
Note: The non-targeted SNe appear to be biased against detection on high surface brightness backgrounds.

Mass vs. SSFR



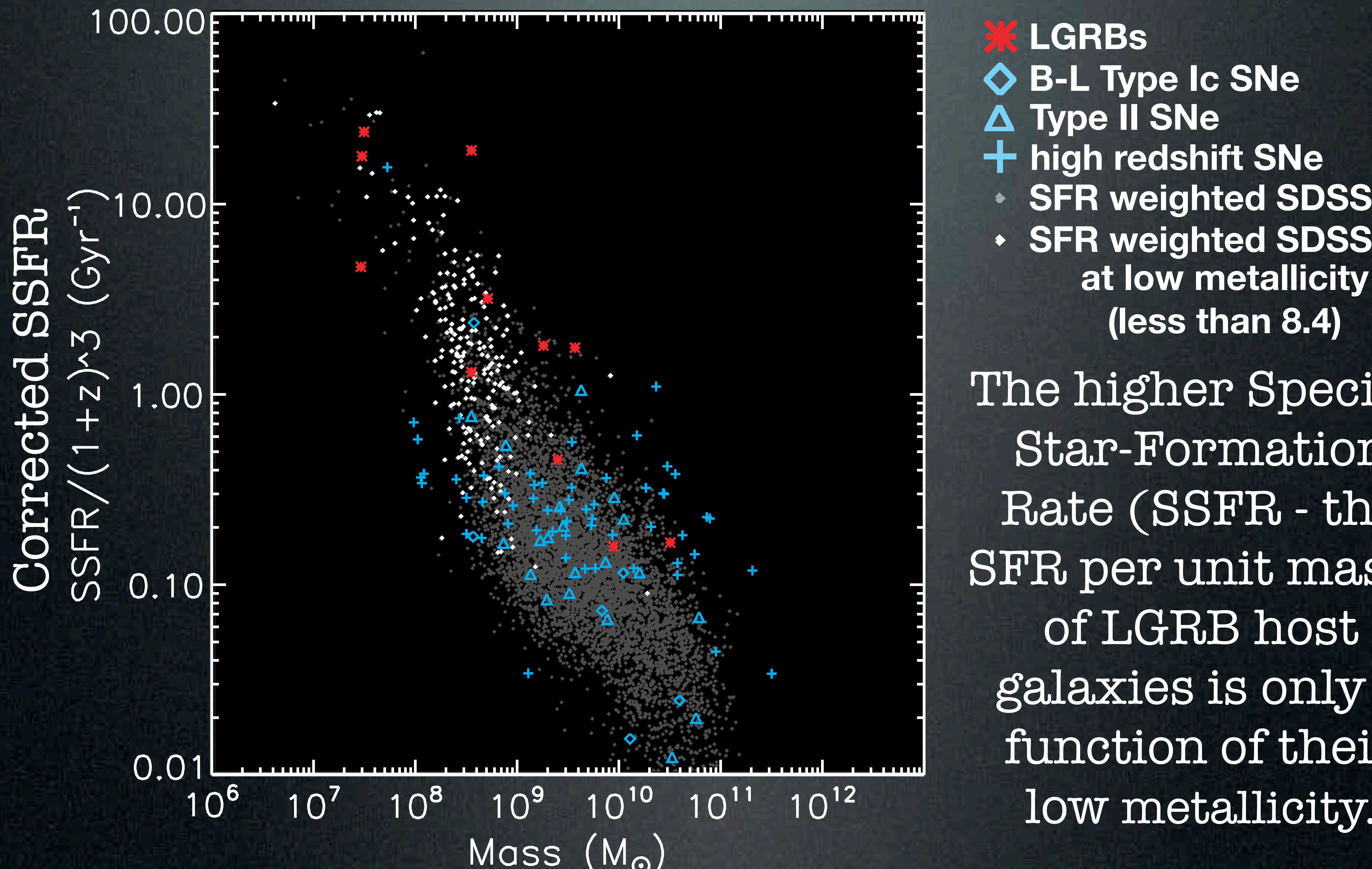
LGRBs
B-L Type Ic SNe
Type II SNe
high redshift SNe
SFR weighted SDSS
100.00
10.00
1.00
0.10
0.01
SSFR (Gyr^{-1})
10^6 10^7 10^8 10^9 10^{10} 10^{11} 10^{12}
Mass ($M_\odot$)

Correcting SSFR Evolution



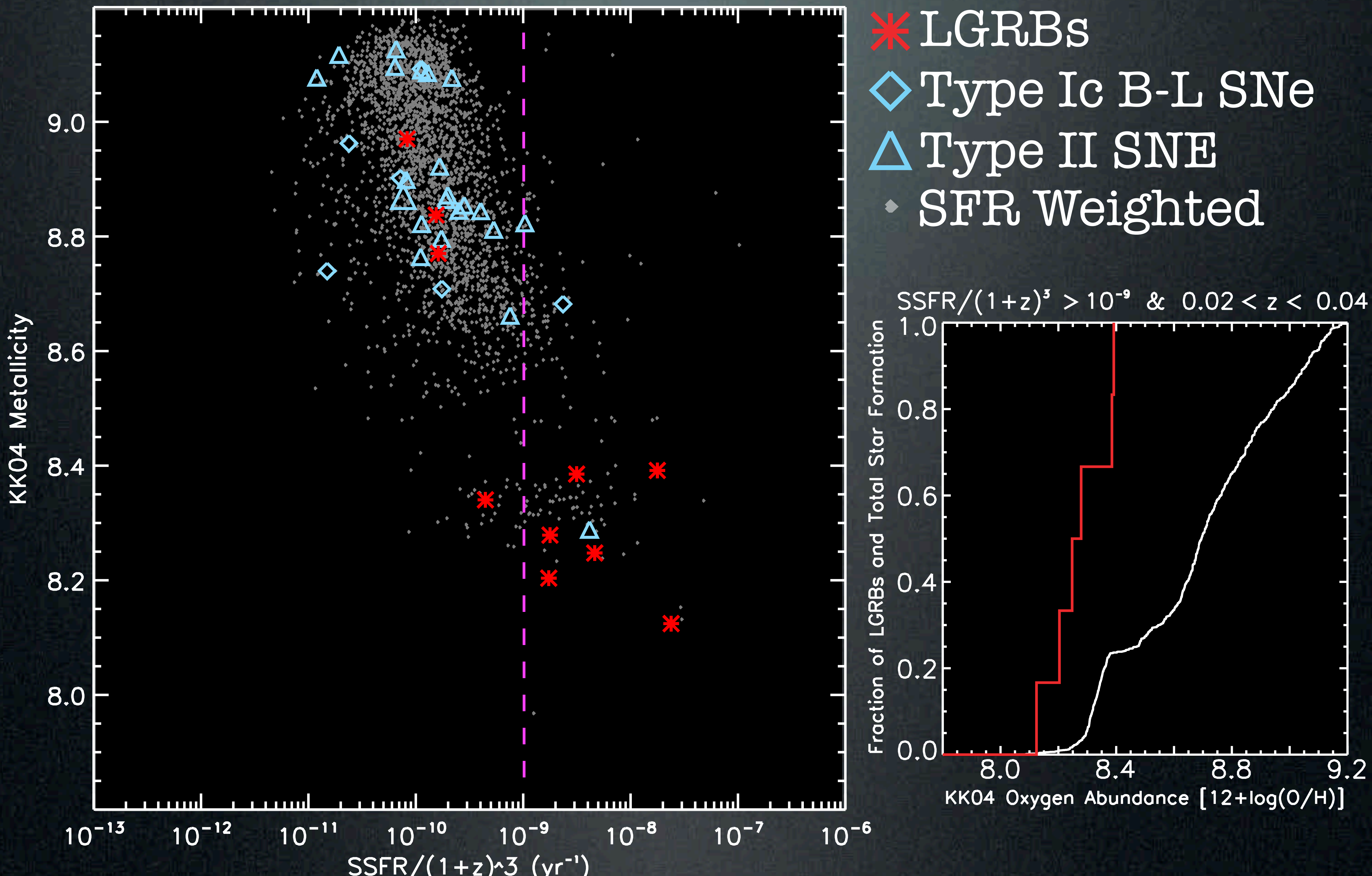
The SSFR is corrected for its evolution over time by dividing it by a correction factor of $(1+z)^3$

The High SSFR Tail



The higher Specific Star-Formation Rate (SSFR - the SFR per unit mass) of LGRB host galaxies is only a function of their low metallicity.

The High SSFR Tail



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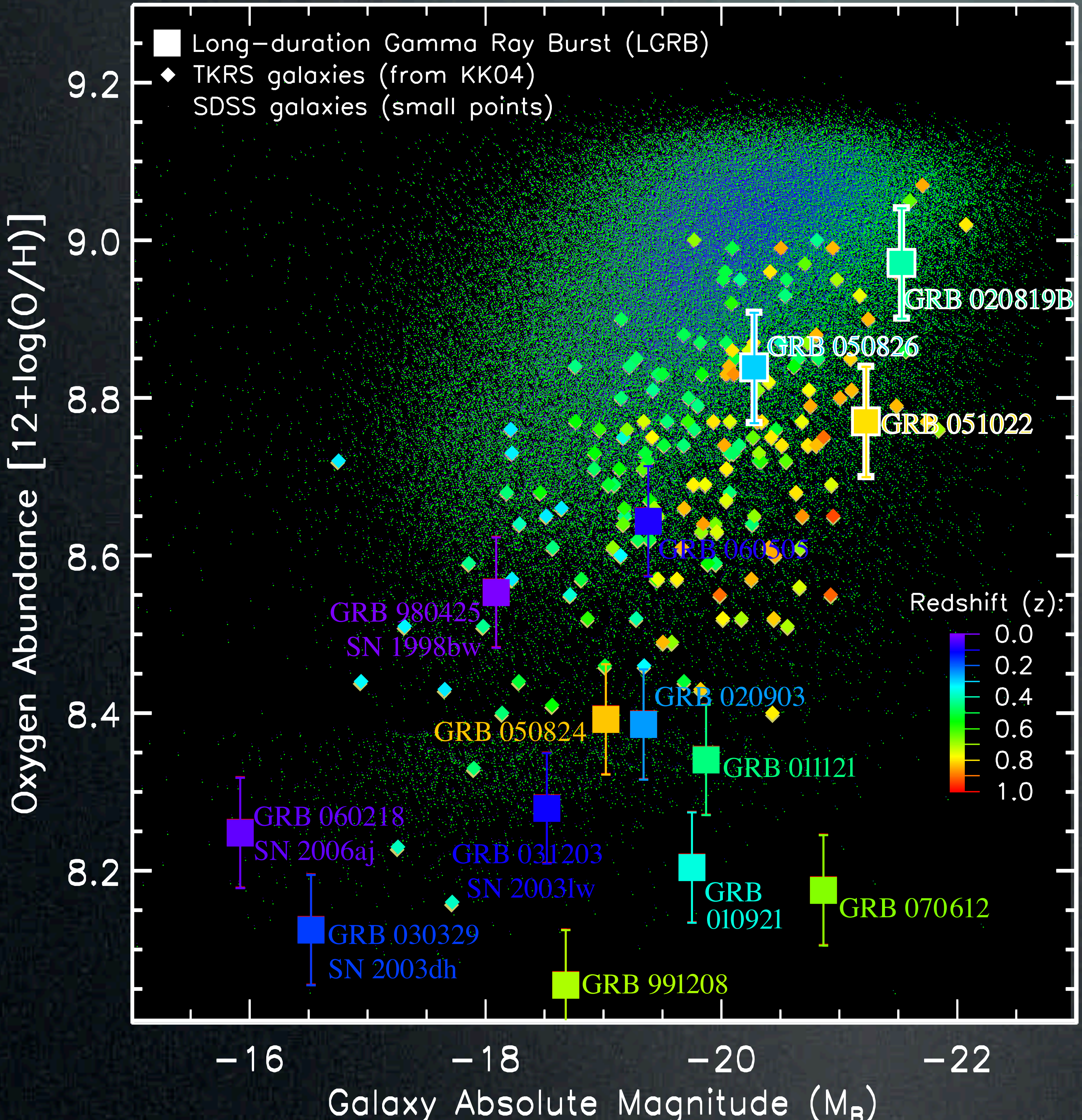
High Metallicity LGRBs



LGRB Host Galaxies

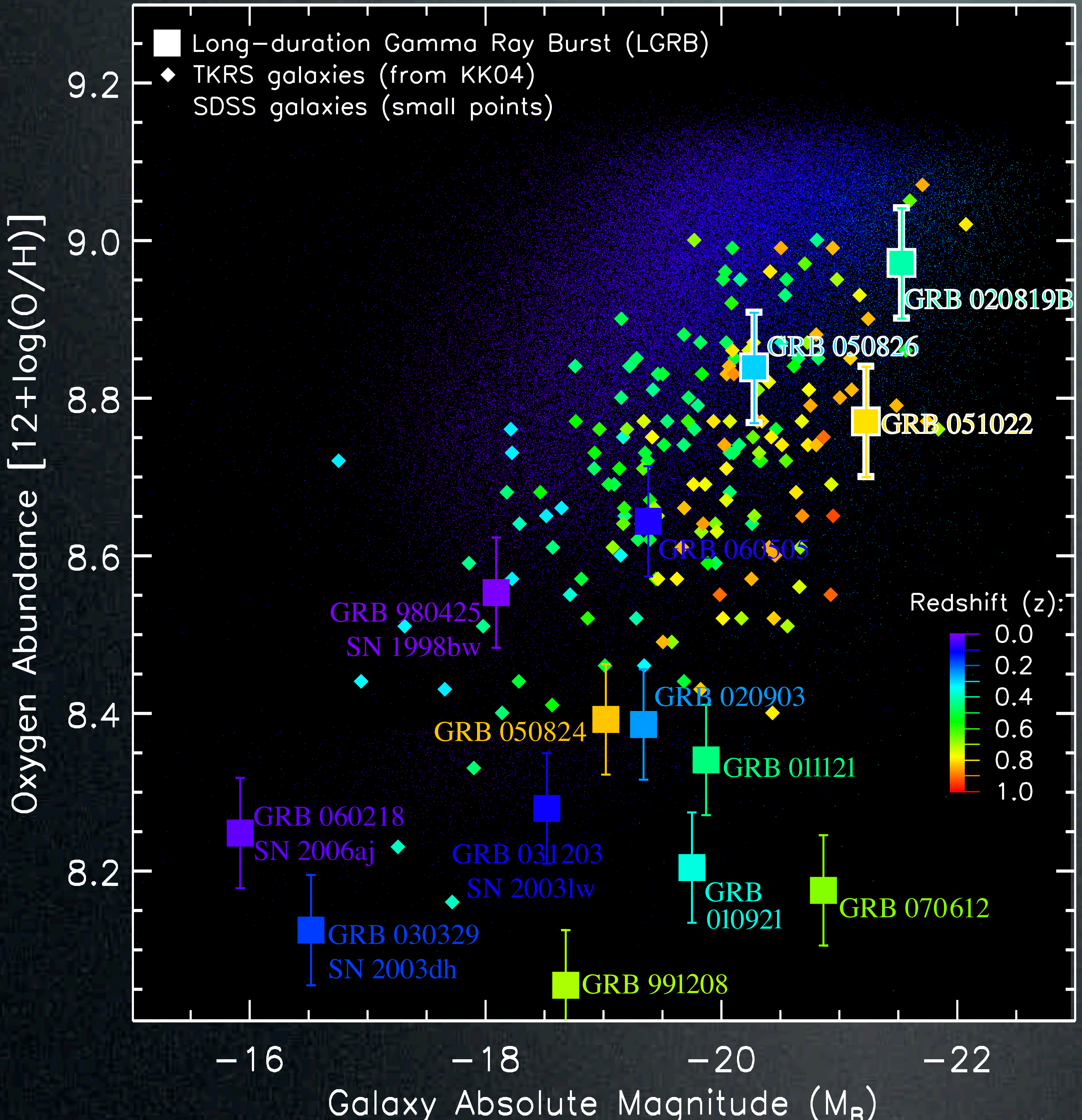
Full SDSS Sample

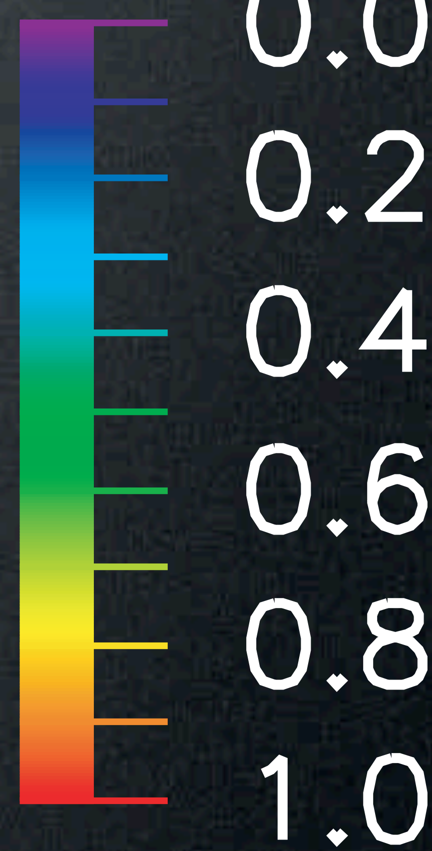
Redshift (z):

TKRS Galaxies

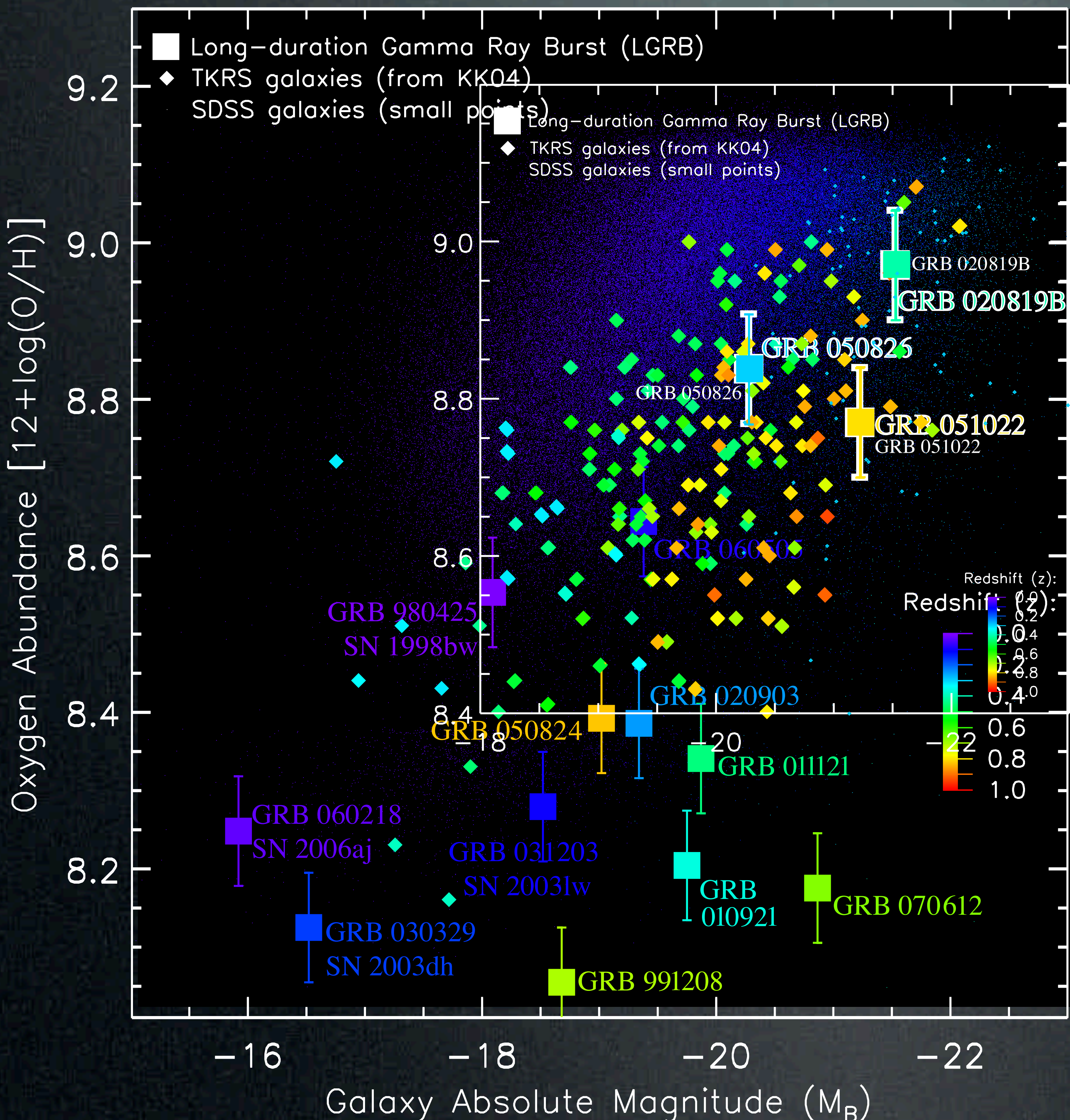
0.0
0.2
0.4
0.6
0.8
1.0

High Metallicity LGRBs





High Metallicity LGRBs



Redshift (z):

The three high metallicity LGRBs are consistent with the general star-forming galaxy population for galaxies of their luminosity and redshift.

Explanations for High Metallicity LGRBs

(1) LGRBs do not occur in high metallicity environments and those seen in high metallicity hosts are in fact occurring in low metallicity environments that have become associated with otherwise high metallicity hosts but remain unenriched.

(2) The LGRB formation mechanism while preferring low metallicity environments does not strictly require it, resulting in a gradual decline in burst formation with increasing metallicity.

(3) The typical low metallicity LGRBs and the few high metallicity cases are the result of physically different burst formation pathways with only the former affected by the metallicity and the later occurring much more infrequently.

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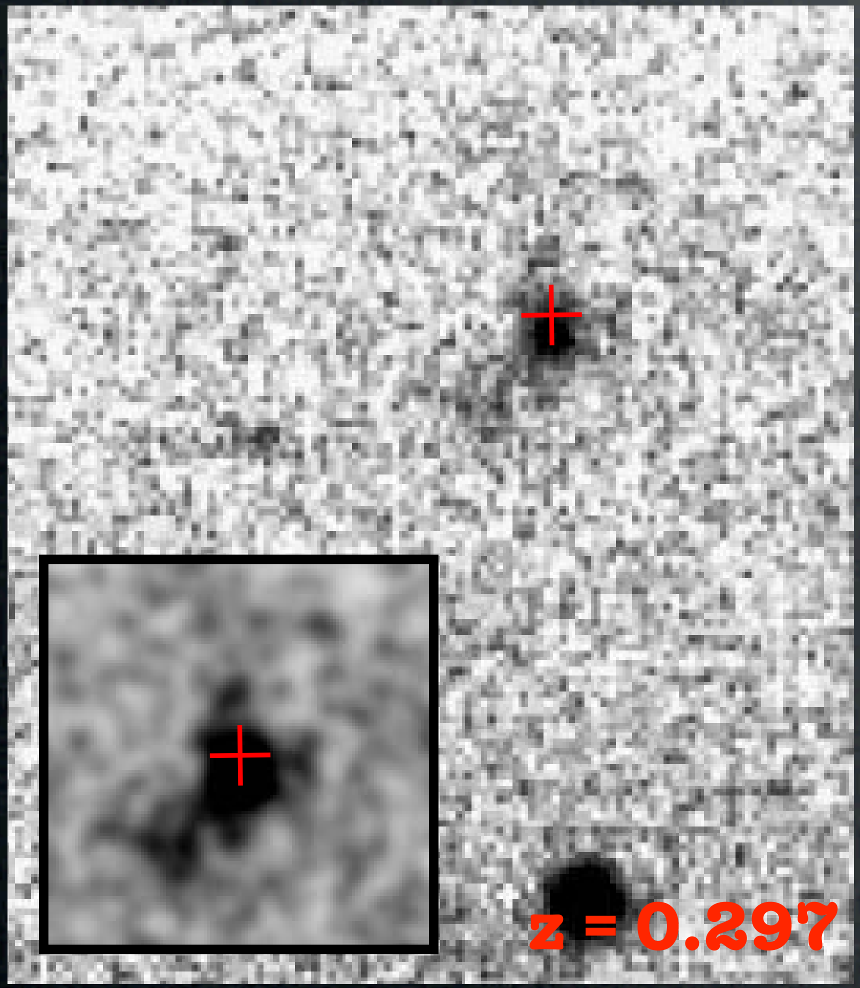
Host Galaxies of the Three High Metallicity LGRBs

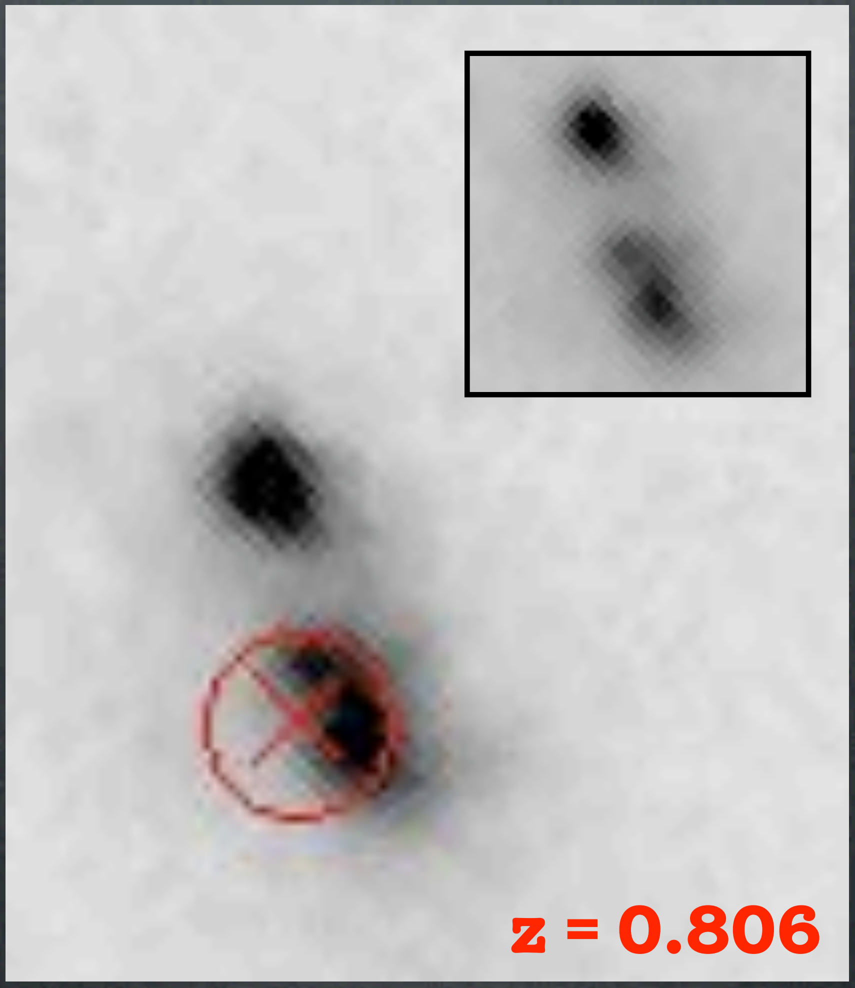
Images blue ward of 4000 Å break in rest frame

LGRB 050826



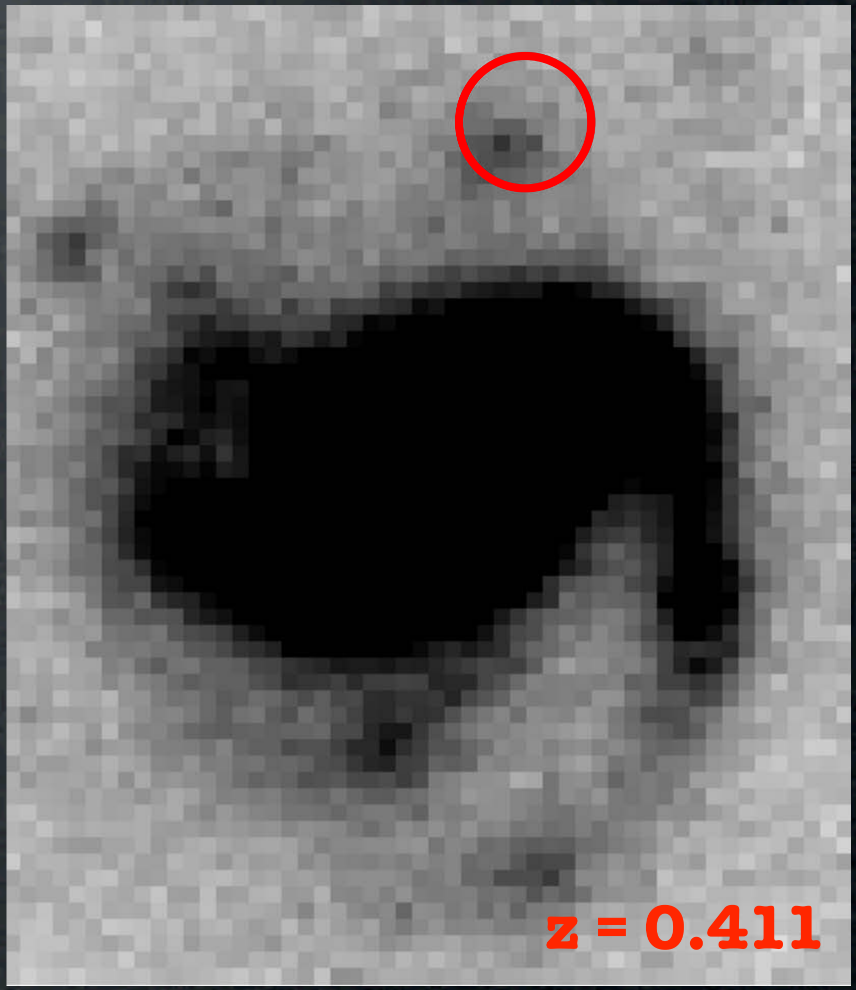
MDM Observatory

LGRB 051022



HST ACS/WFC

LGRB 020819B



Gemini GMOS

Conclusions

- Long-duration Gamma Ray Bursts (LGRBs) have a strong intrinsic preference for low metallicity environments.
- High Metallicity LGRBs do exist but are rare. They occur at about 1/25th the rate (per unit star-formation) of the low metallicity events.
- This difference in rate may reflect a difference in how an exploding star gains the rapid rotation necessary to form an LGRB: at low metallicity the star retains its rapid rotation from when it was formed, while at high metallicity an accreting binary companion is needed to transfer mass and rotation onto the star that explodes.
- Mannucci et al. (2011) argued that the low metallicity preference of LGRBs was a consequence of the high SSFR of their environments and the anti-correlation between SSFR and metallicity seen in the general galaxy population. Here we show that <u>metallicity</u> is the critical factor and that the observed high SSFR environments of LGRBs are actually caused by their low metallicity preference.