Properties of Galaxies hosting Gamma-Ray Bursts

Sandra Savaglio (Max-Planck-Institut für extraterrestrische Physik, Garching)

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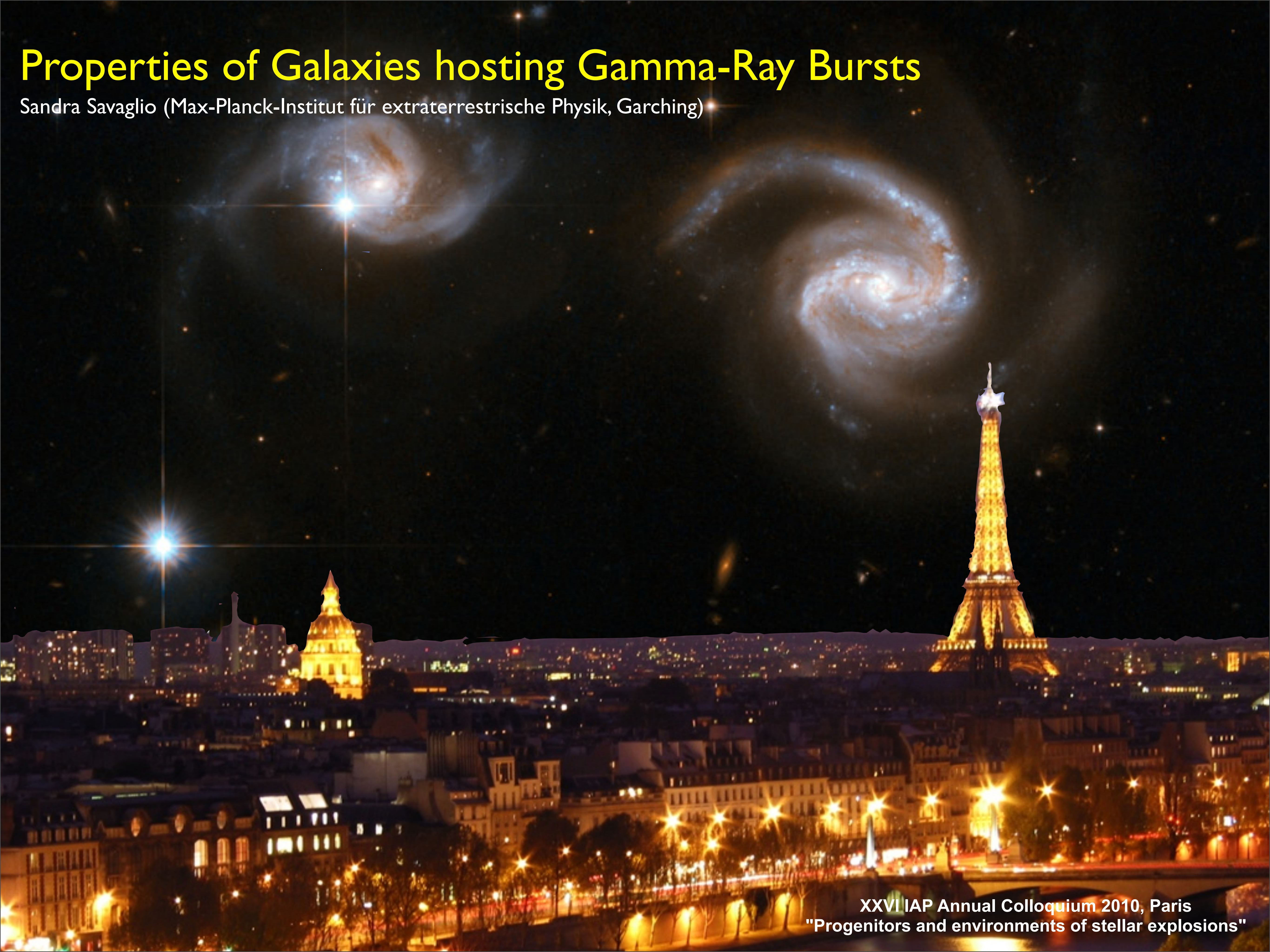

XXVI IAP Annual Colloquium 2010, Paris
"Progenitors and environments of stellar explosions"

Long-duration GRB: CC SN
Short-duration GRB: NS/BH Merger

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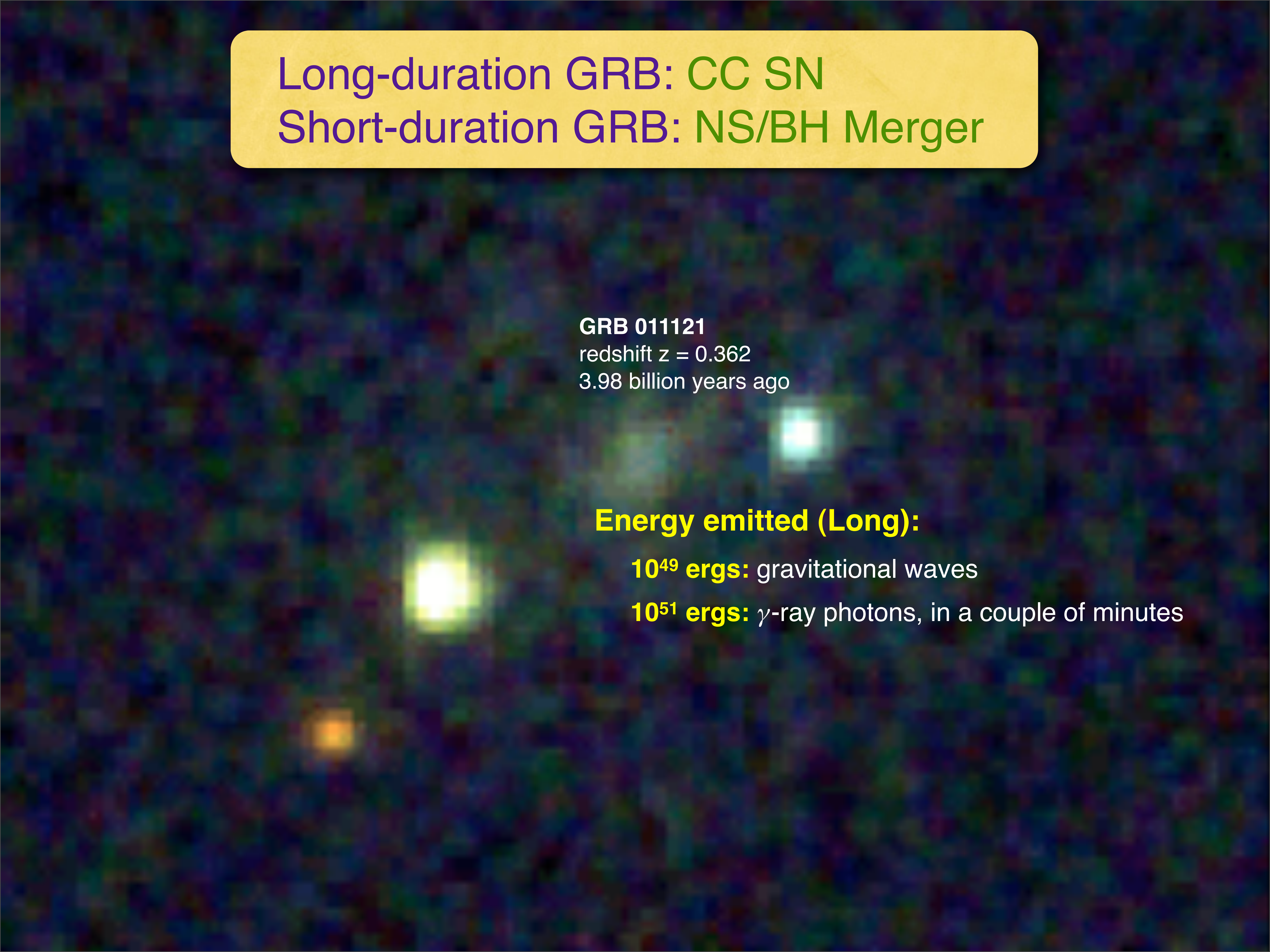
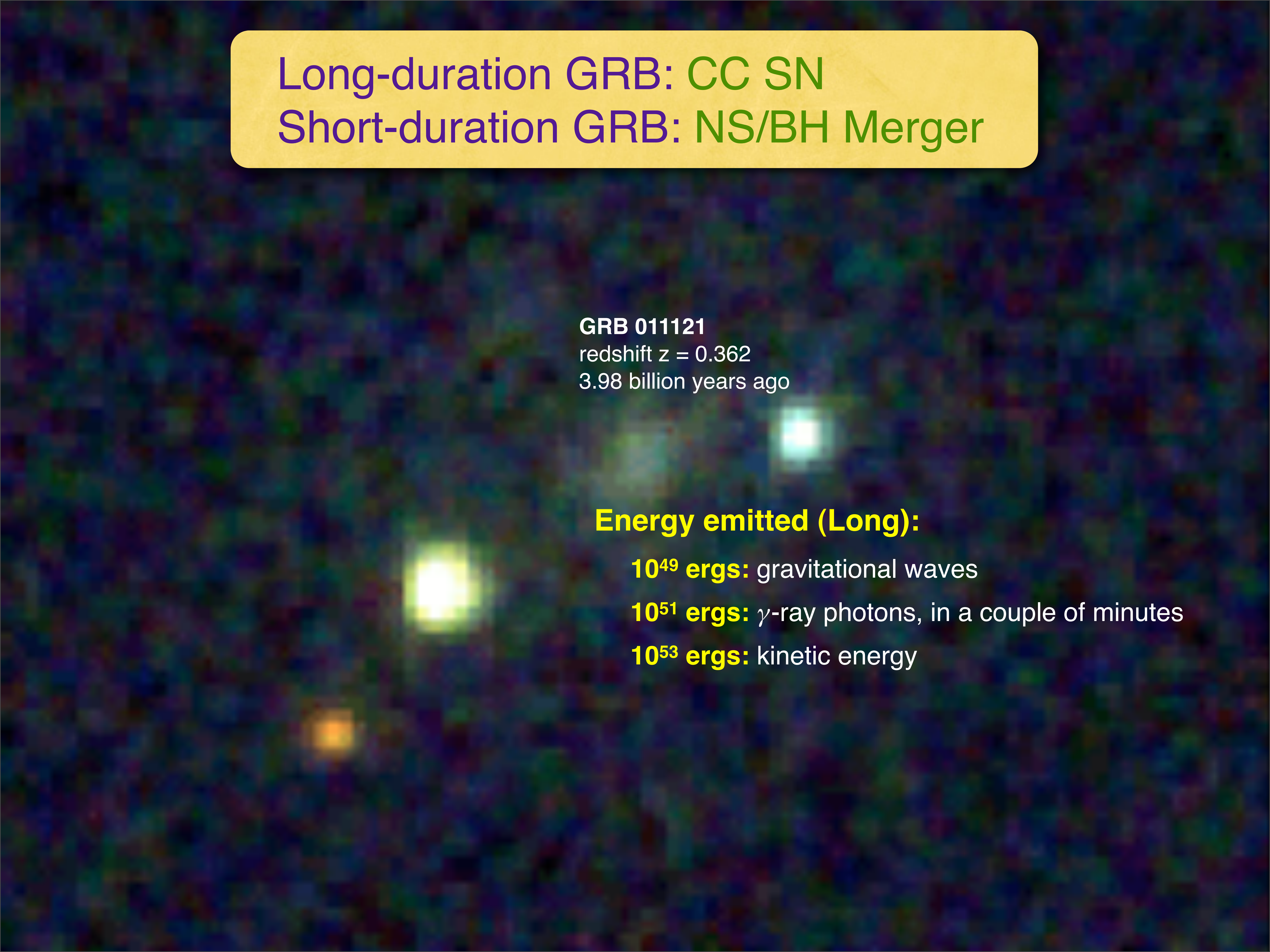


Long-duration GRB: CC SN
Short-duration GRB: NS/BH Merger
GRB 011121
redshift z = 0.362
3.98 billion years ago
Energy emitted (Long):
10^{49} ergs: gravitational waves
10^{51} ergs: γ-ray photons, in a couple of minutes



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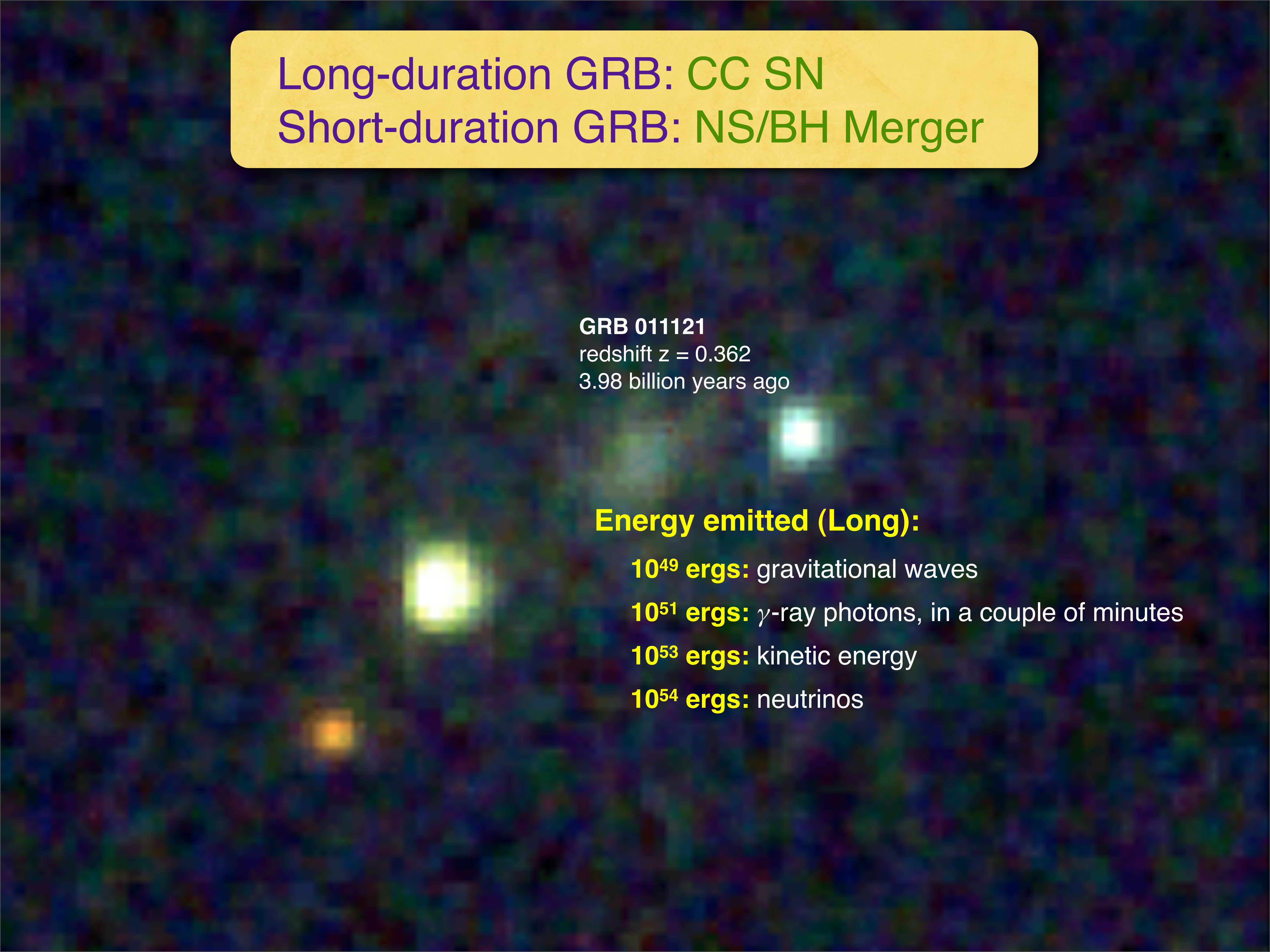
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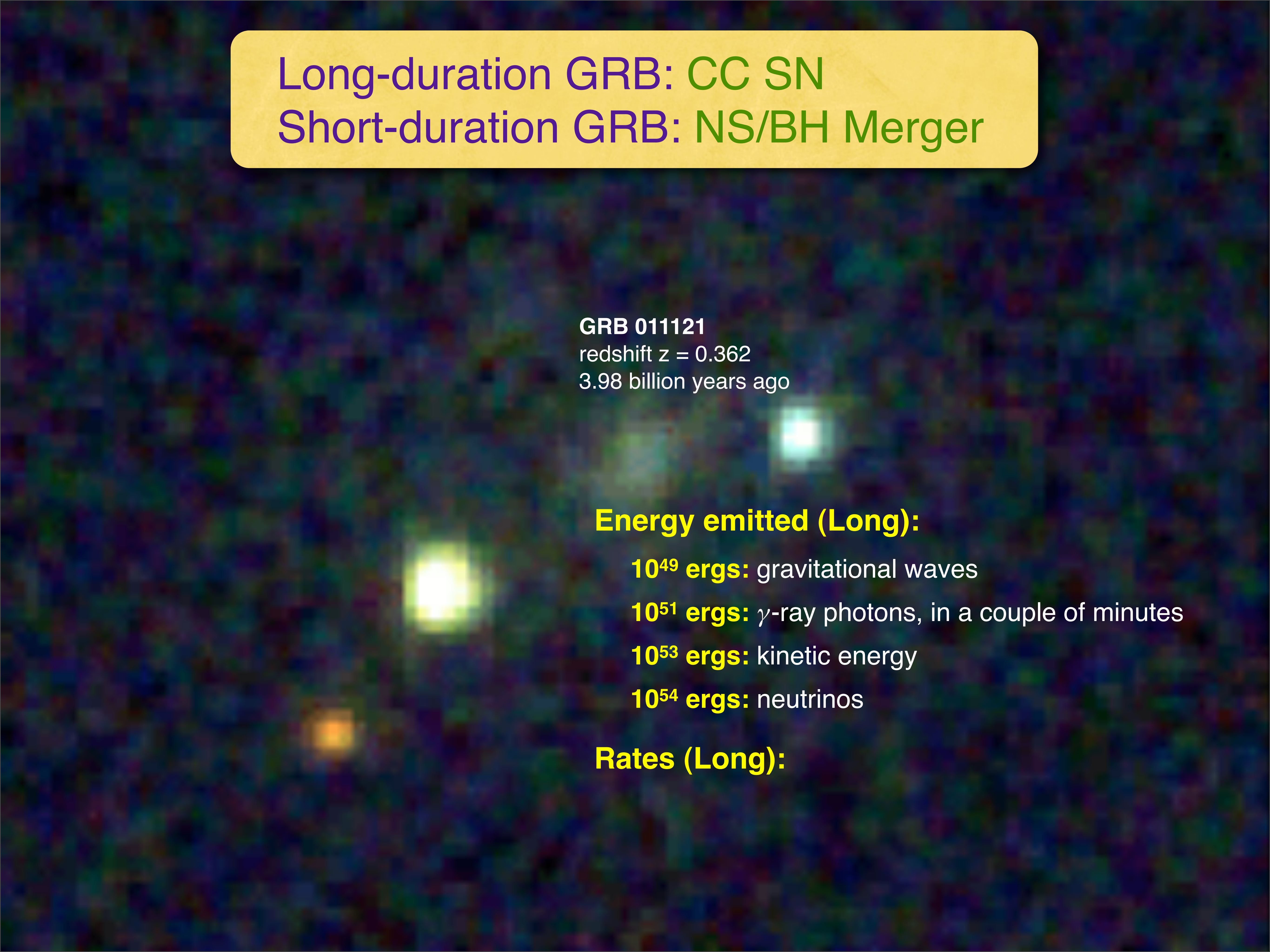

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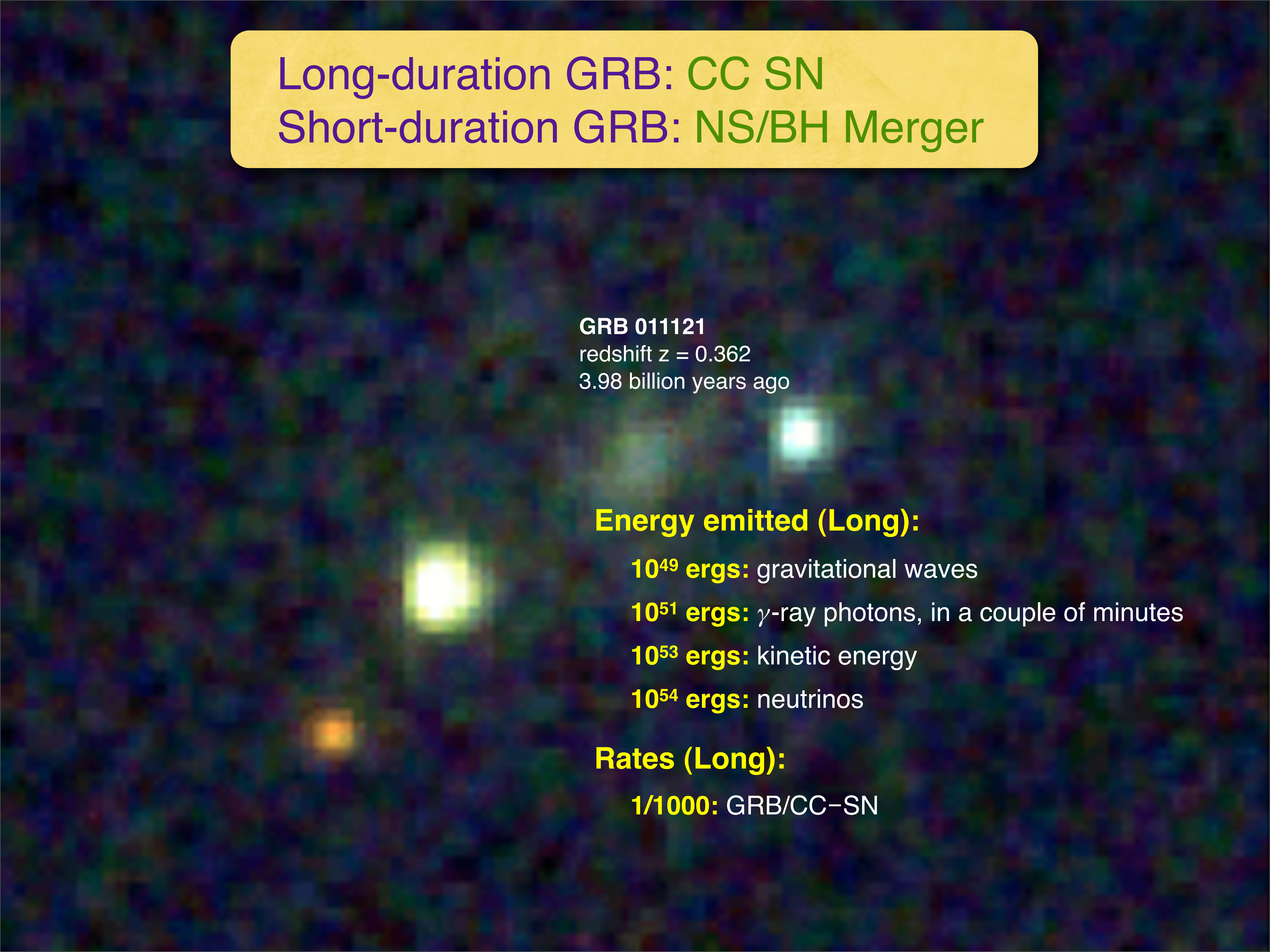

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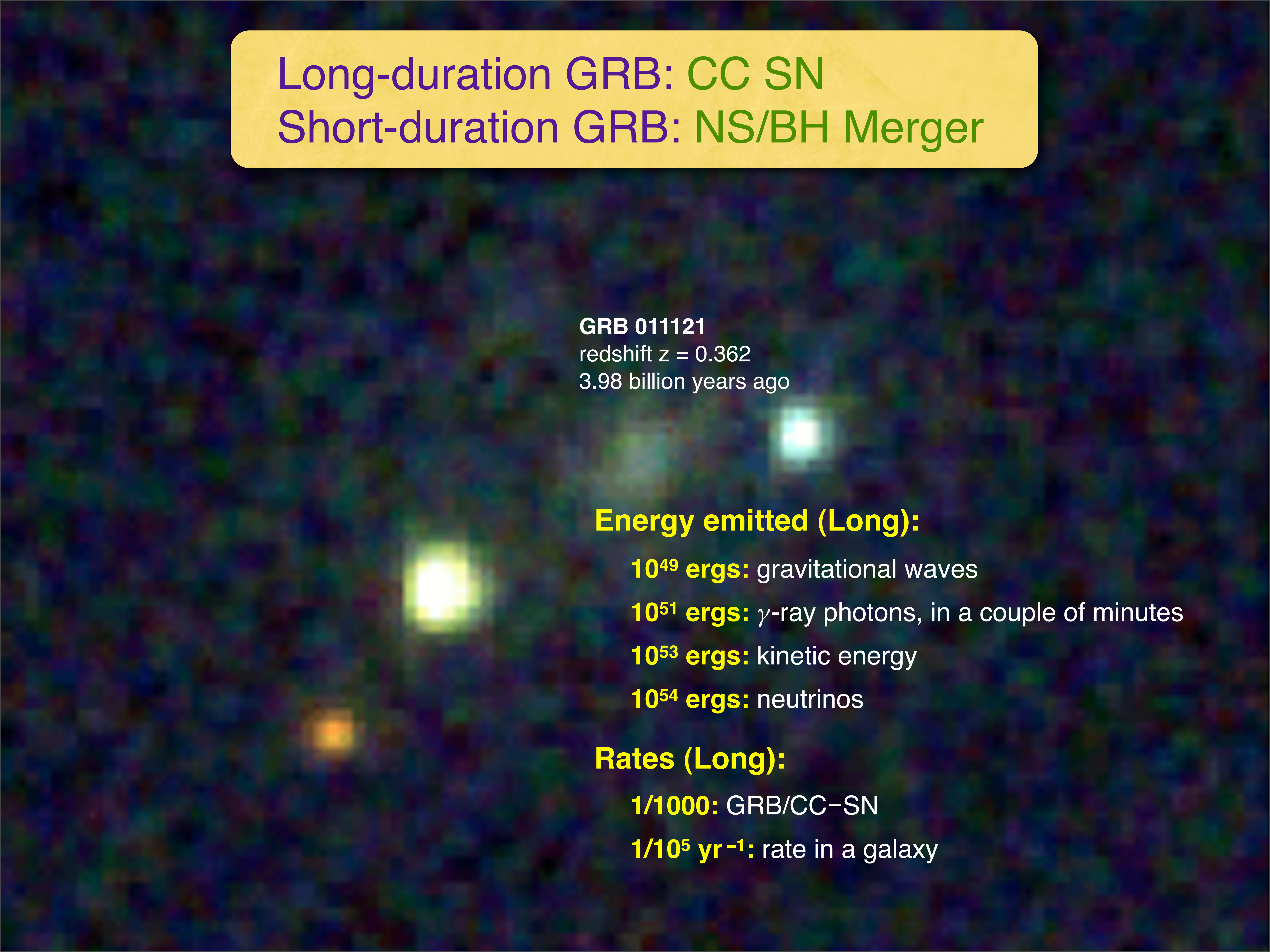
- **1/1000:** GRB/CC−SN



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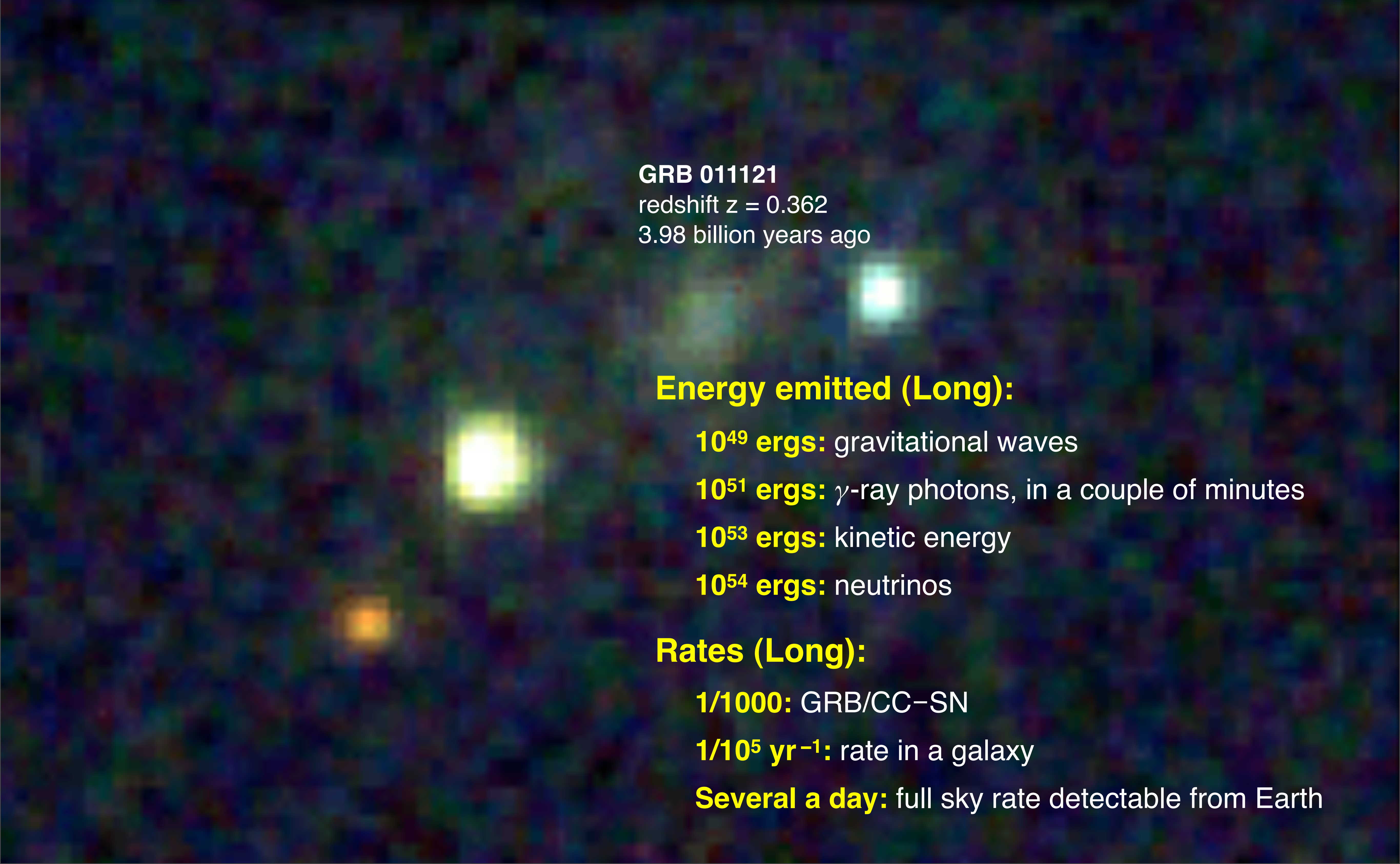

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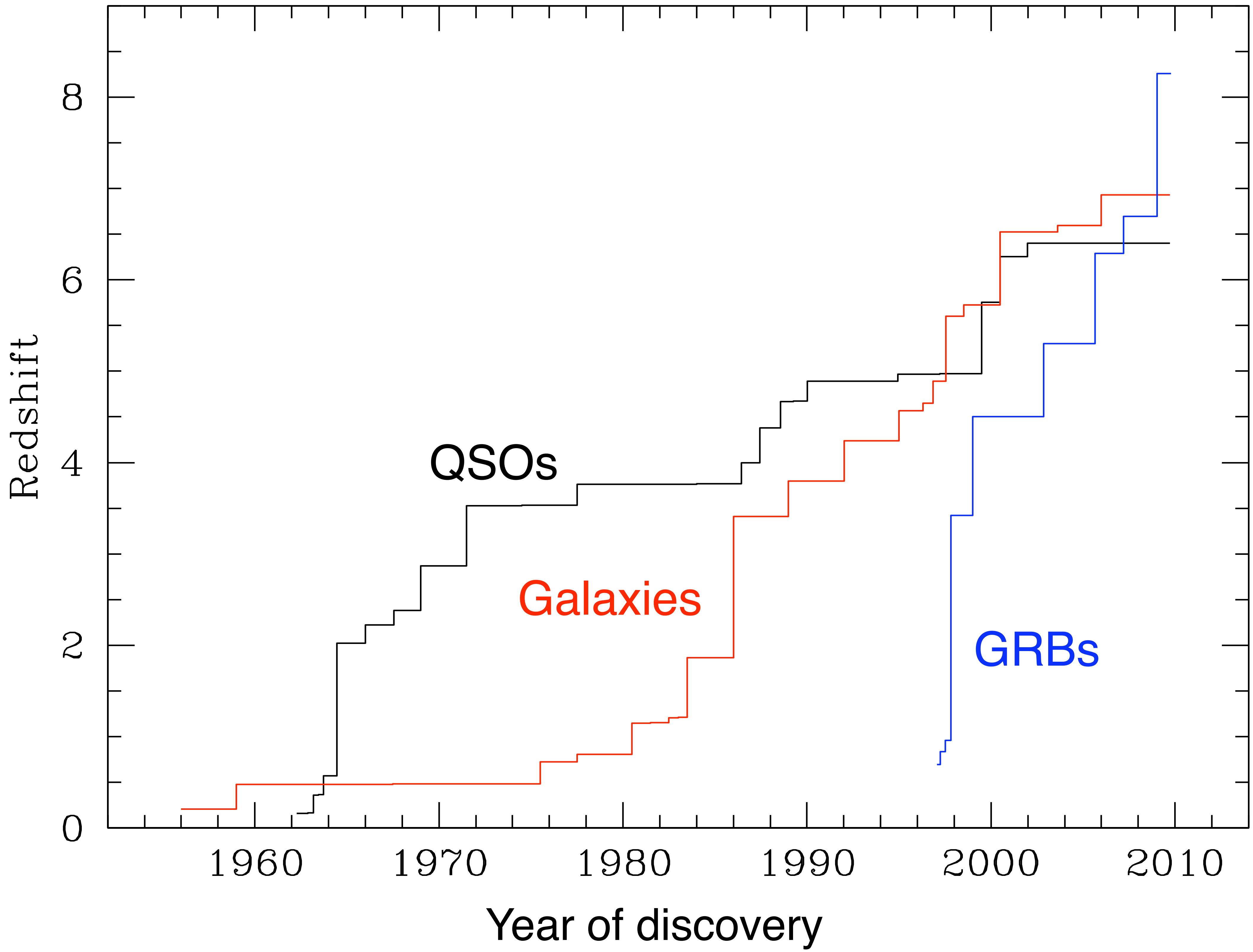
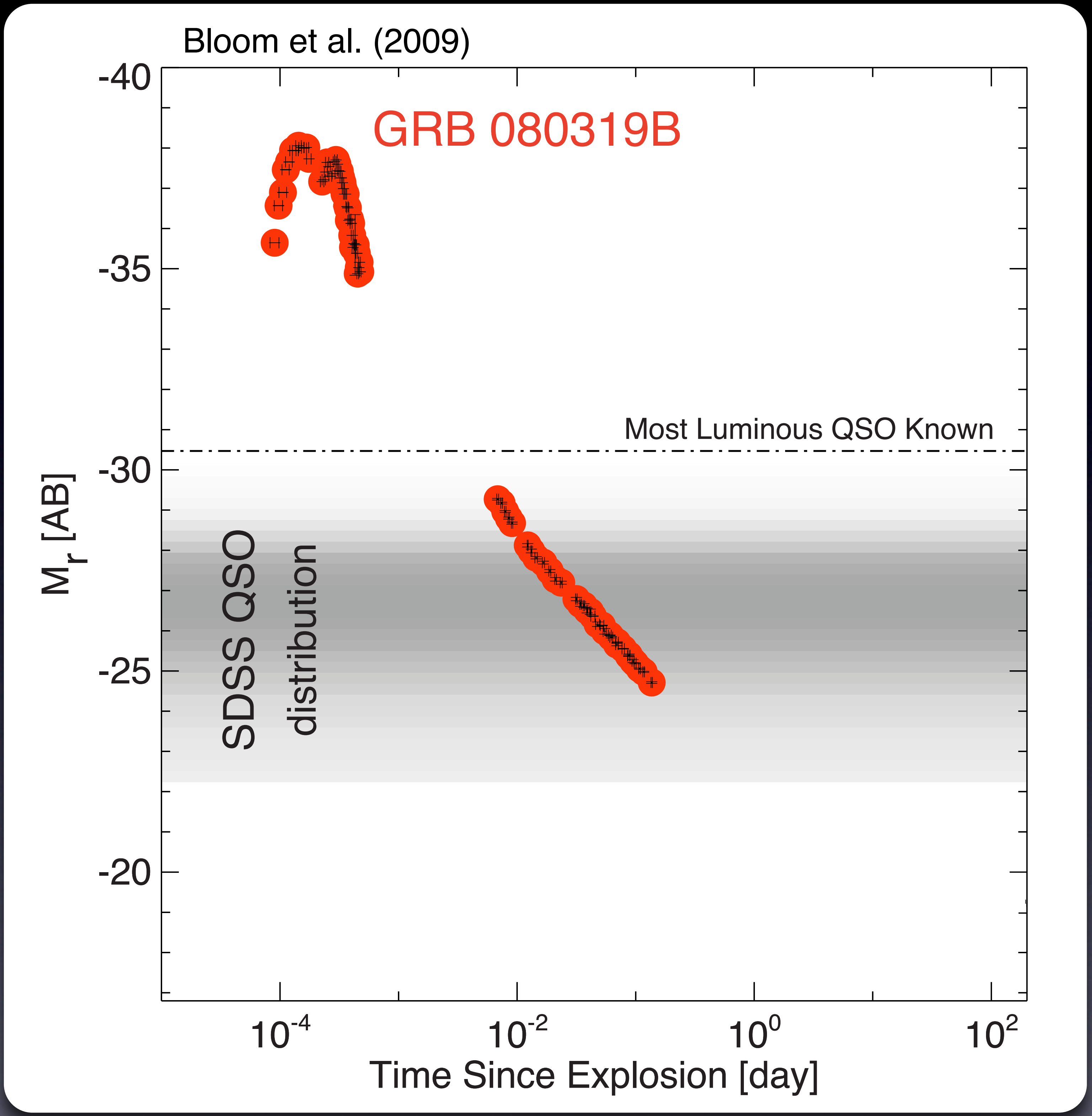
Rates (Long):

- **1/1000:** GRB/CC−SN
- **$1/10^5$ yr^{-1}:** rate in a galaxy
- **Several a day:** full sky rate detectable from Earth

GRBs as cosmological probes

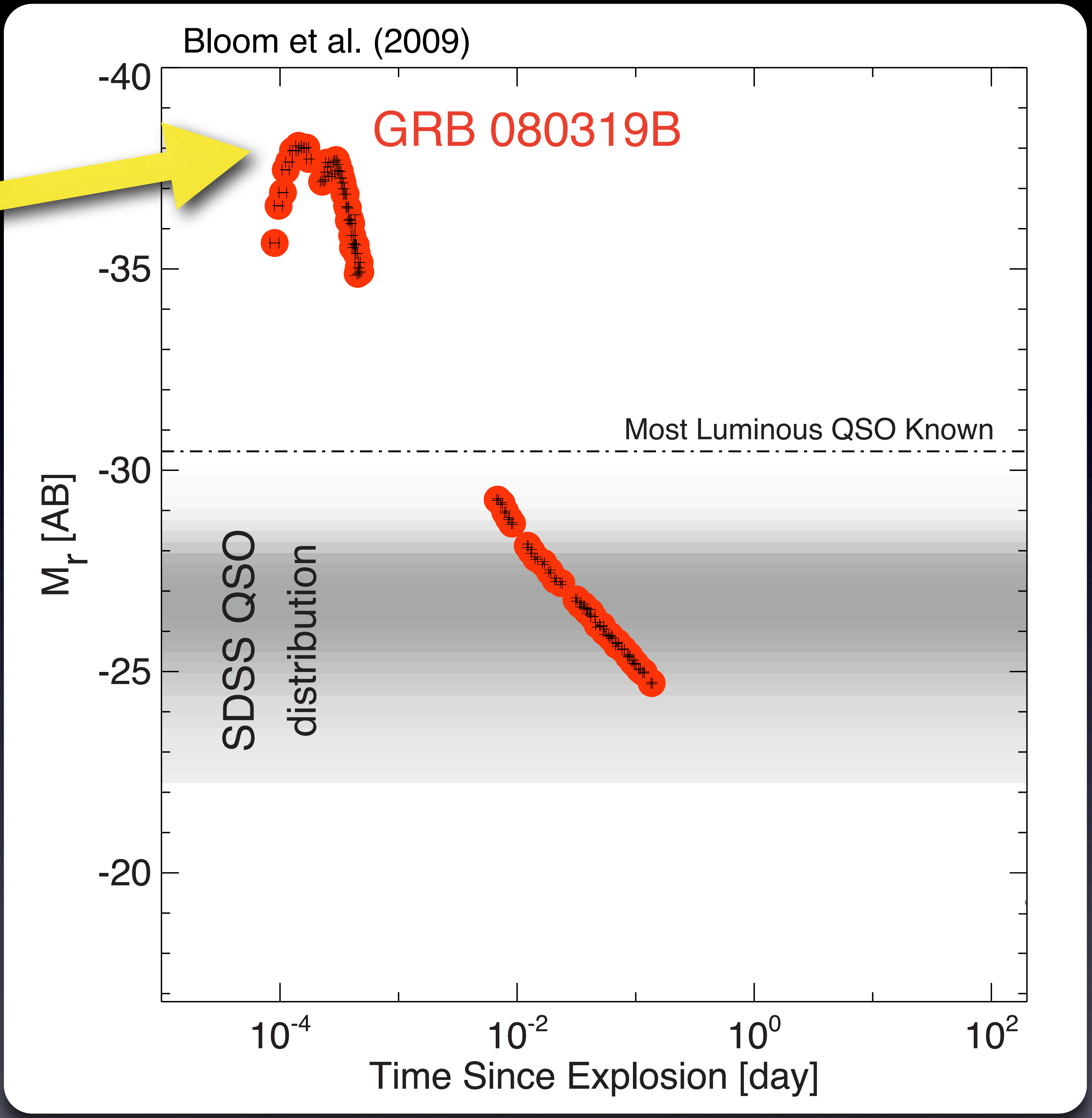


Golden Age of Gamma-Ray Bursts



Golden Age of Gamma-Ray Bursts

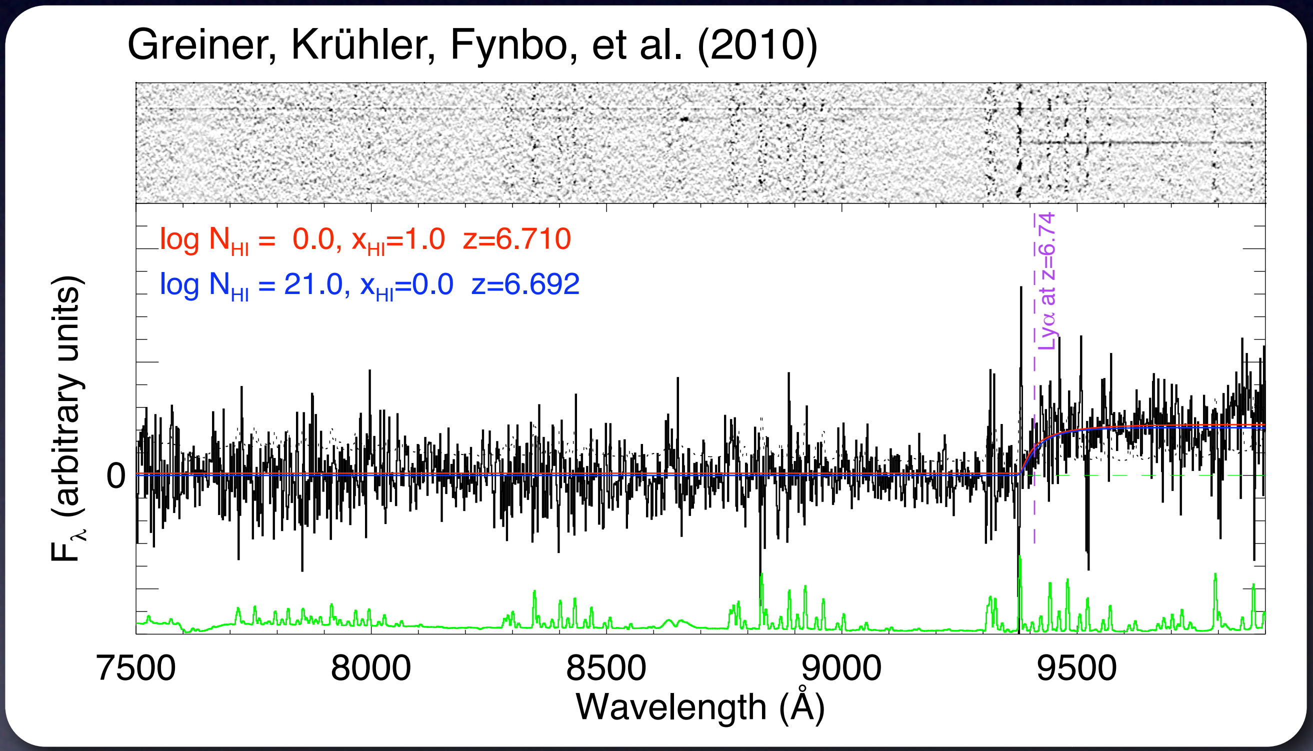
Visual magnitude $m = 5.6$



GRB 080319B

Brightest source recorded by humanity (z=0.937)

Golden Age of Gamma-Ray Bursts



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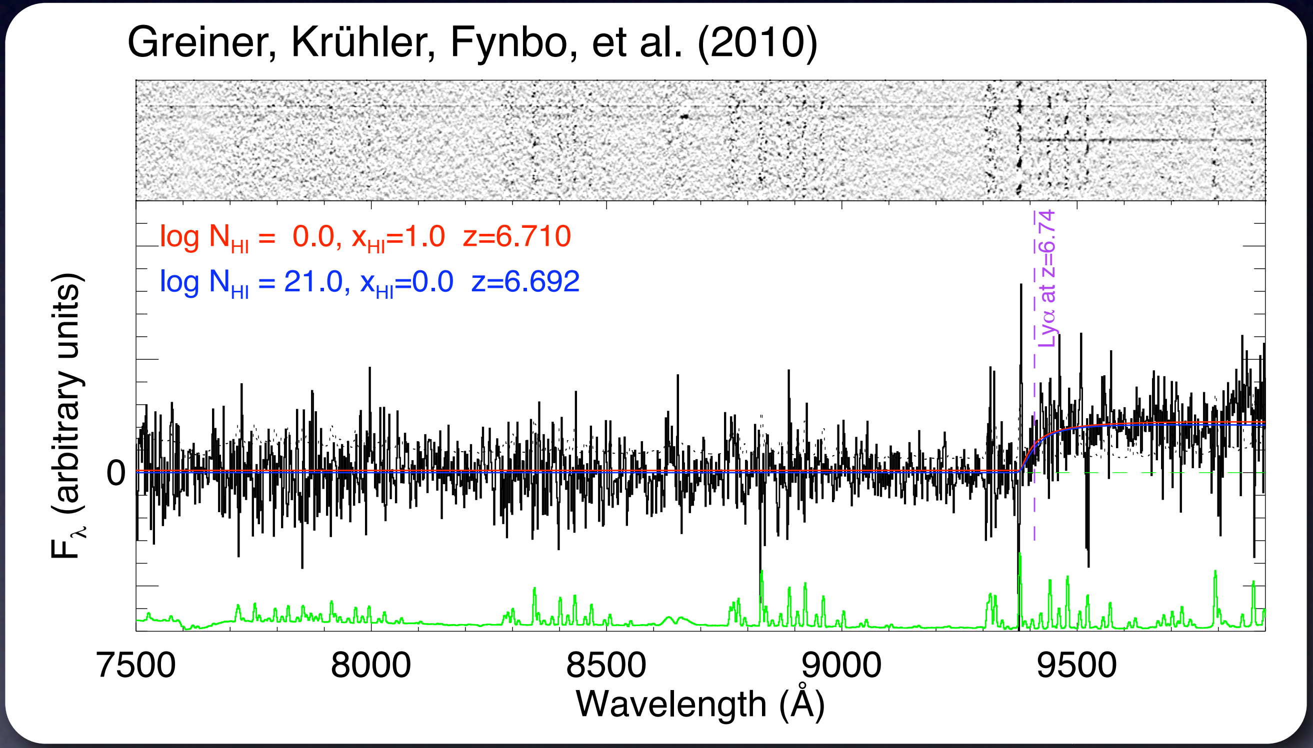
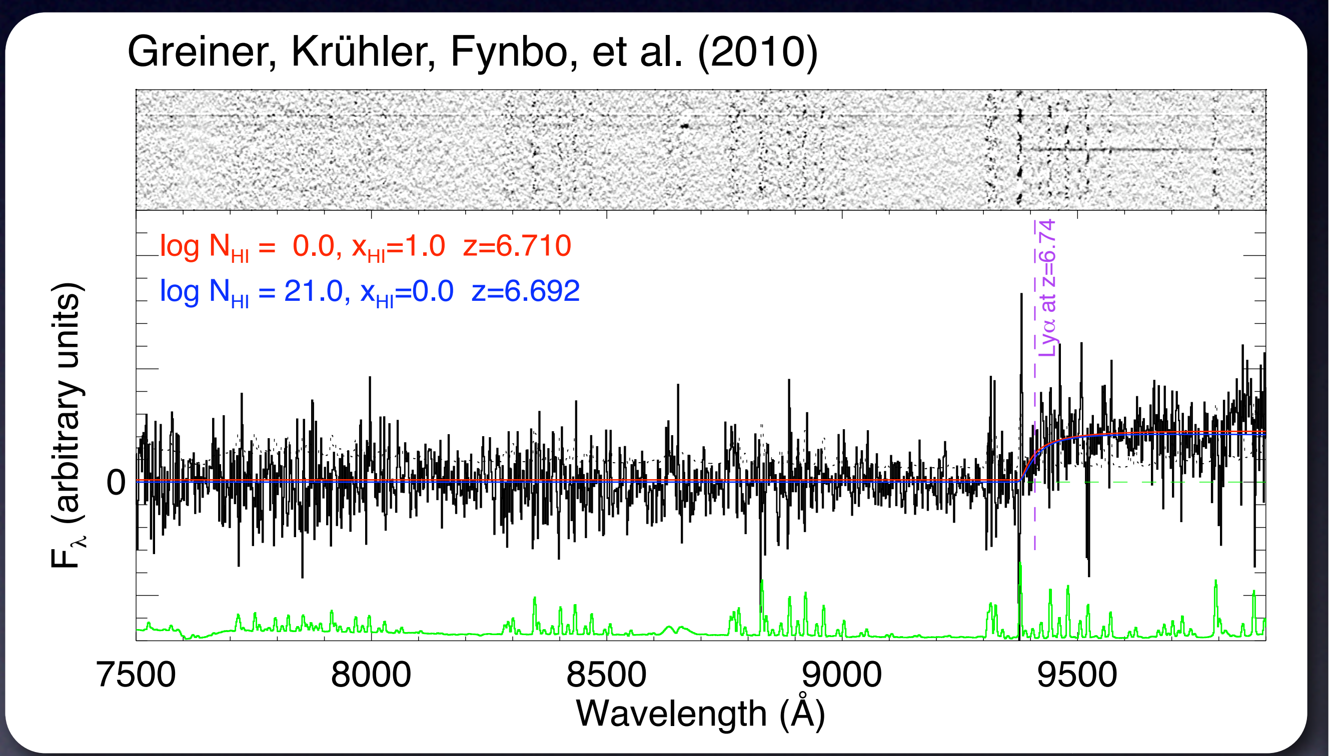


GRB 080913

Second most distant object known (z=6.7)

Golden Age of Gamma-Ray Bursts



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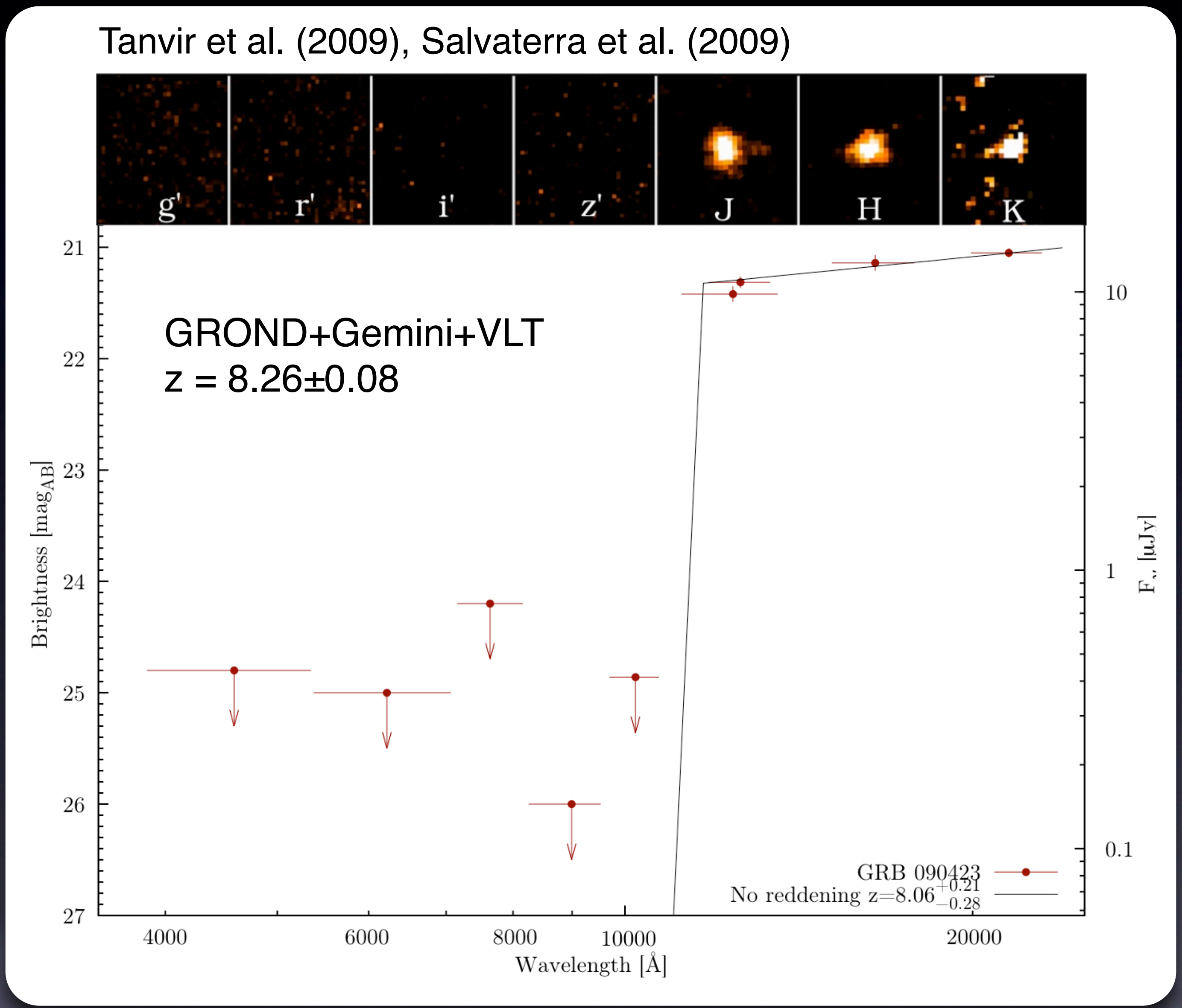
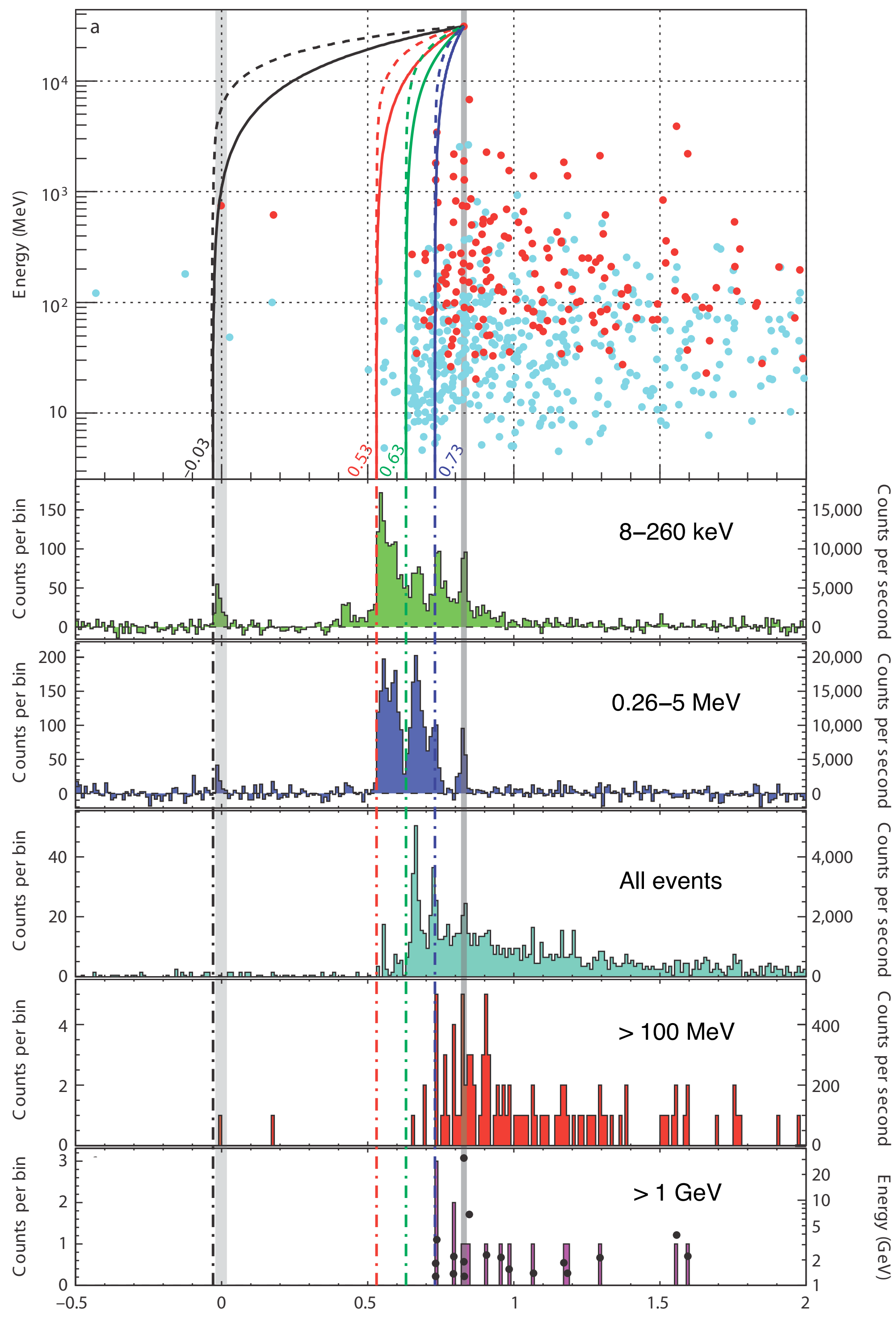


GRB 090423

The most distant object known (z=8.26)

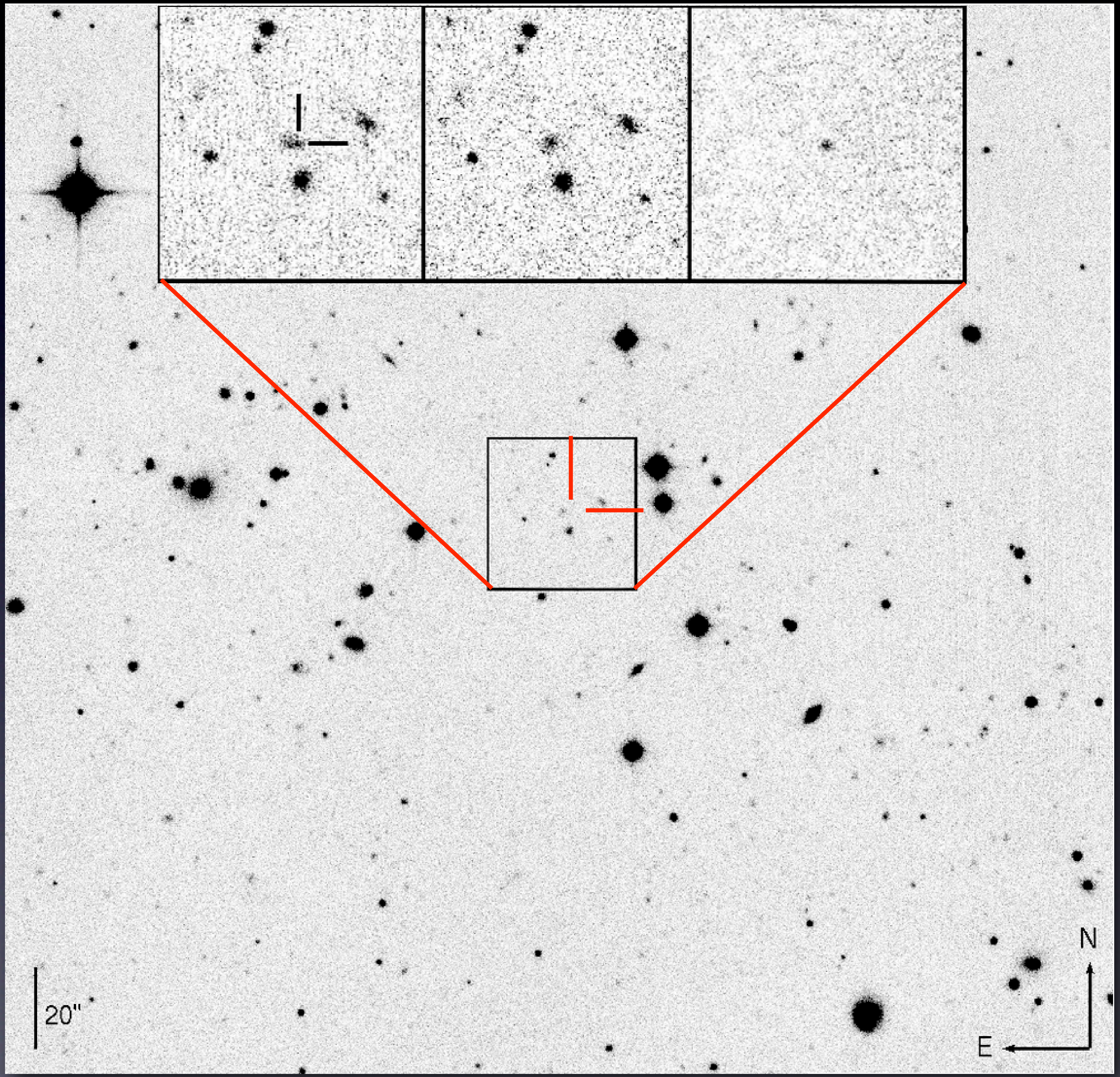
Golden Age of Gamma-Ray Bursts

Abdo et al. (2009a)



Time since trigger (sec)

McBreen, Krühler, Rau, Greiner et al. (2010)
Rau, McBreen, Krühler, Greiner (2009)



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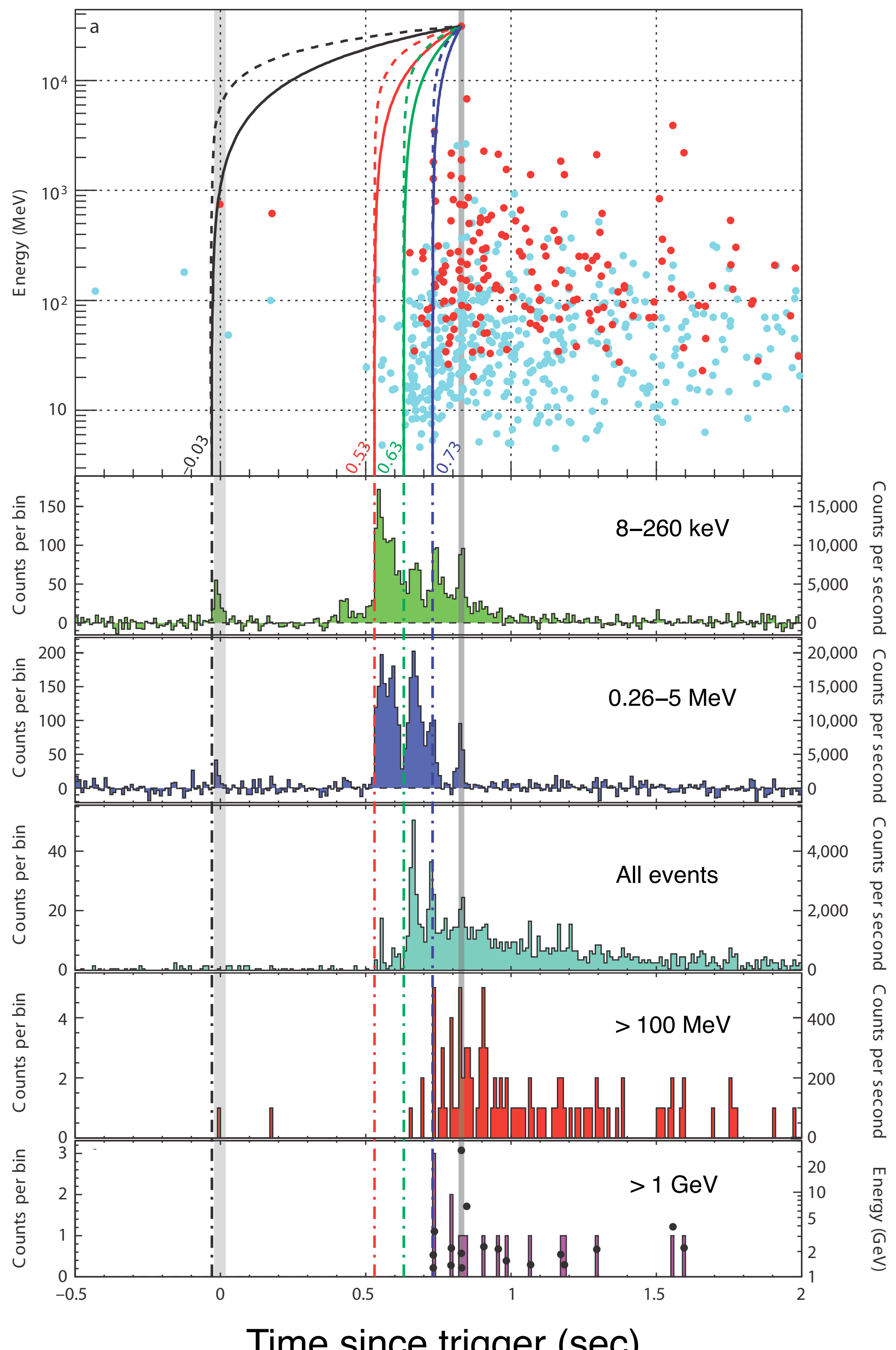

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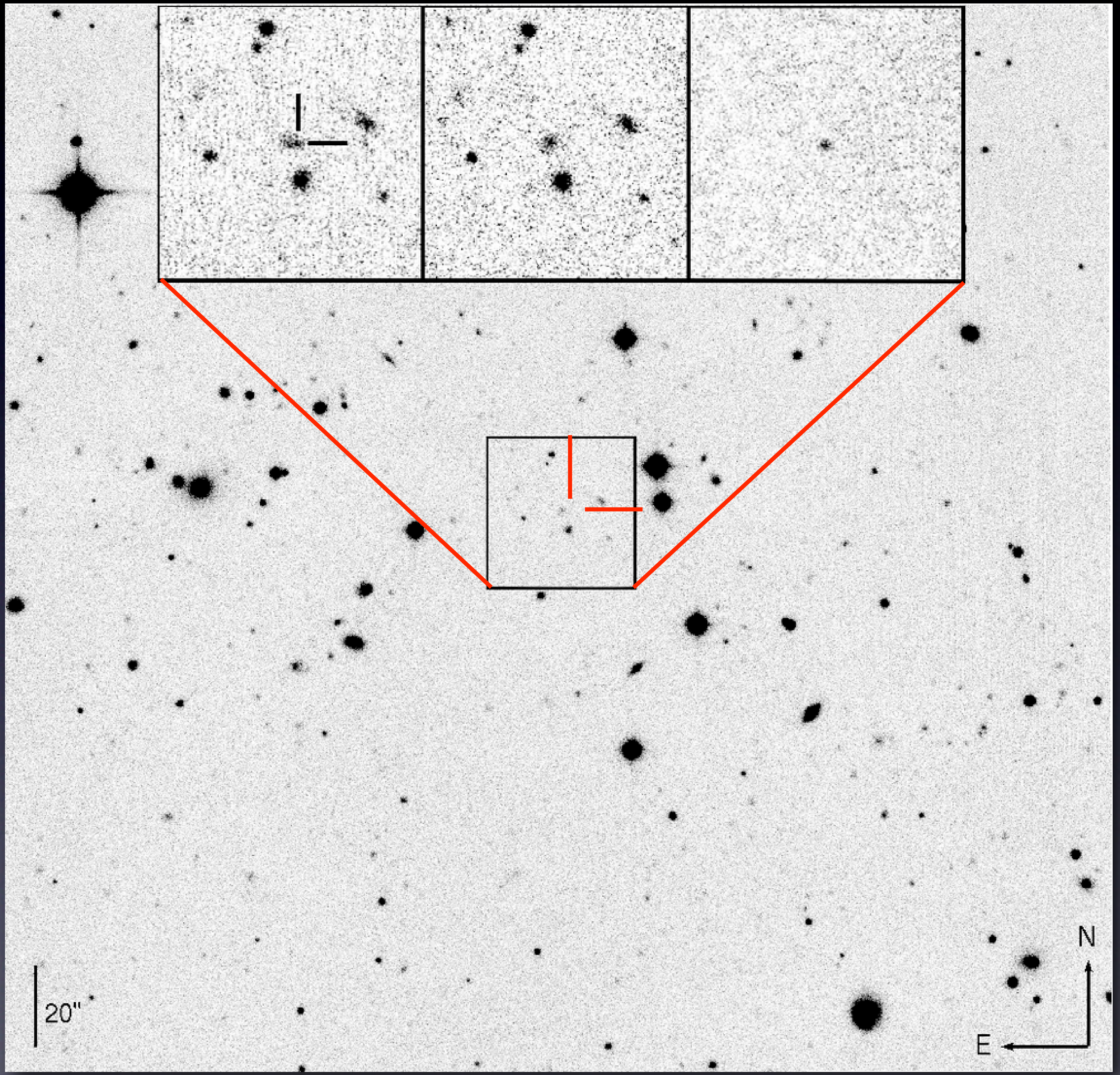
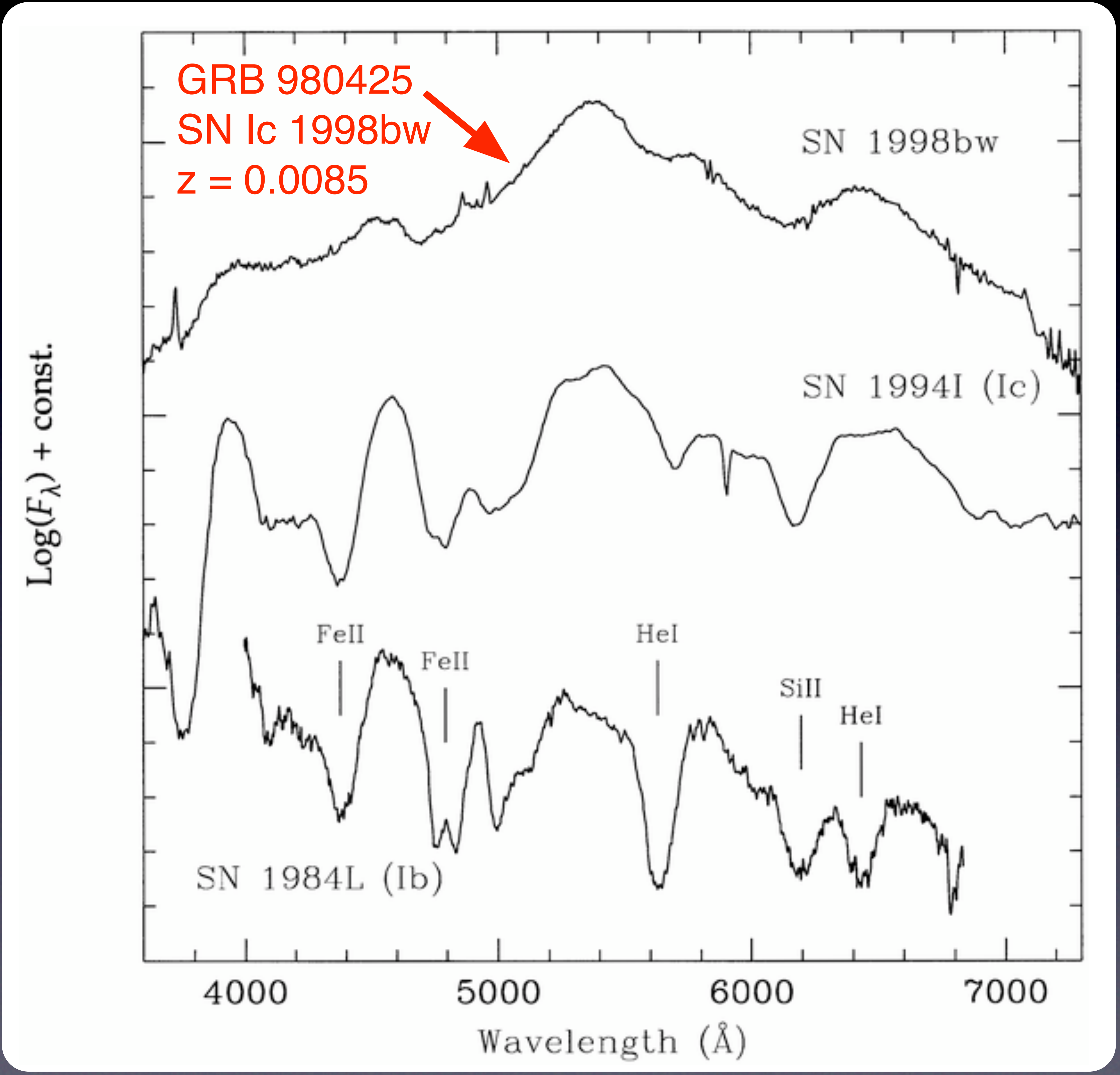


GRB 090510

Lorentz Invariance tested to highest precision (z=0.903)

Gamma-ray burst - SN connection

Gamma-ray burst - SN connection



Galama et al. (1998)

Gamma-ray burst - SN connection

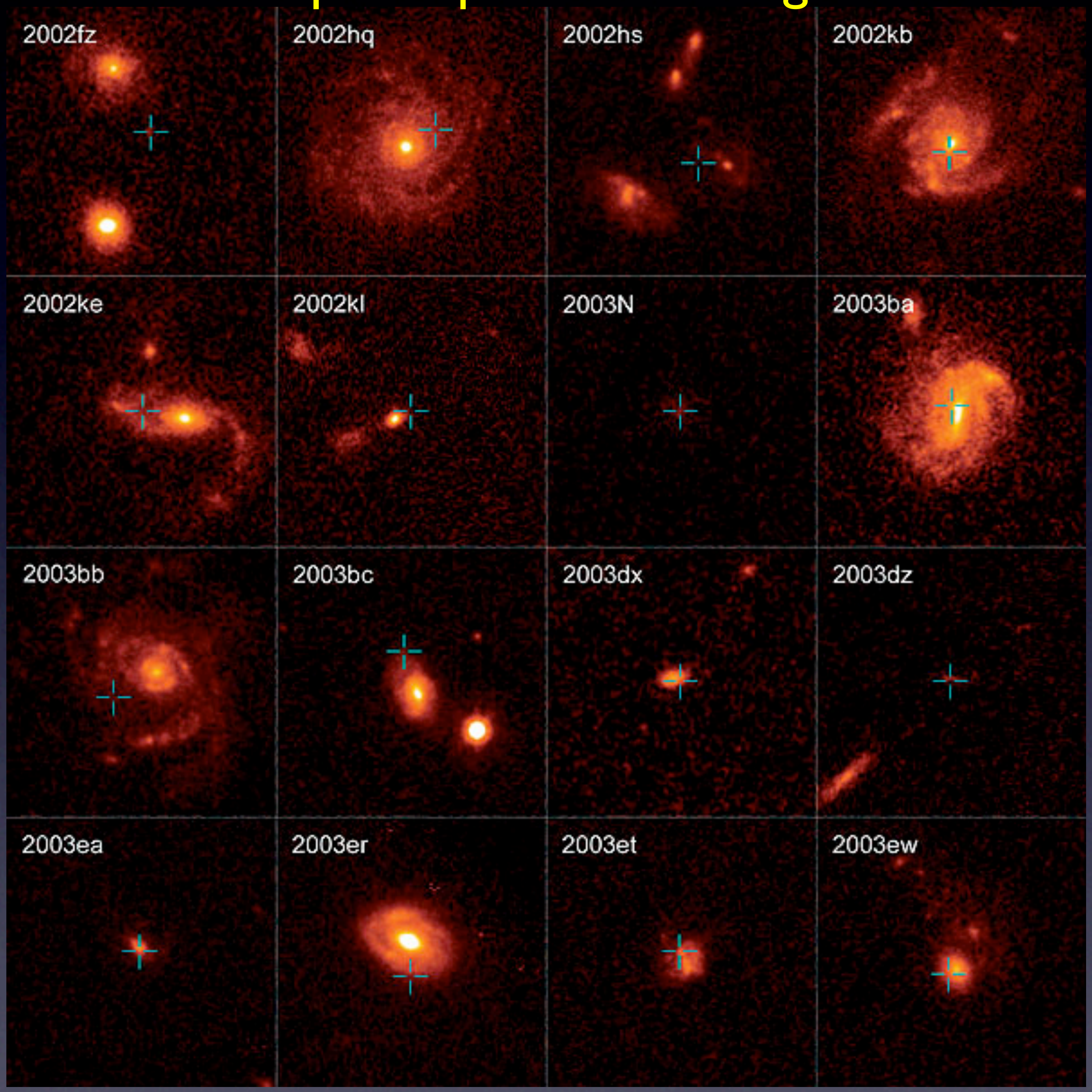
Gamma-ray burst - SN connection

GRB with spectroscopically confirmed SN

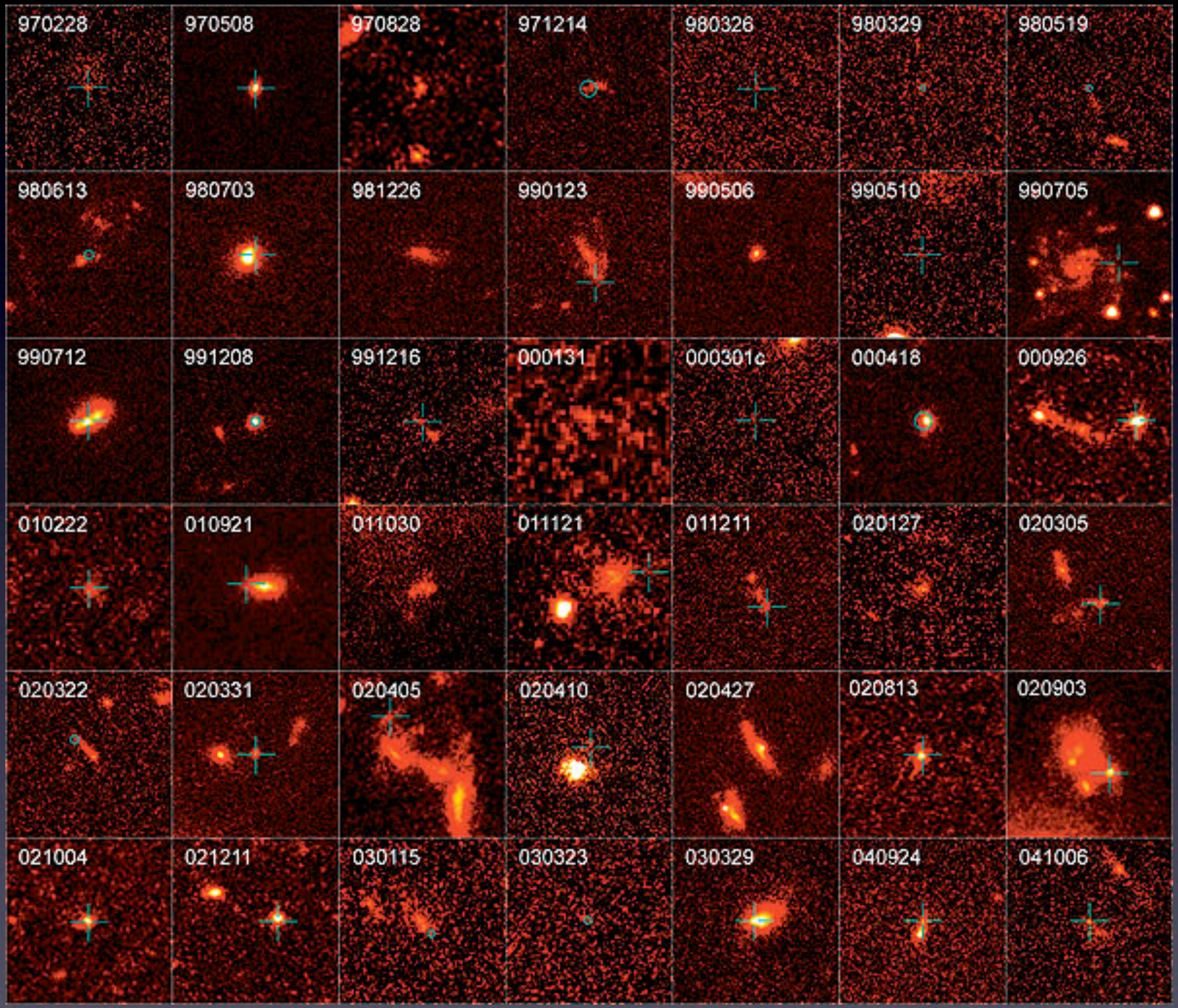
GRB	z	12 + log(O/H) (T_e)	Host type	M_B	References
980425	0.0085	8.25	Dwarf spiral	–17.6	Hammer et al. (2006)
020903	0.25	7.97	Irregular	–18.8	Hammer et al. (2006)
030329	0.168	7.72	Irregular	–16.5	Levesque et al. (2010)
031203	0.105	8.02 ± 0.15	Irregular	–21.0	Prochaska et al. (2004)
060218	0.0335	7.54+0.16	Irregular	–15.9	Wiersema et al. (2007)
100316D	0.0591	8.23 ± 0.15	Spiral? Irr?	–19	Starling et al. (2010)

GRB environment

Core-collapse supernova host galaxies

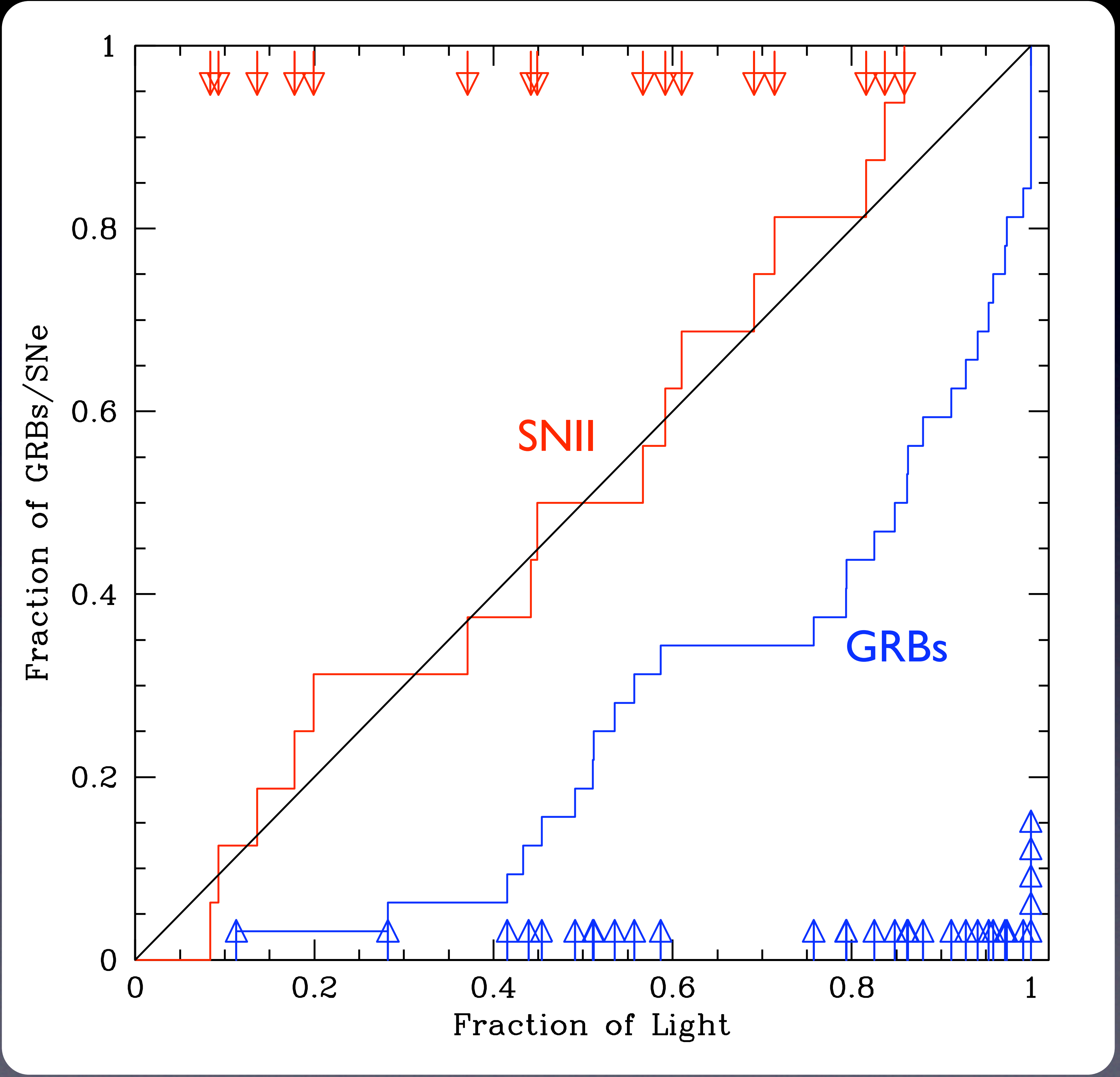


GRB host galaxies



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

GRB environment



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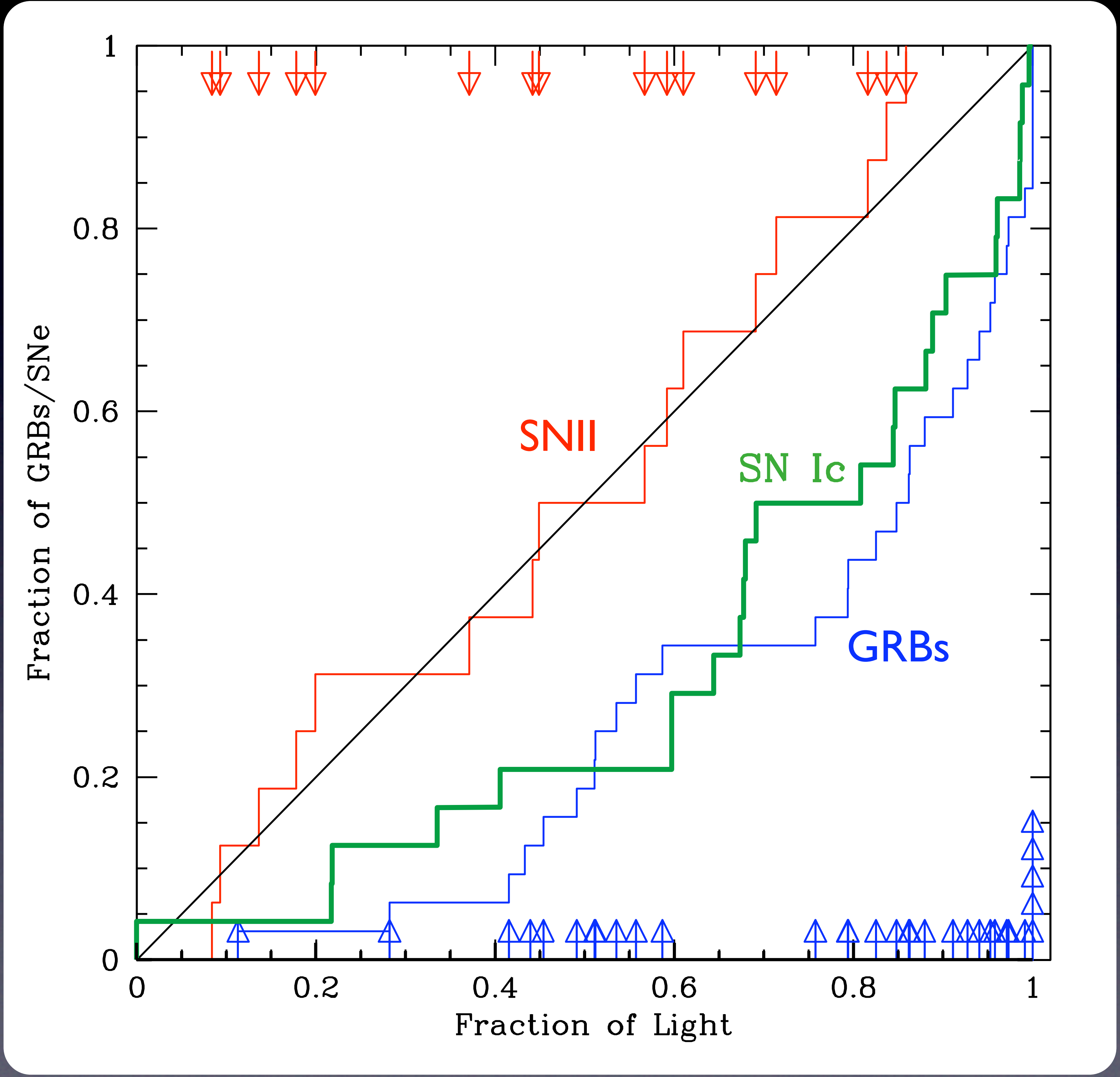

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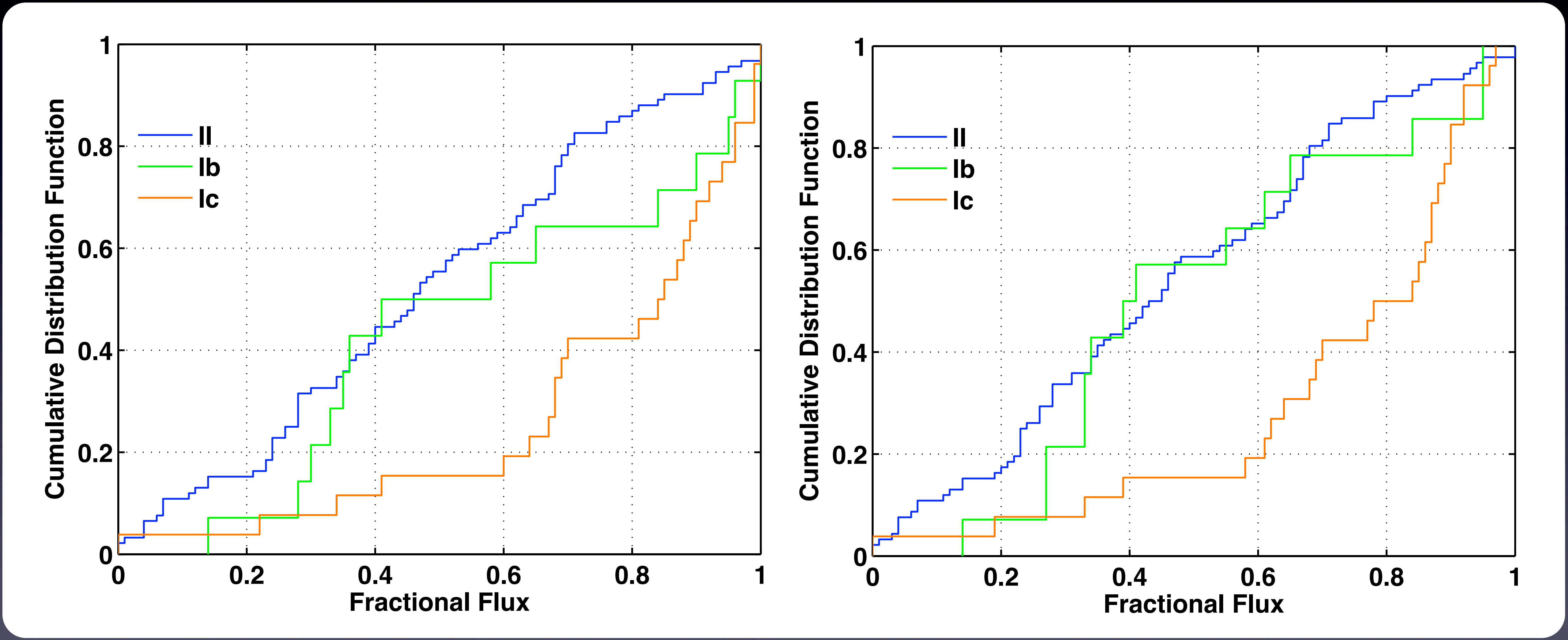
Kelly, Kirshner & Pahre (2008)

GRB environment

Light distribution of Wolf-Rayet stars vs. GRBs



Leloudas et al. (2010)
(see also Han et al. 2010)

GRB environment

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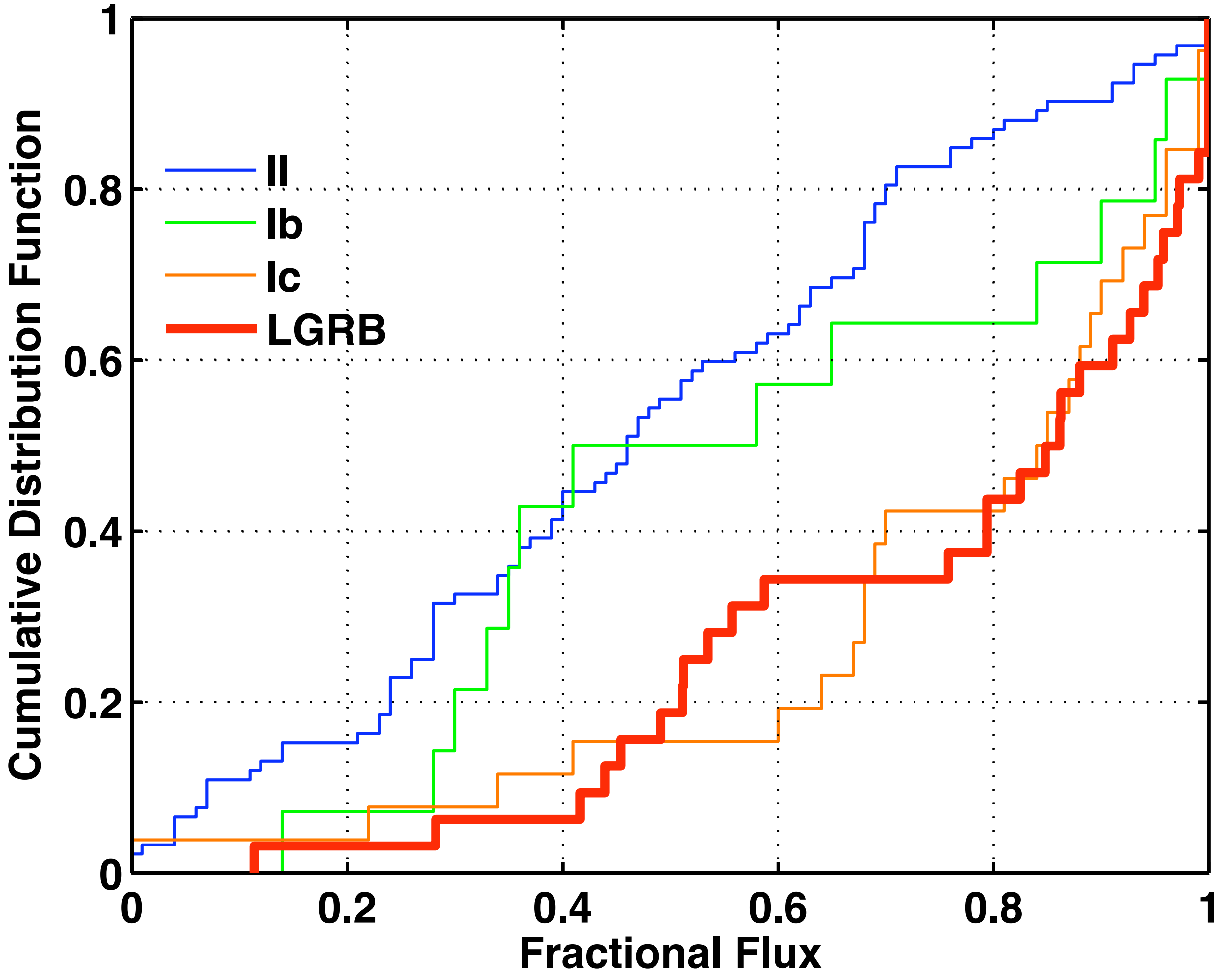

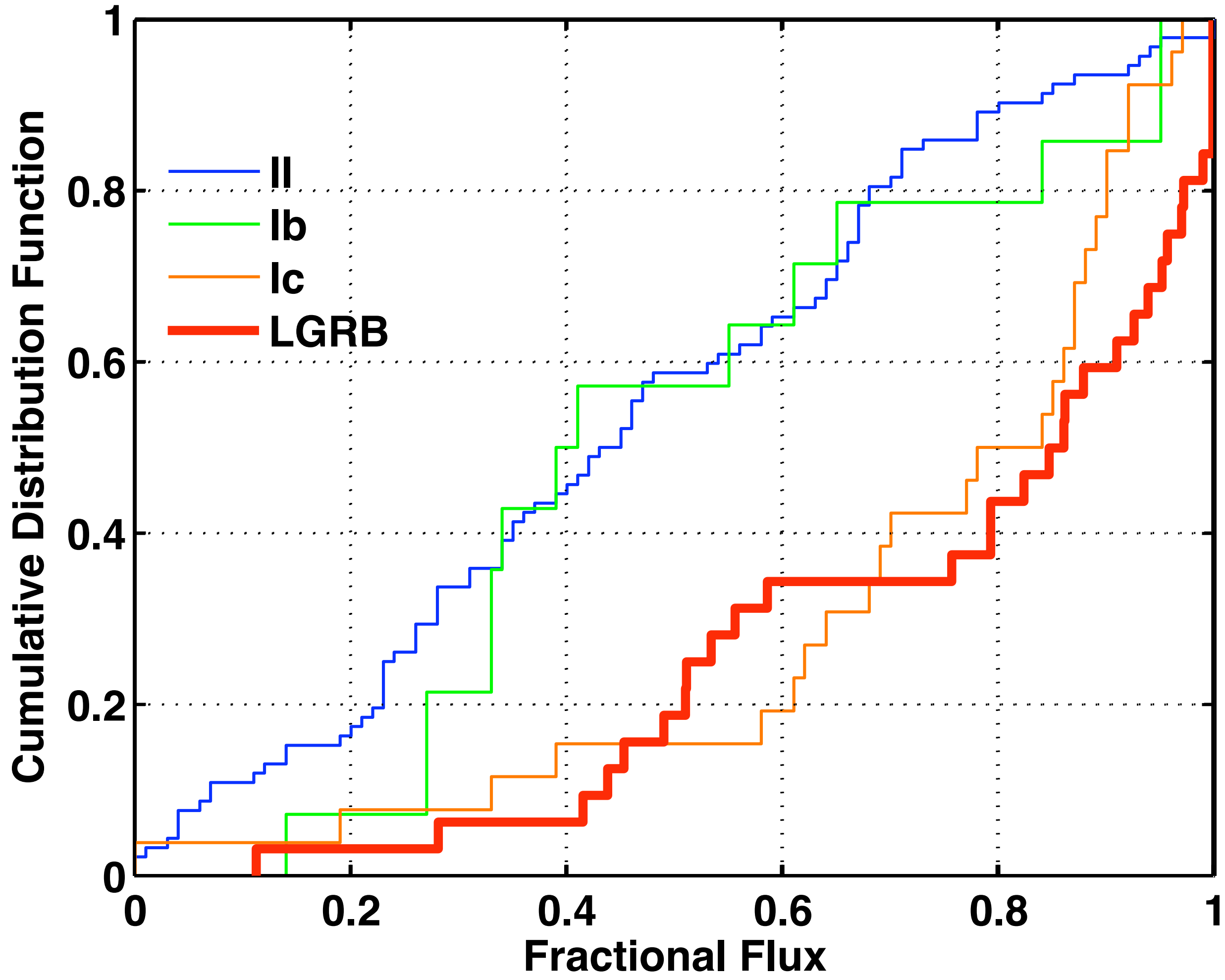

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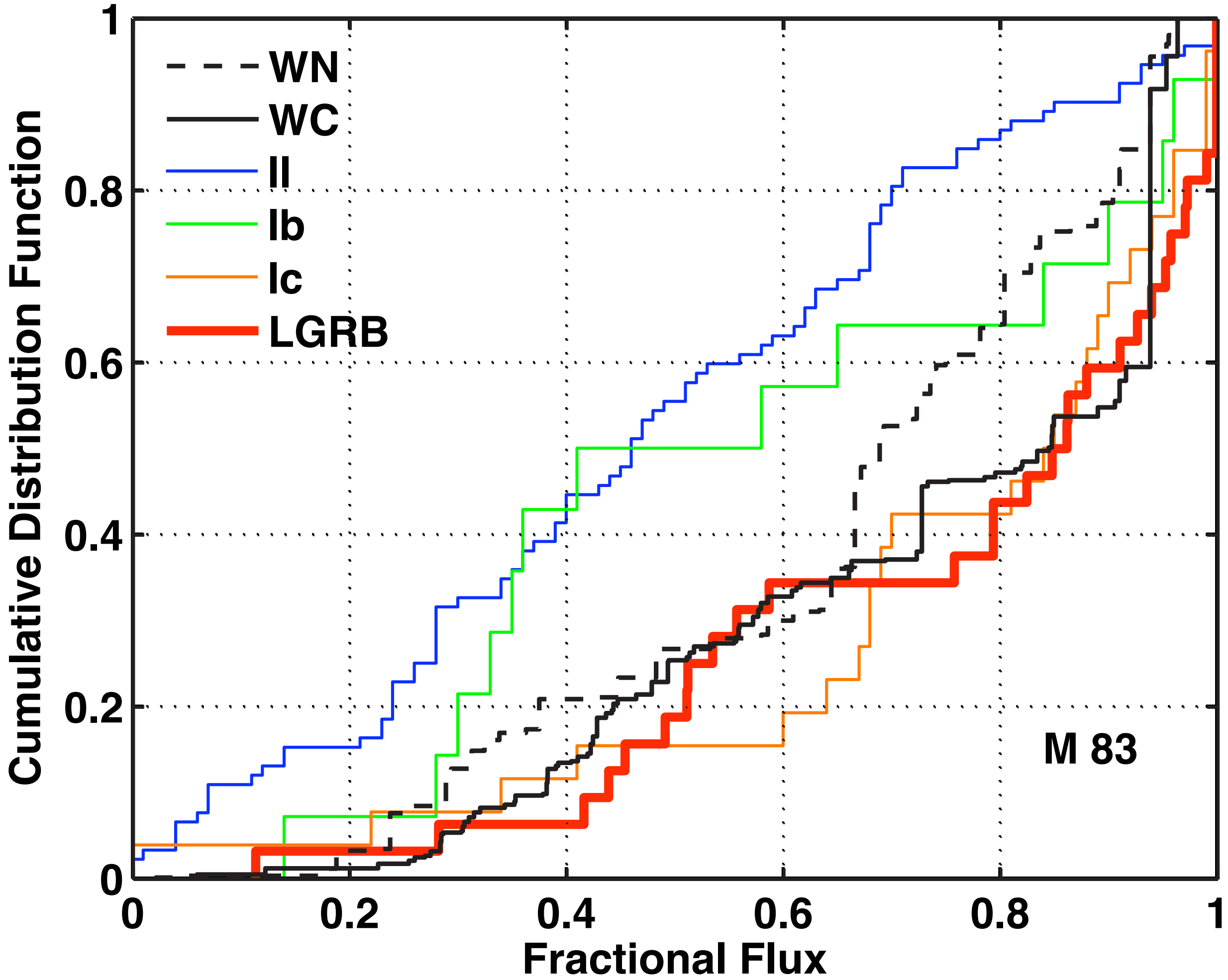

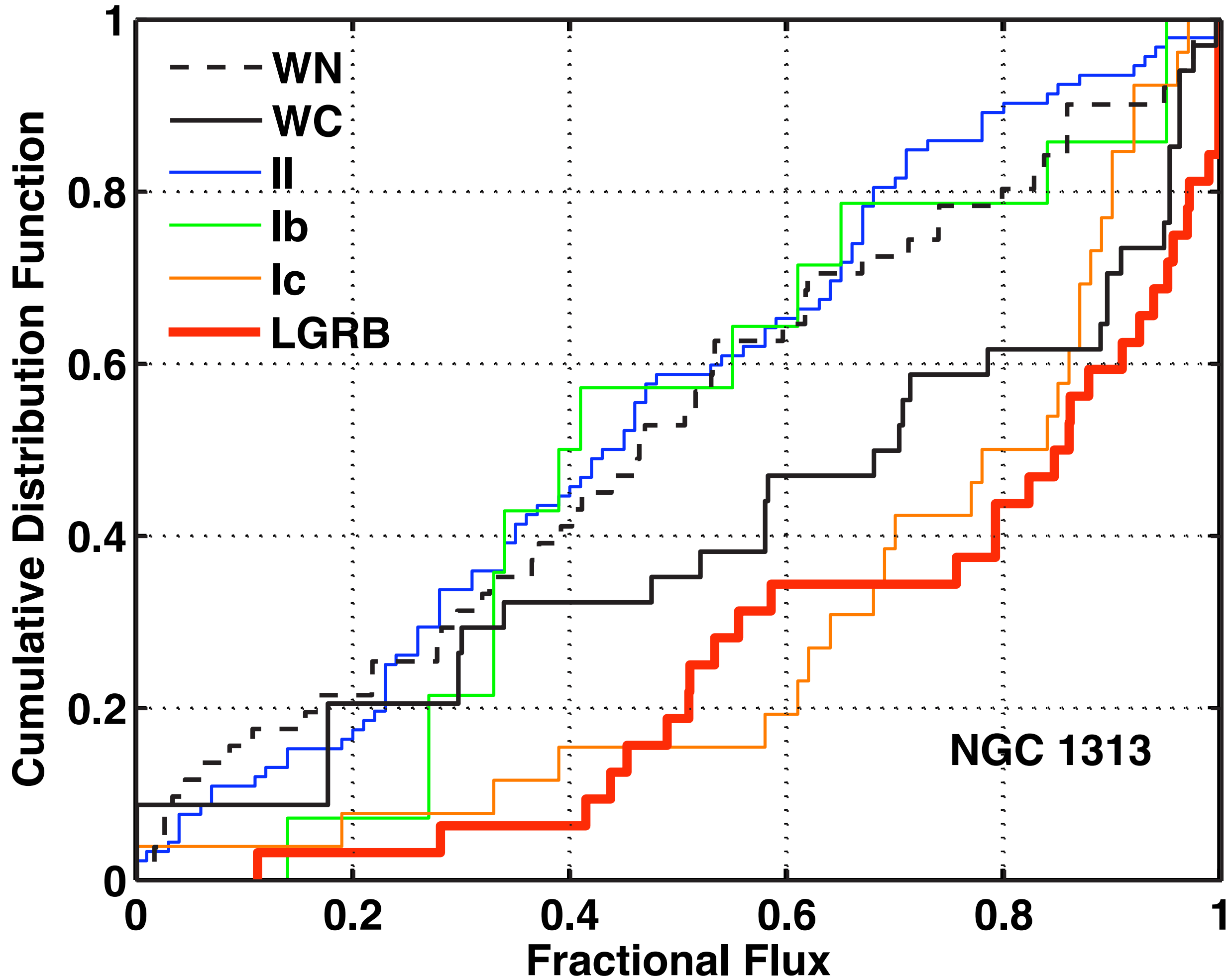

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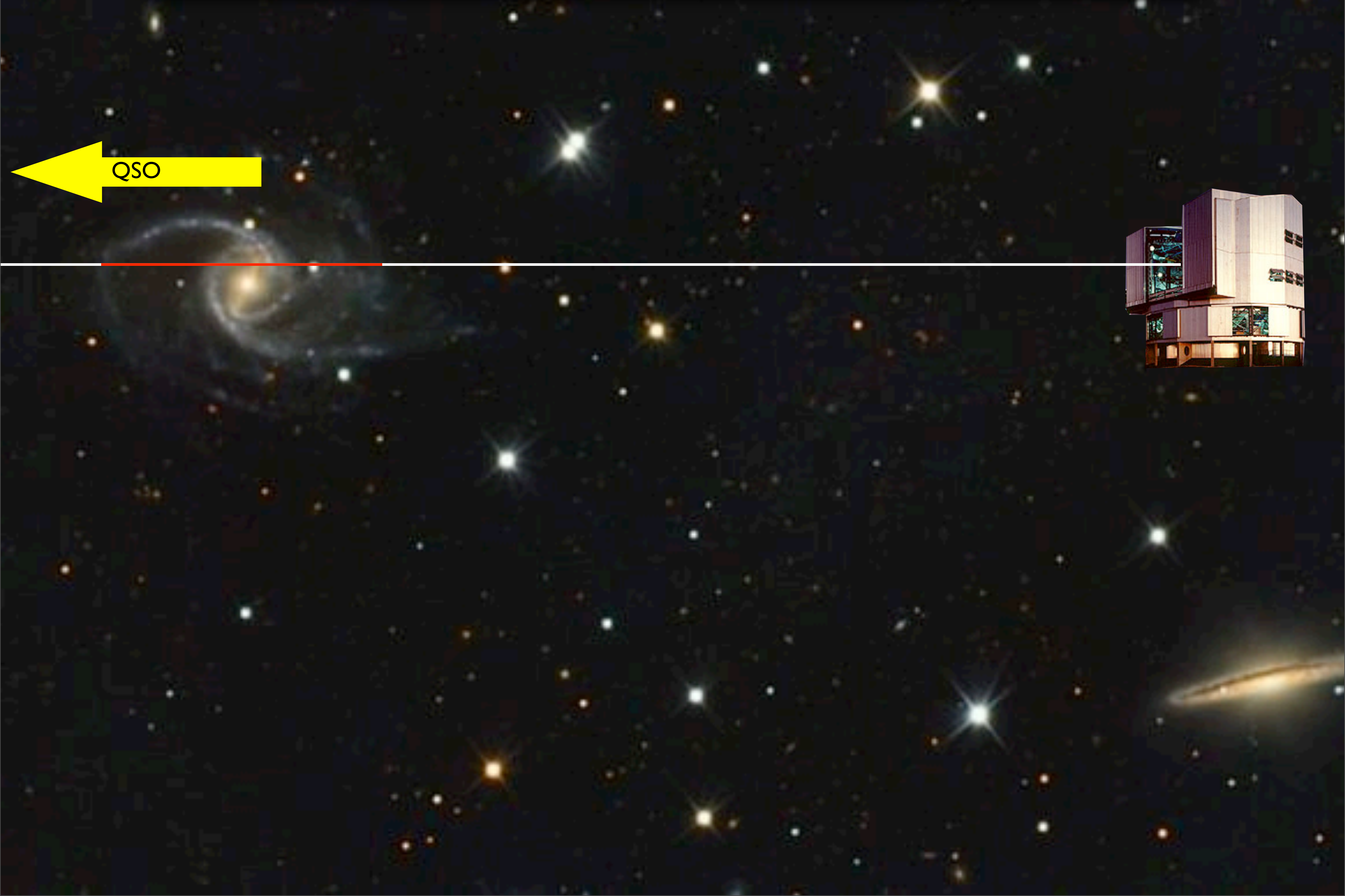
GRBs to investigate the

Cosmic Chemical Evolution

GRBs and the Cosmic Chemical Evolution



GRBs and the Cosmic Chemical Evolution

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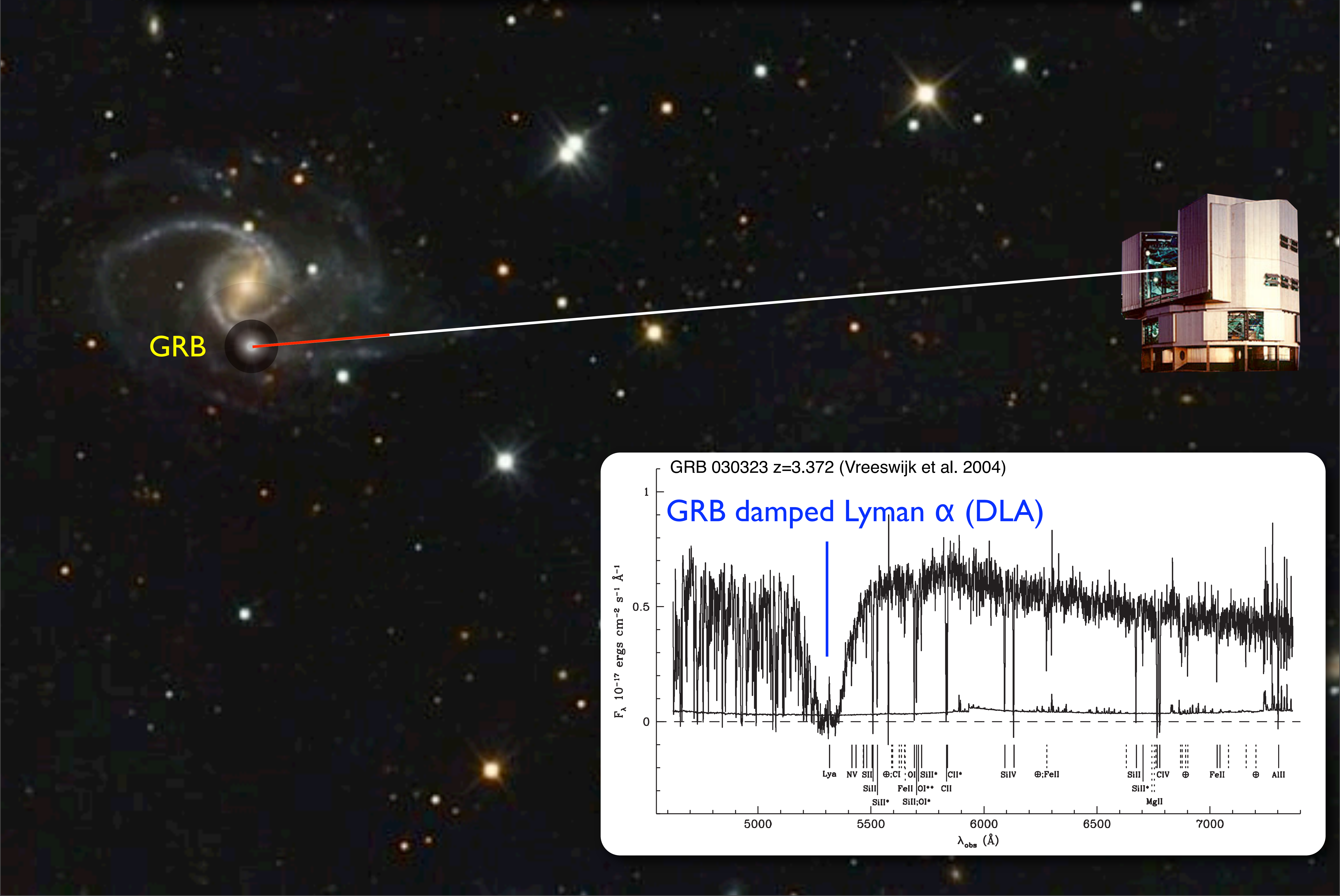
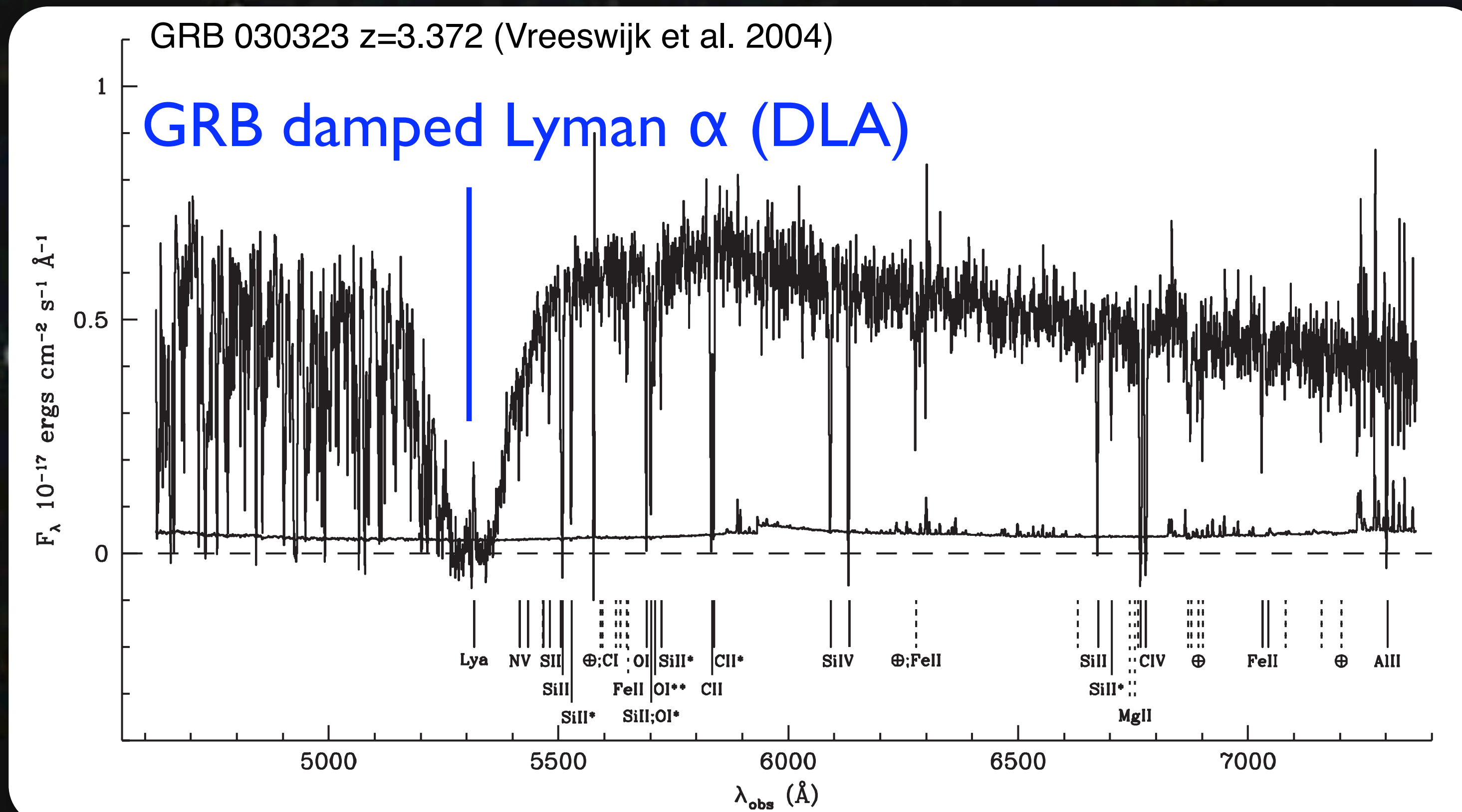


GRBs and the Cosmic Chemical Evolution



Cold interstellar medium ($T \lesssim 1000$ K)

Heavy element enrichment

Dust extinction

Dust depletion

Molecular hydrogen

GRBs and the Cosmic Chemical Evolution

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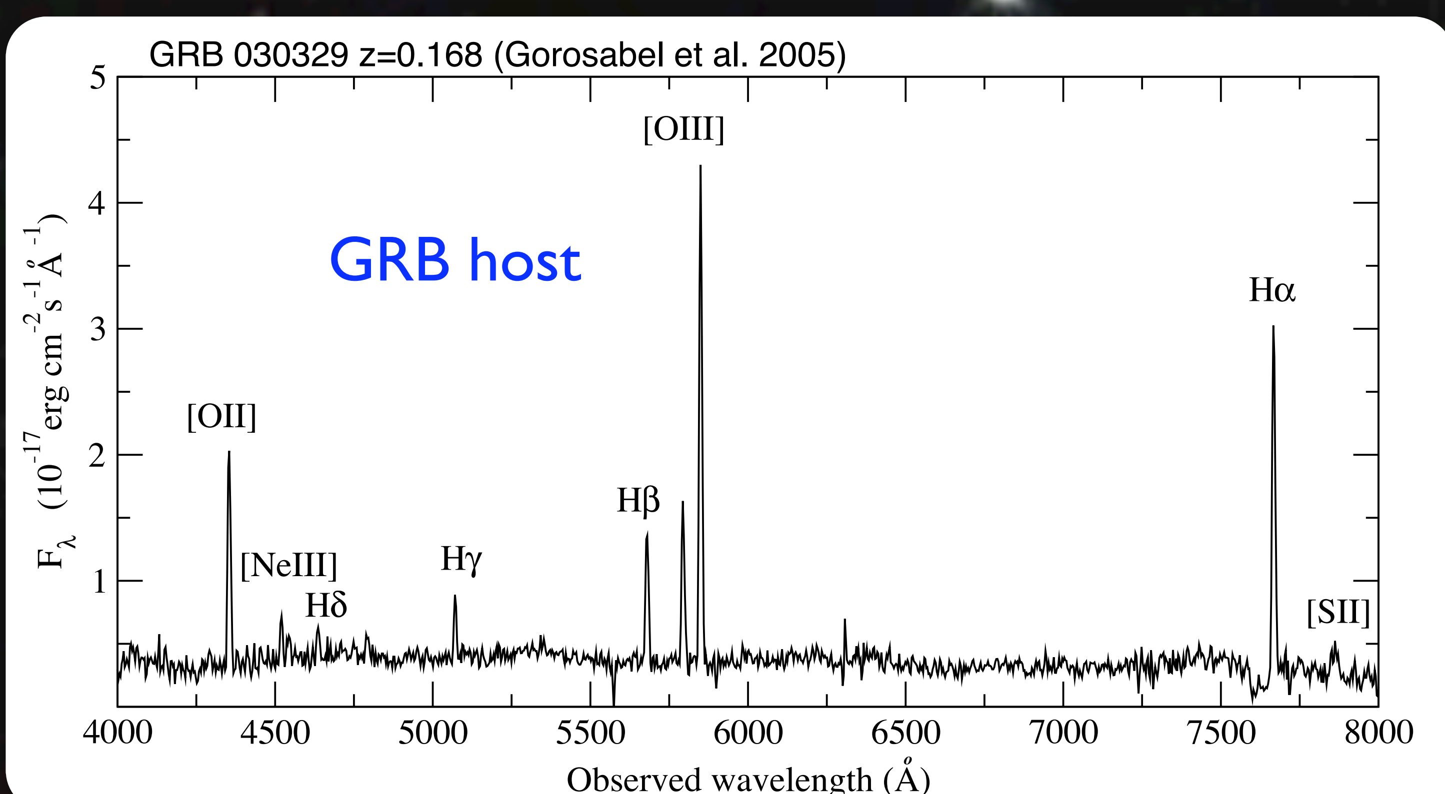

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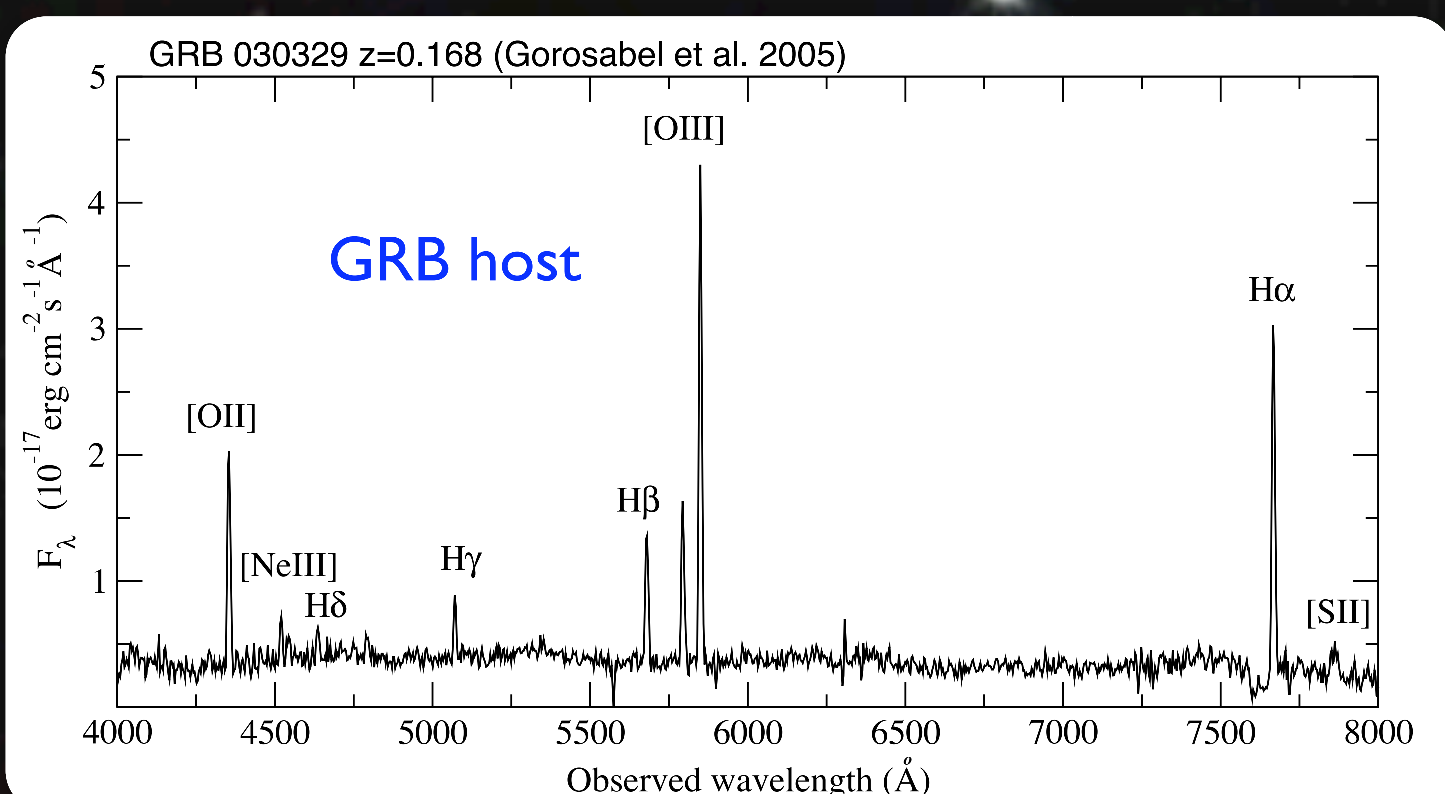
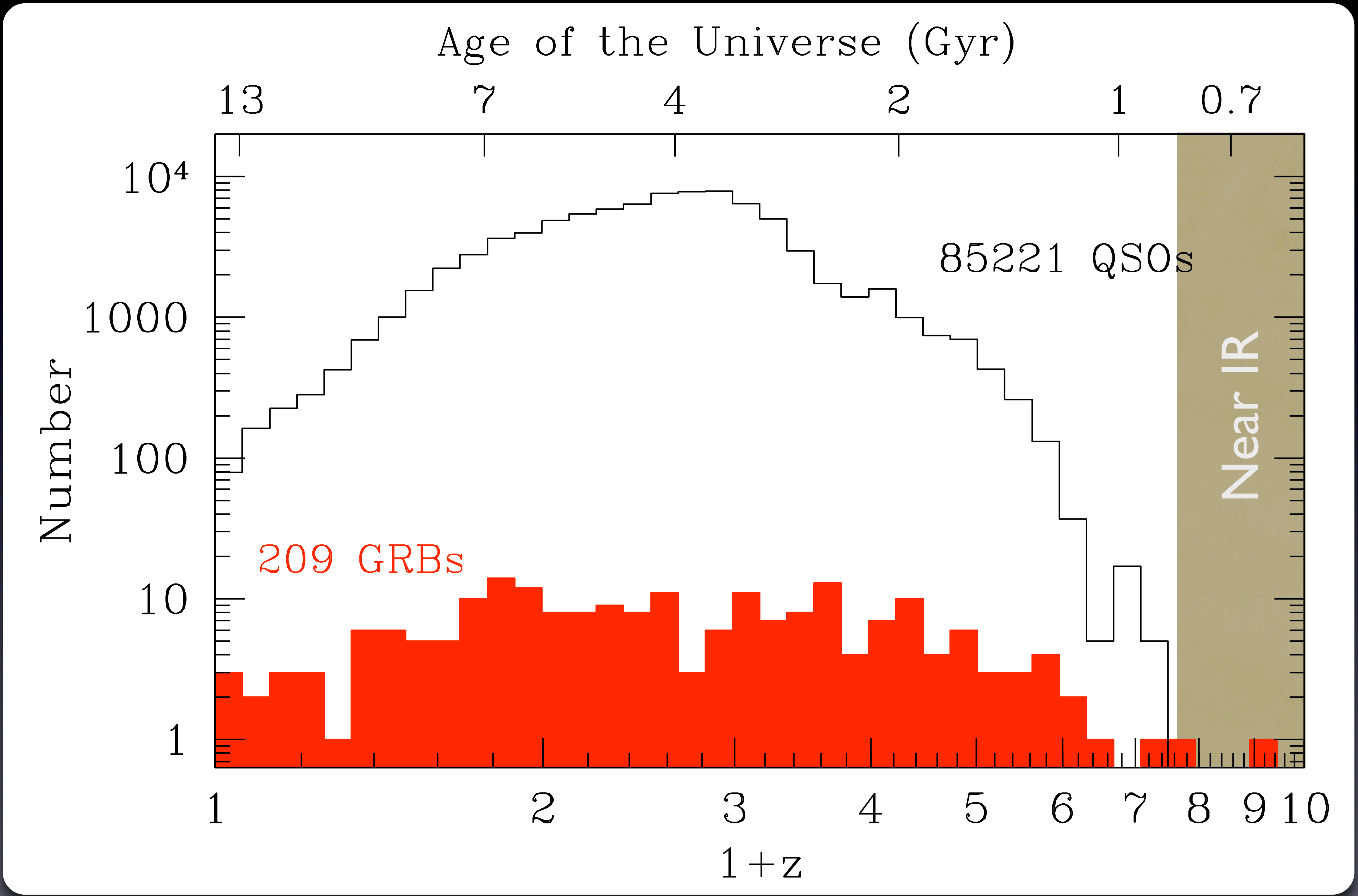


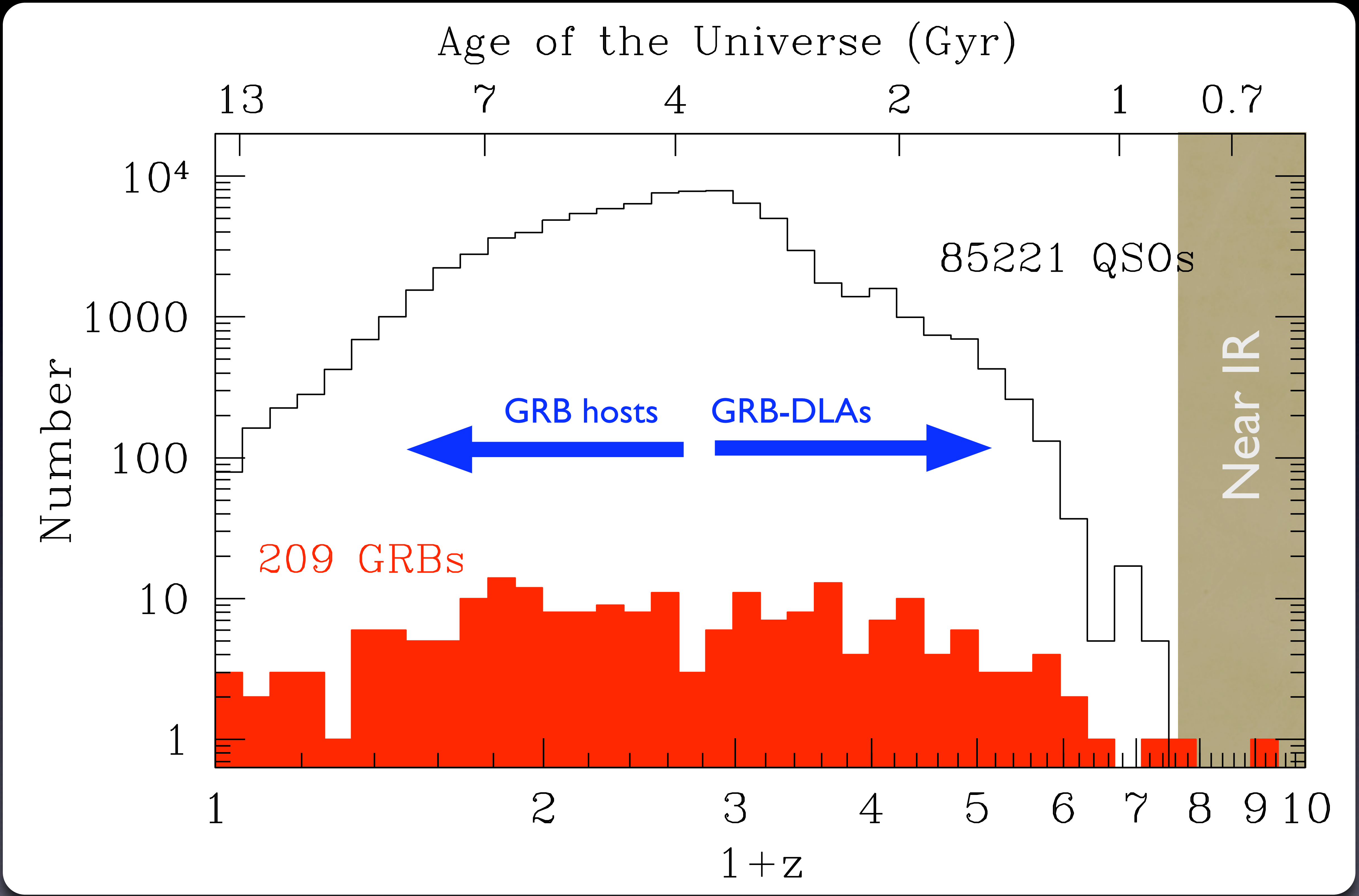
<u>Warm interstellar medium ($T \sim 10^4$ K)</u>
Heavy element enrichment
Dust extinction
Star formation rate
Gas electron density
Gas temperature

GRBs as cosmological probes



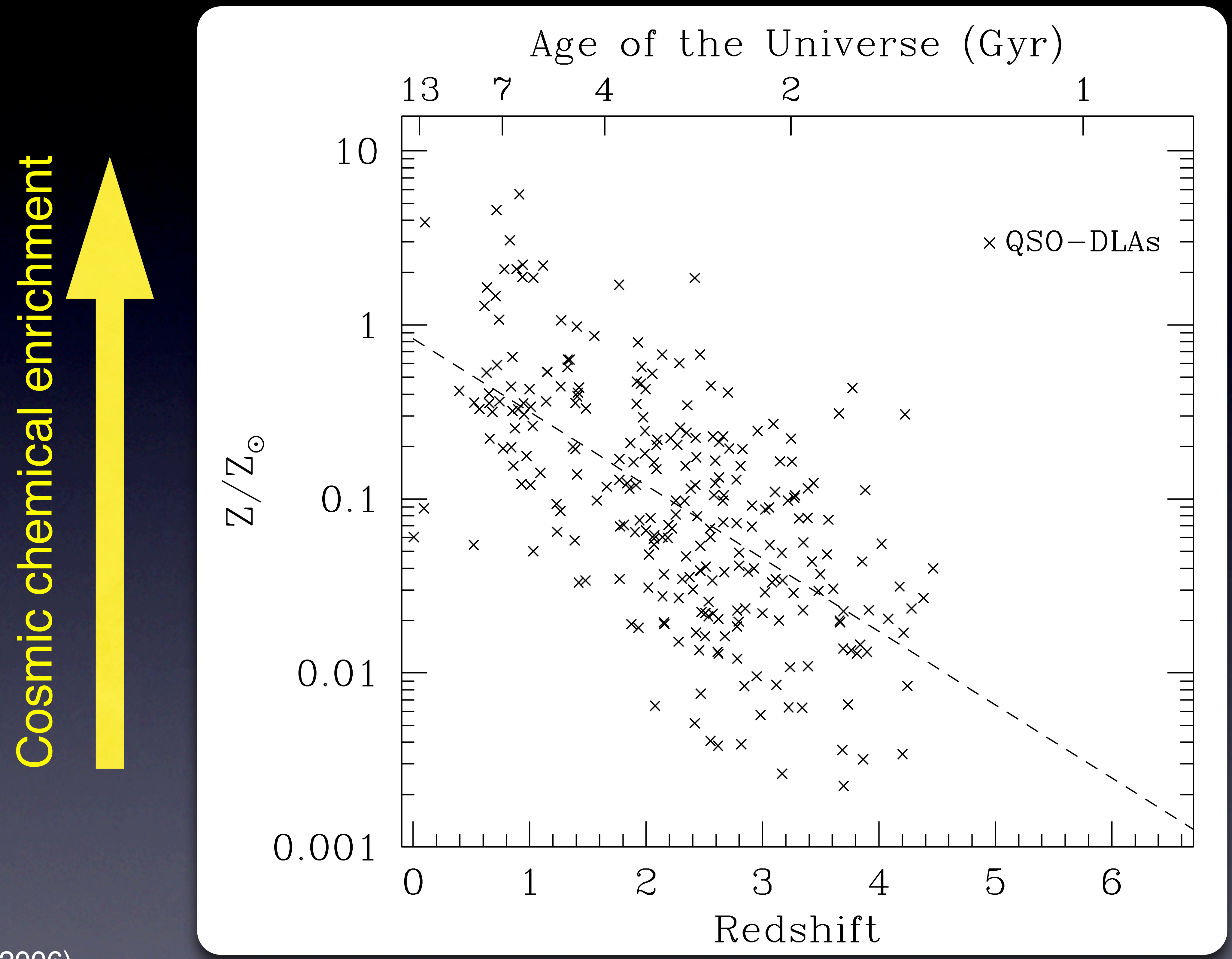
log (time)

GRBs as cosmological probes



log (time)

Cosmic chemical evolution with GRBs



Savaglio (2006)
Rau, Savaglio, Krühler, Afonso, Greiner et al. (ApJ, sub.)
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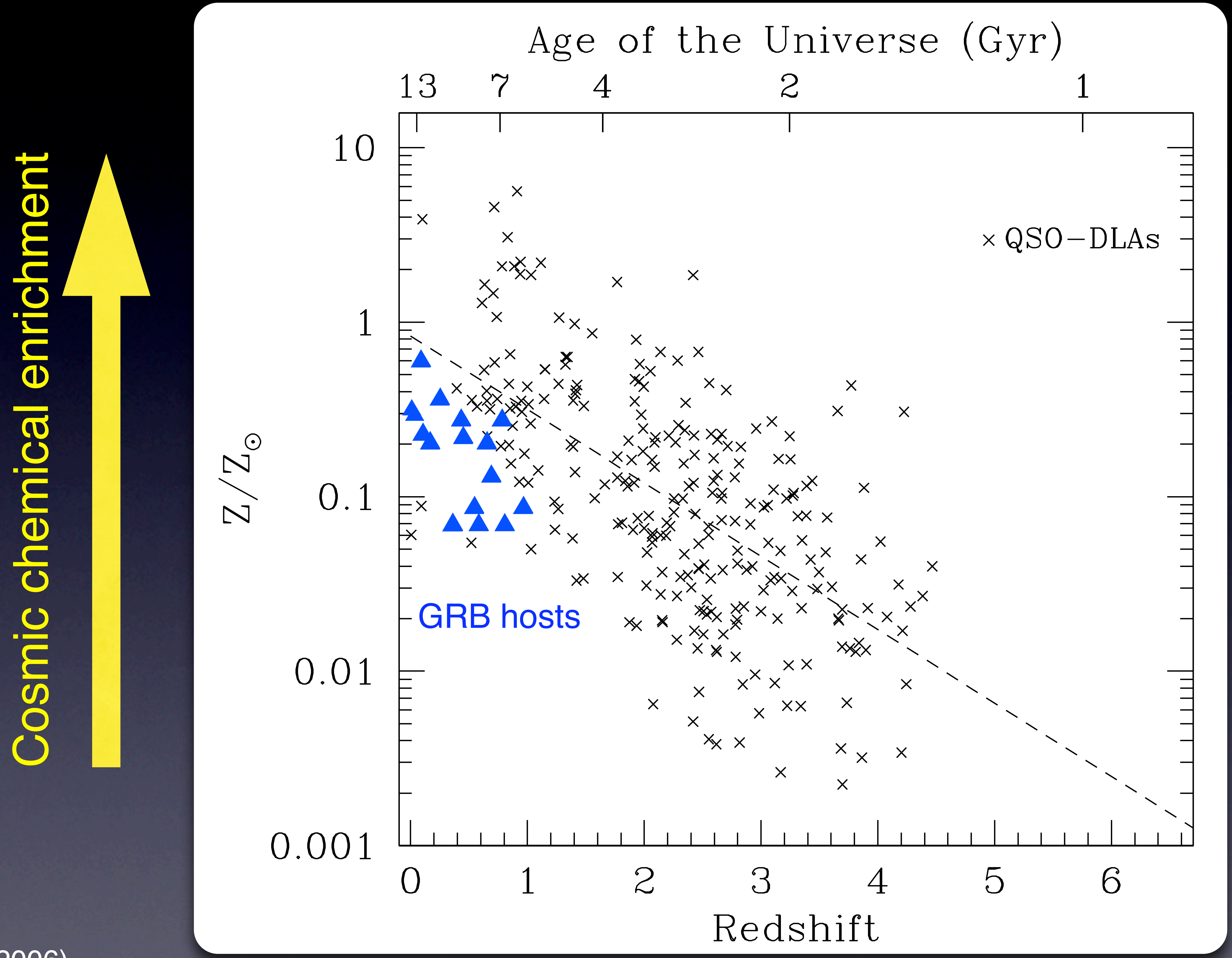

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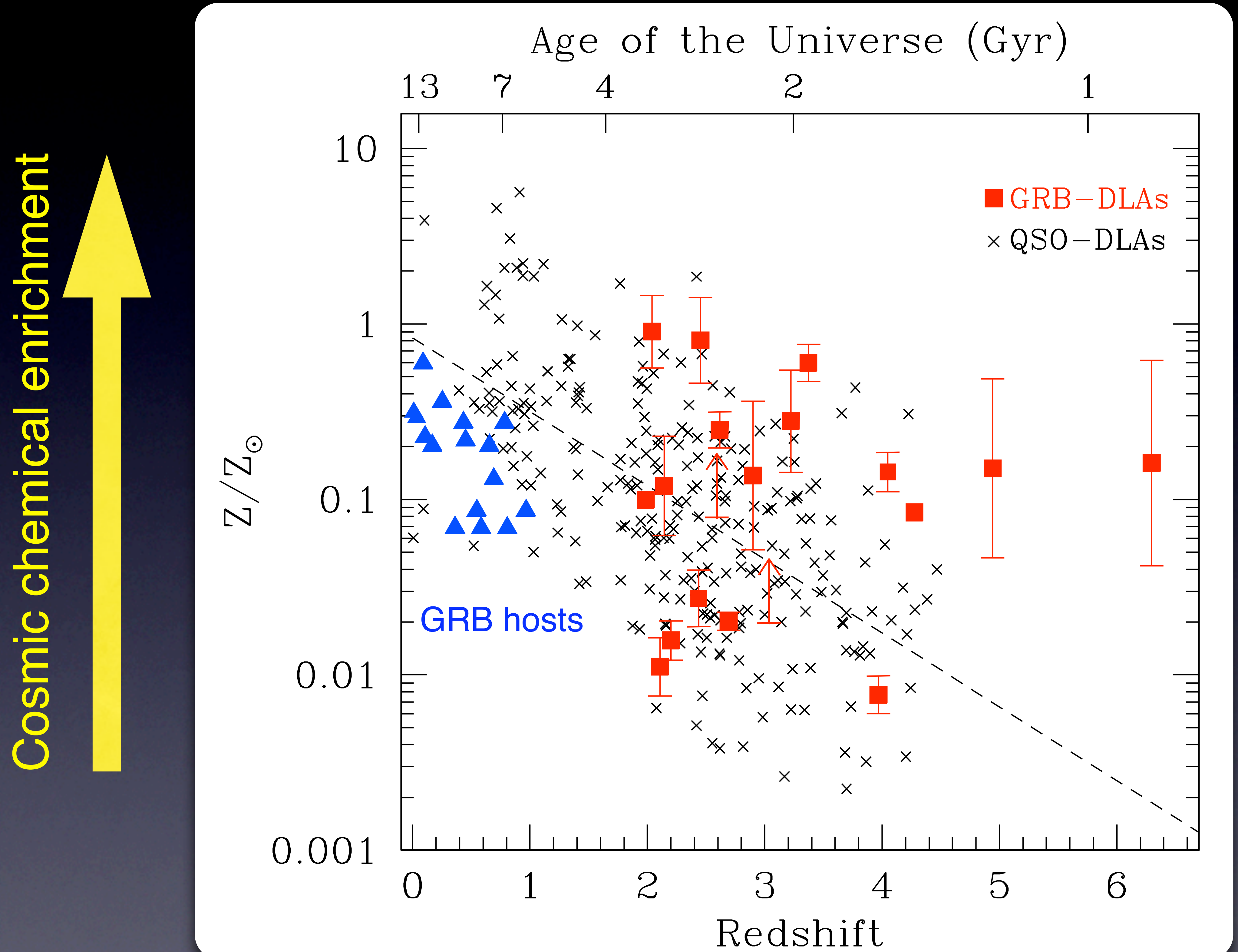

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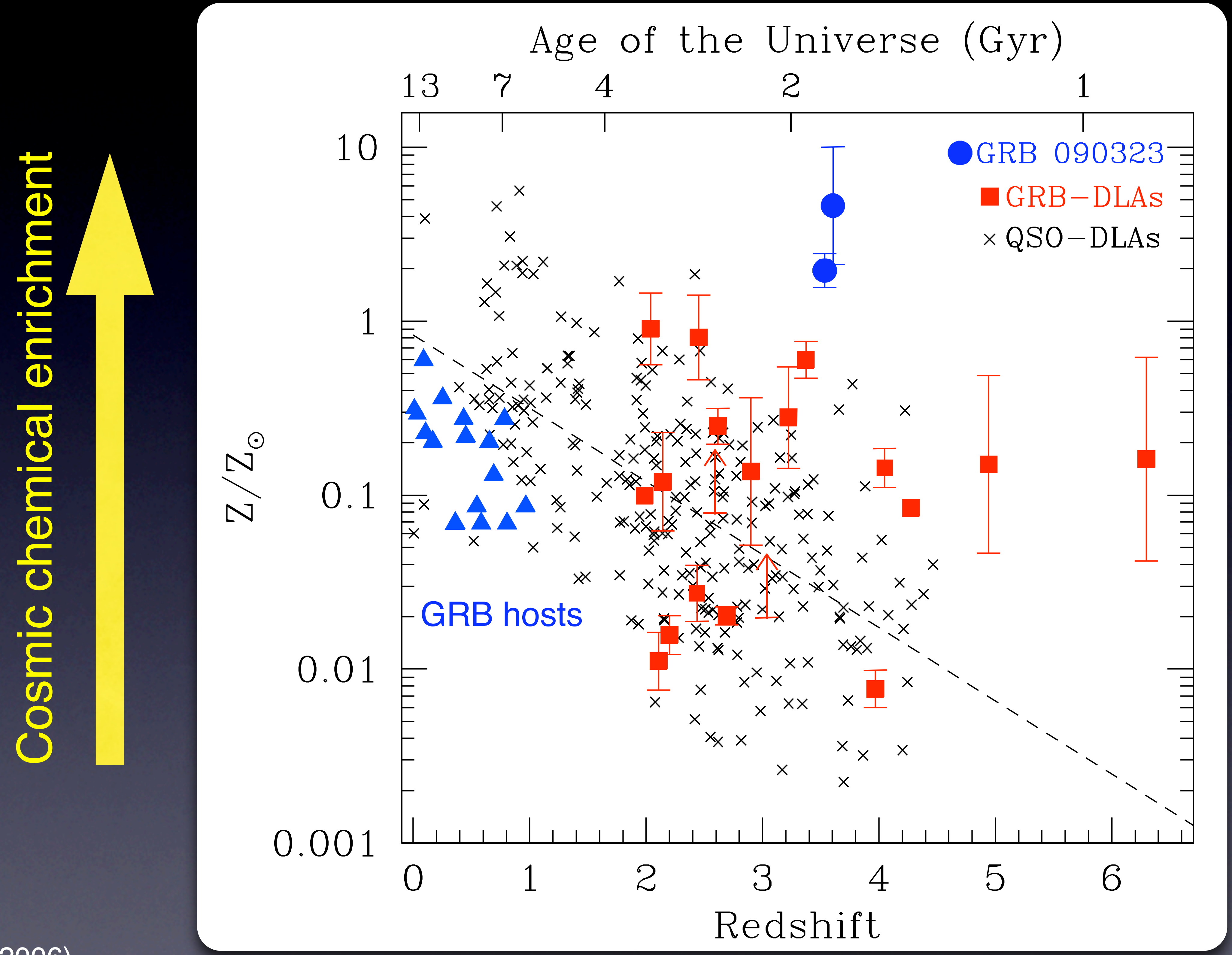

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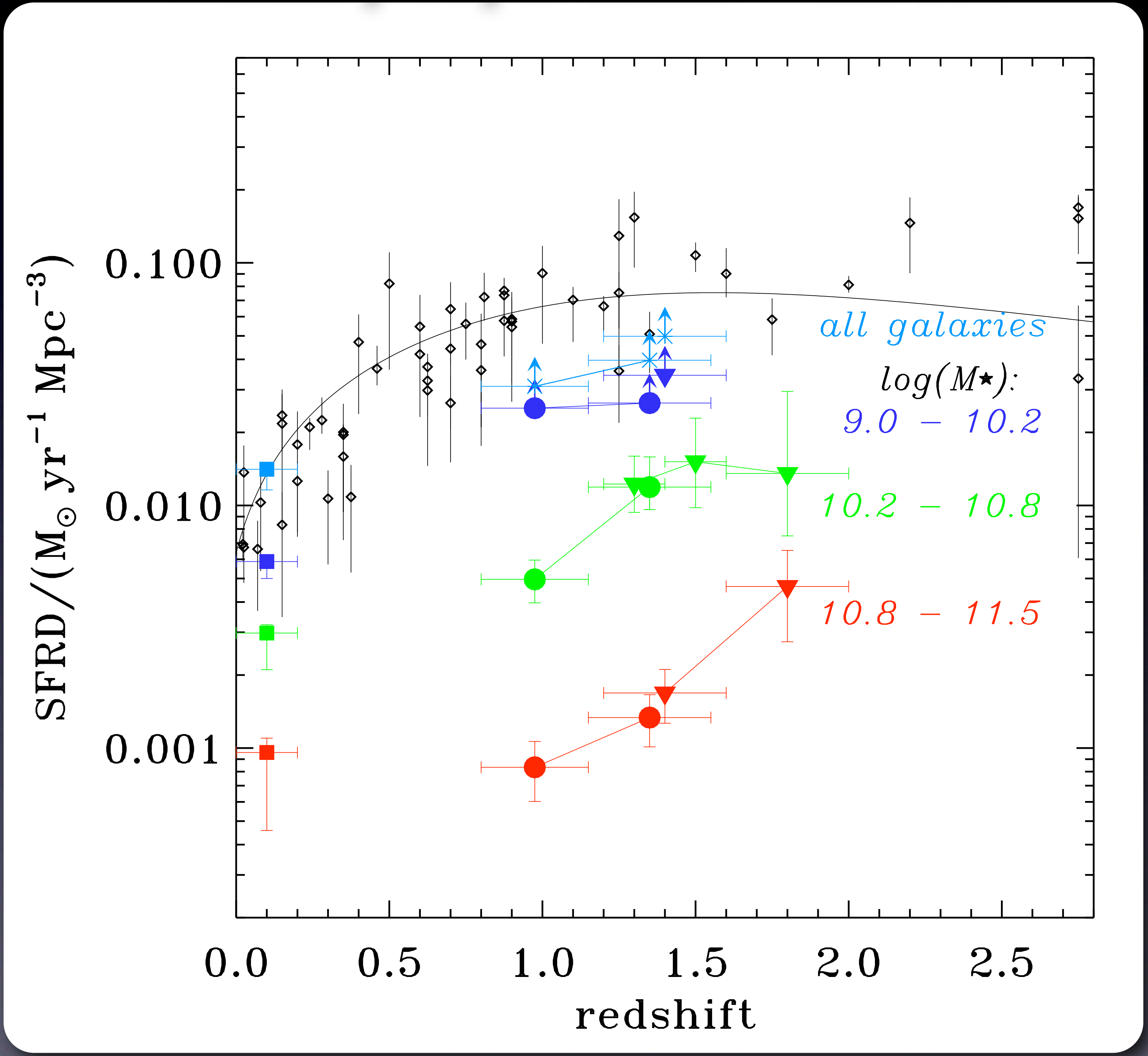
How can we relate the GRB-host population to galaxy formation & evolution?

The Galaxy Evolution context

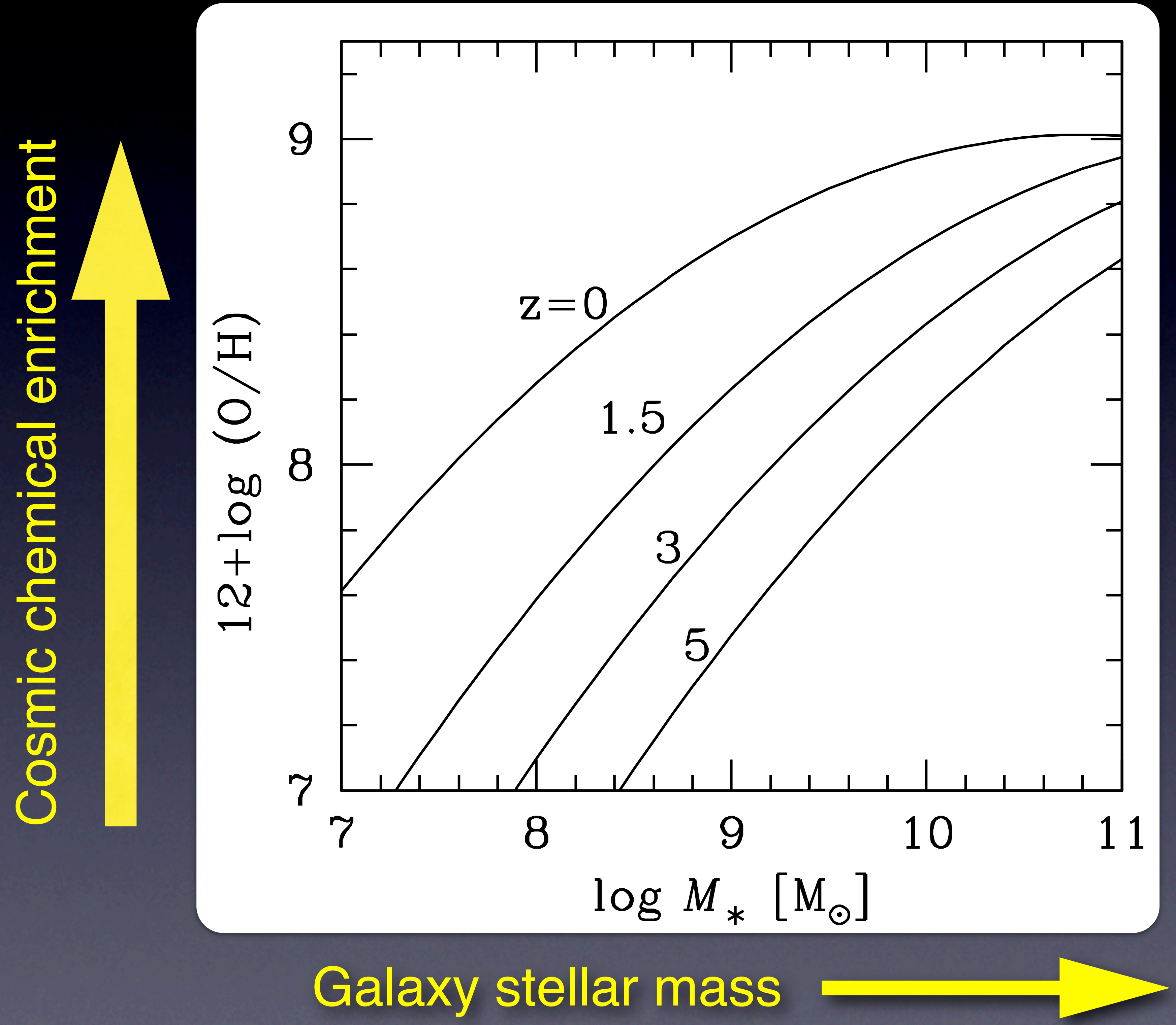
Madau plot per stellar-mass bin



Juneau et al. (2005)

The Galaxy Evolution context

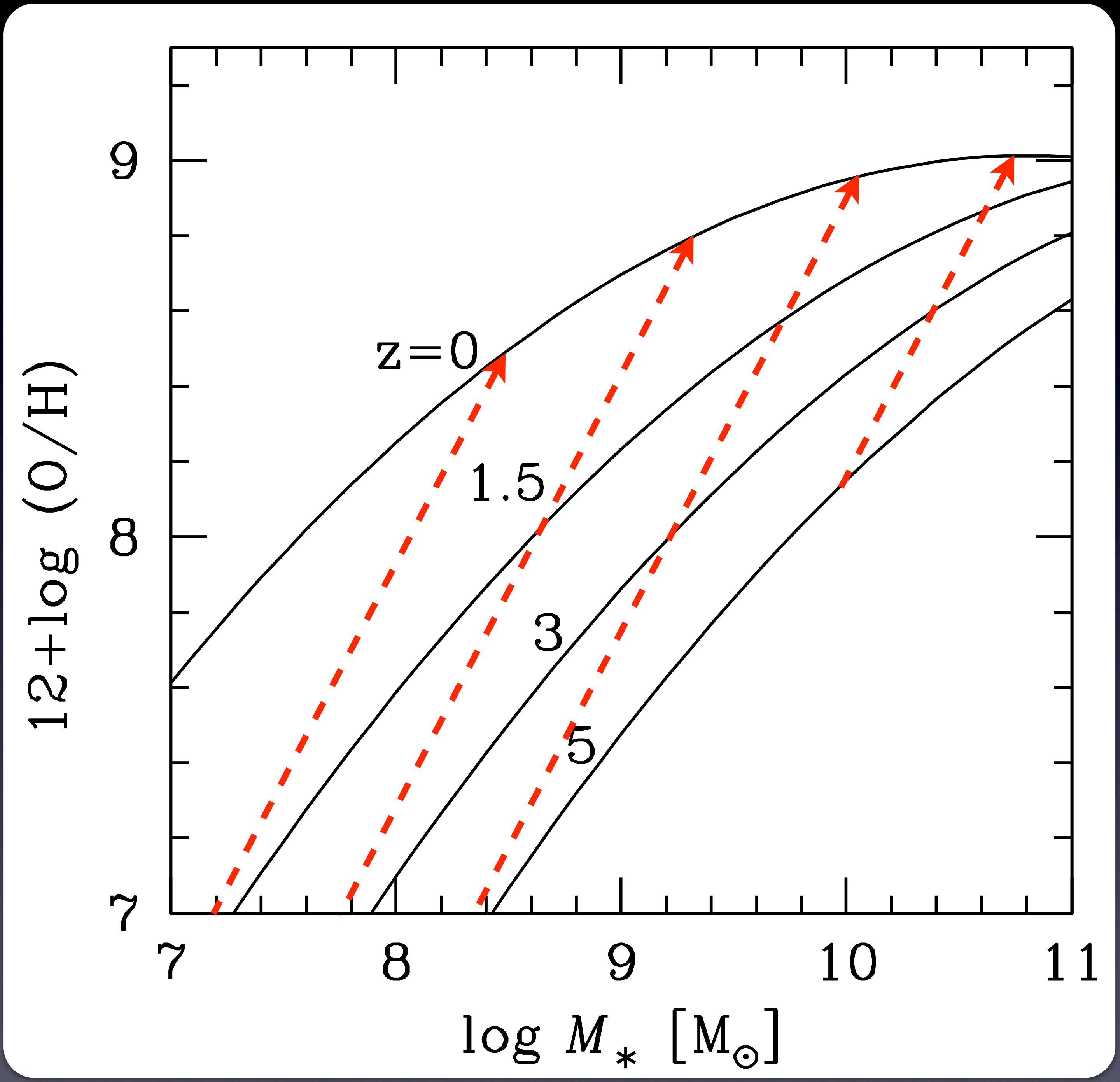
Mass–metallicity relation



Savaglio, Glazebrook, Le Borgne, et al. (2005)
(see also Tremonti et al. ’04, Erb et al. ’06, Maiolino et al. ’08)

The Galaxy Evolution context

Mass–metallicity relation

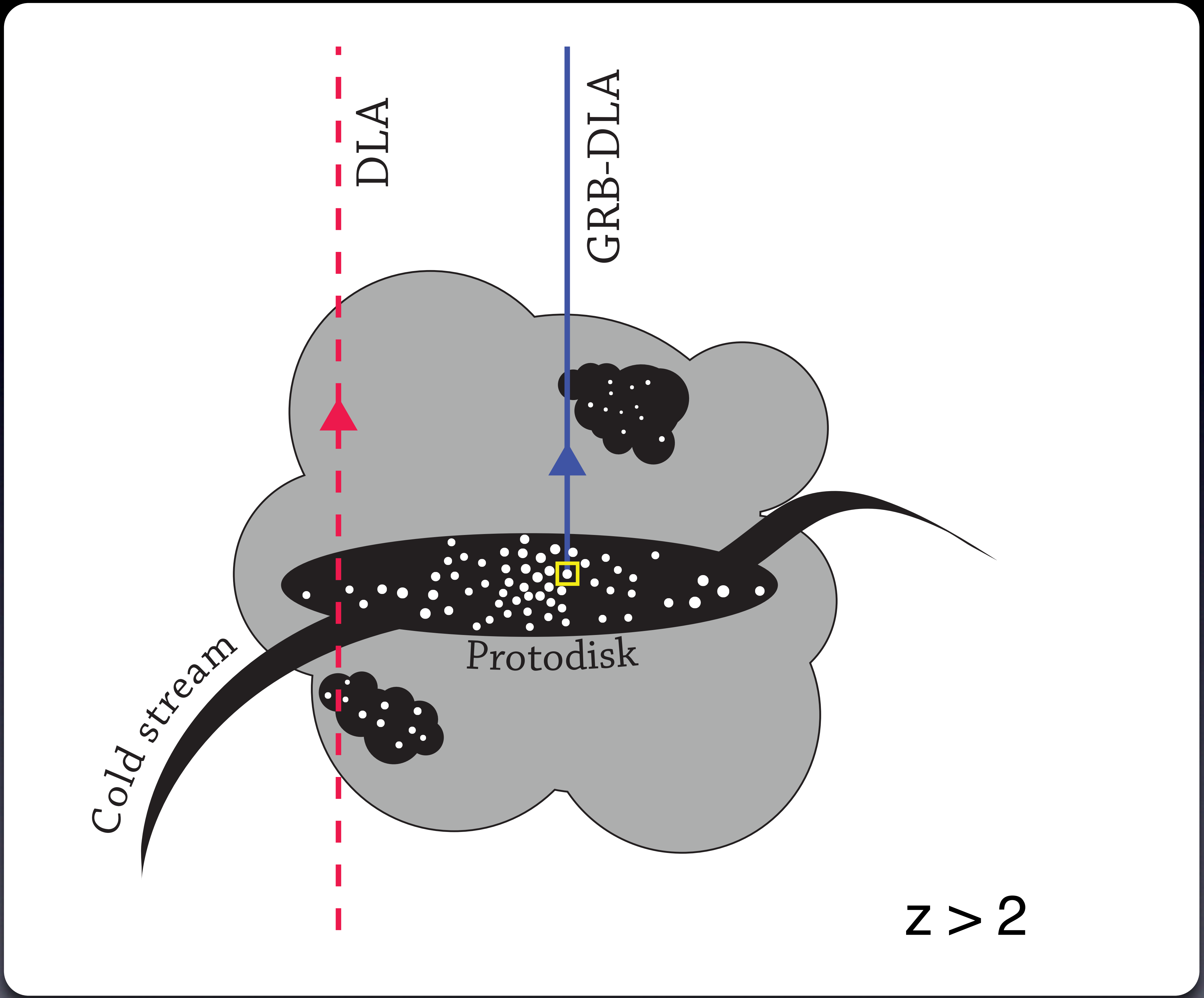


Cosmic chemical enrichment

Galaxy stellar mass

Savaglio, Glazebrook, Le Borgne, et al. (2005)
(see also Tremonti et al. ’04, Erb et al. ’06, Maiolino et al. ’08)

GRB-DLAs vs. QSO-DLAs



Pontzen et al. (2010)
(see also Fynbo et al. 2008)

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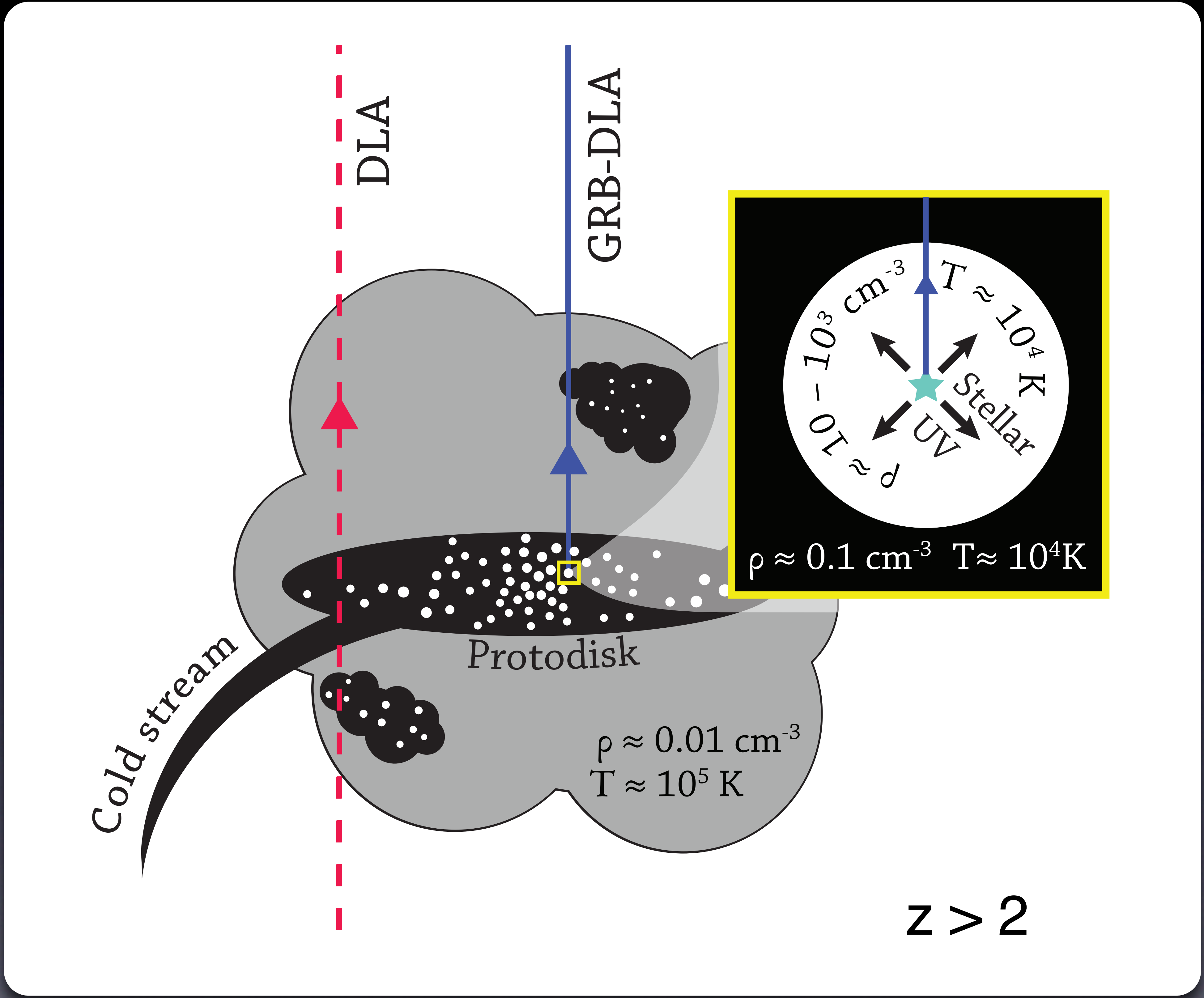

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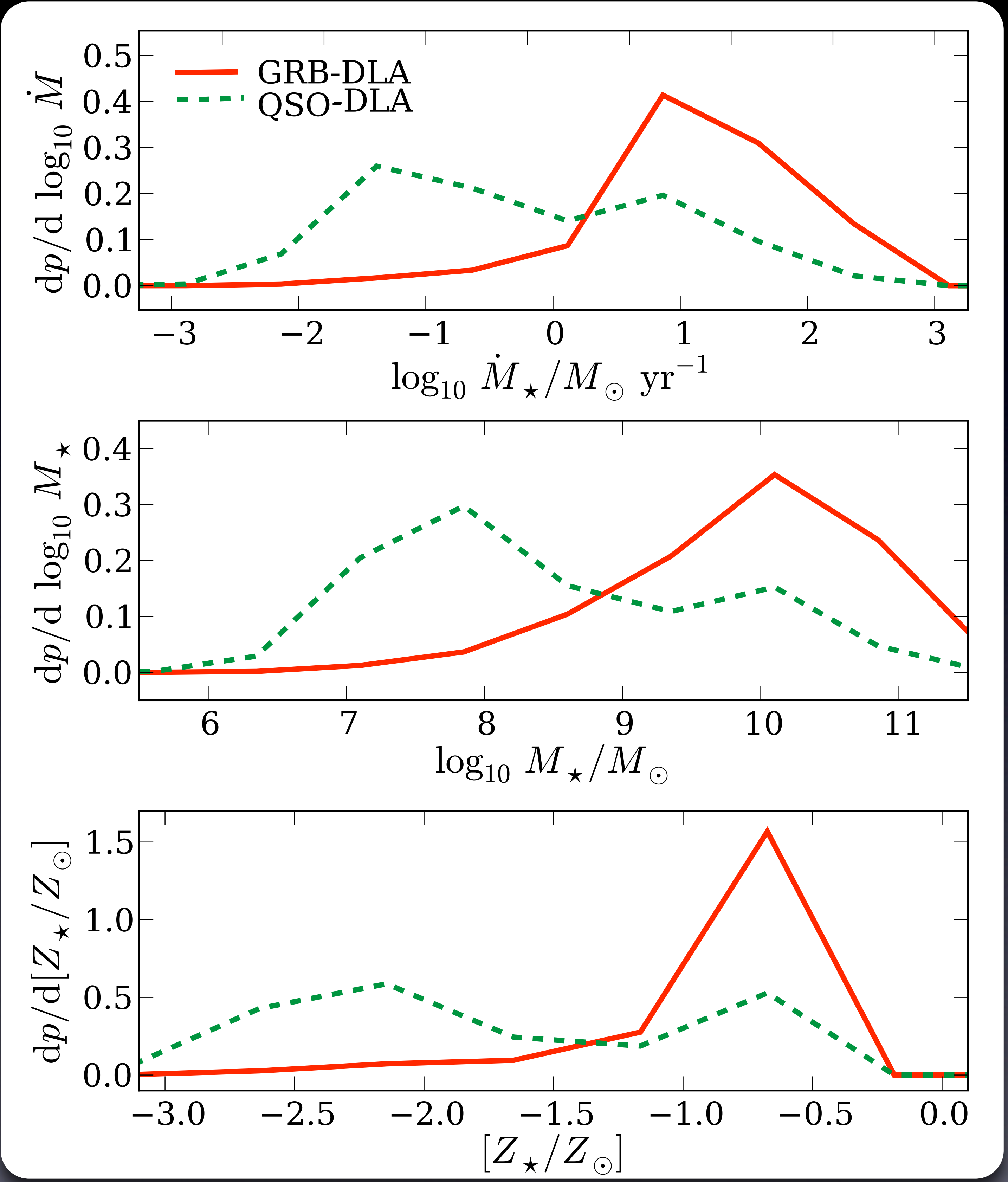

Pontzen et al. (2009)

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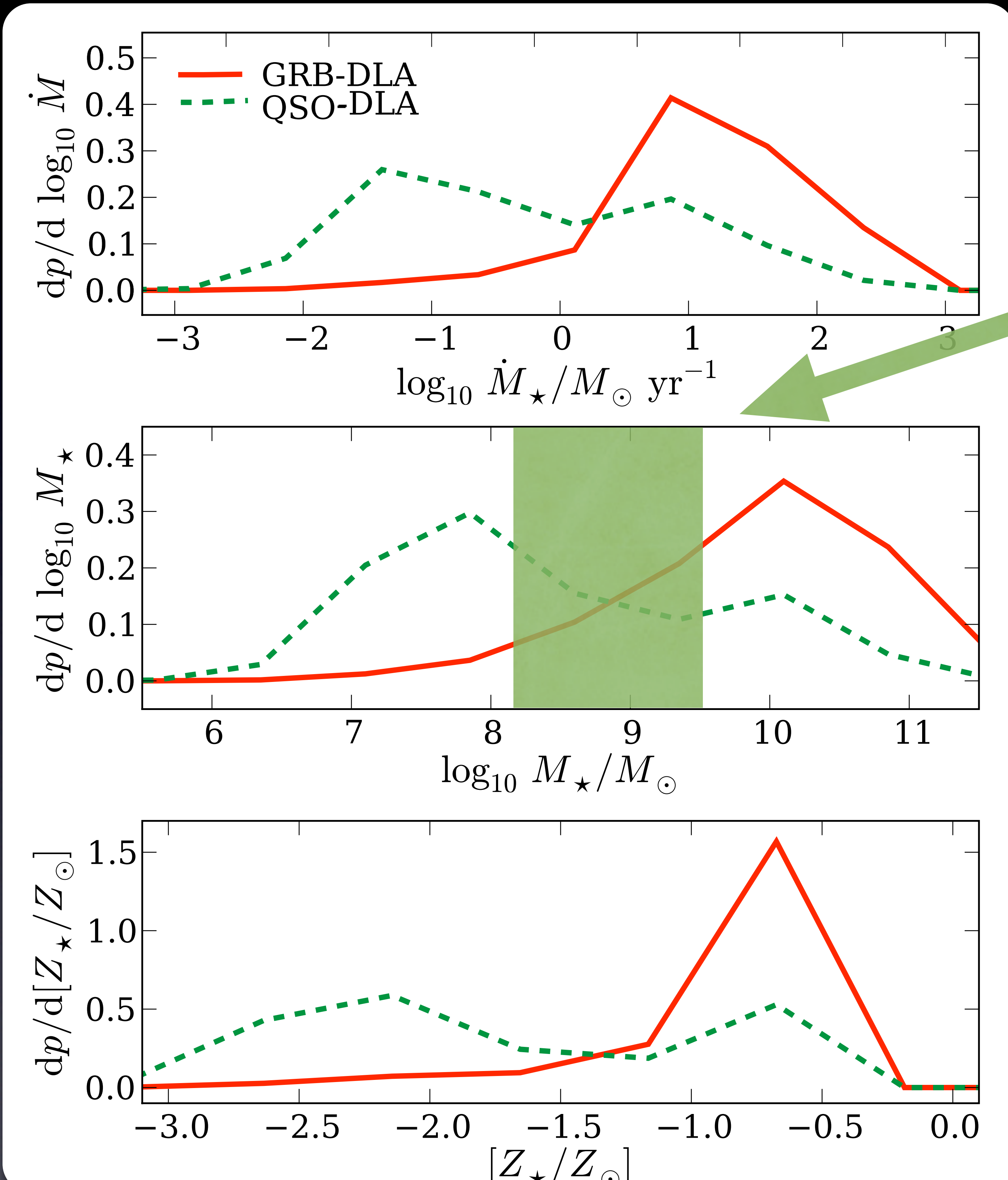
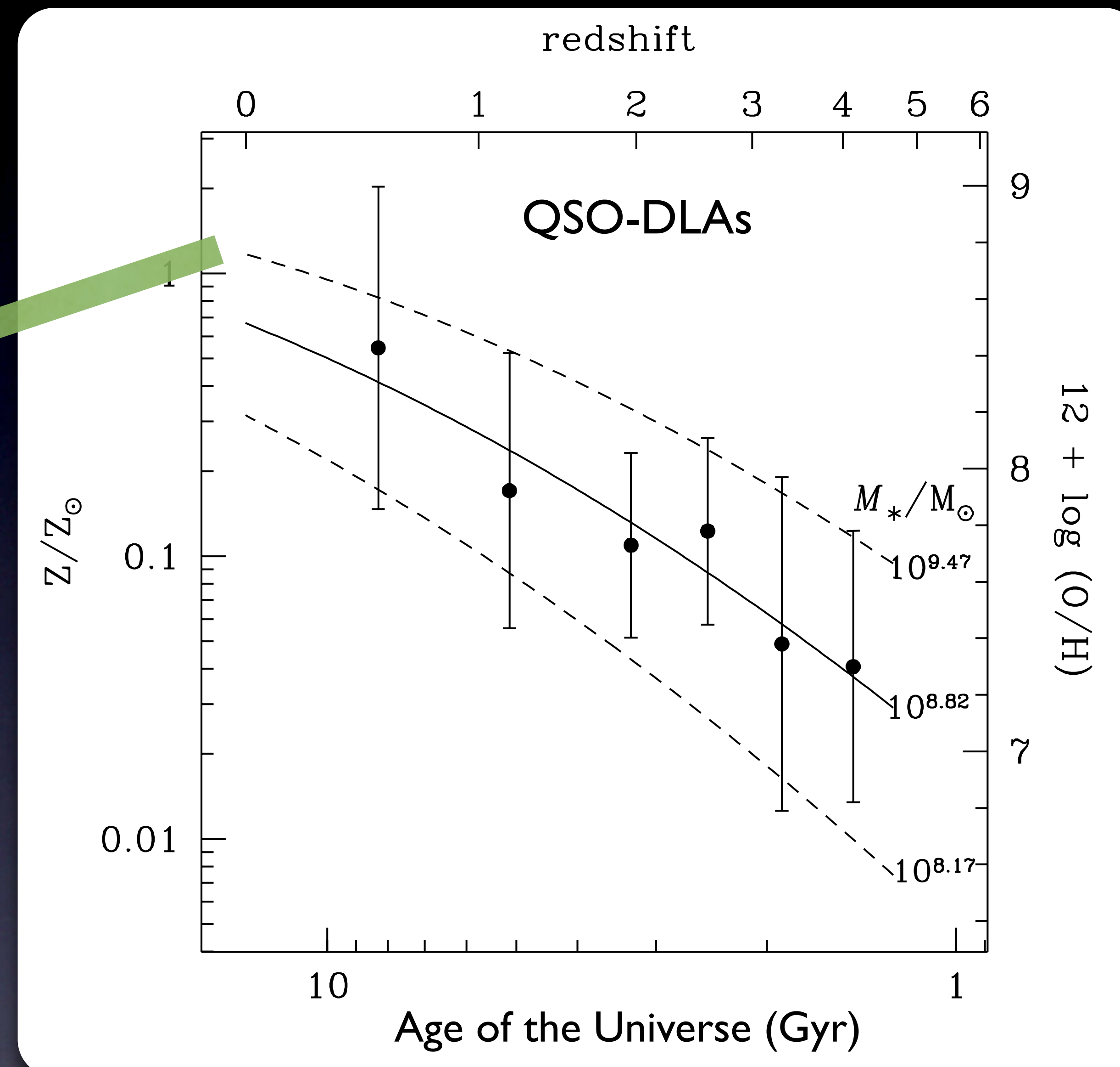


Pontzen et al. (2009)



Savaglio et al. (2005)

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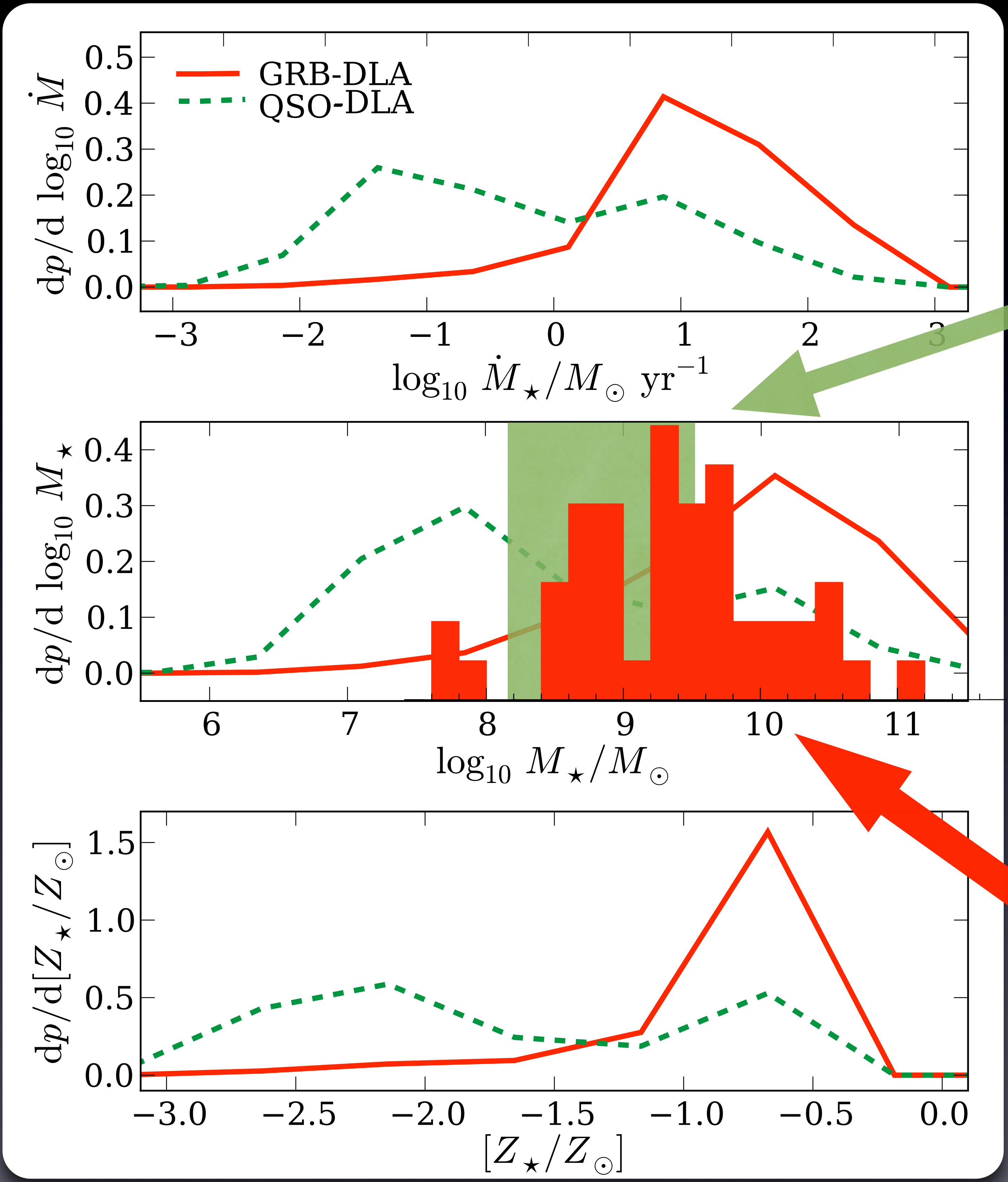
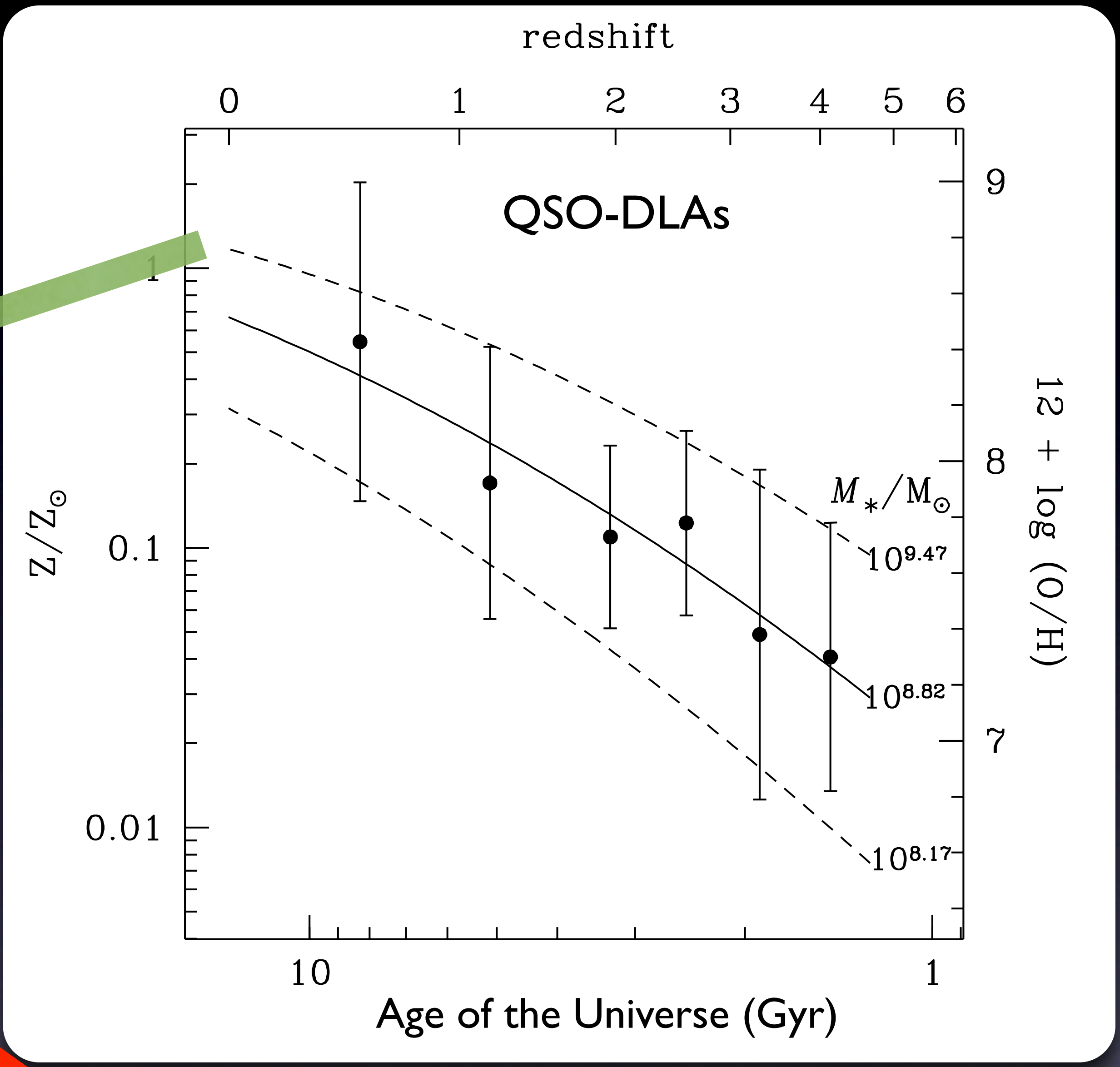


Pontzen et al. (2009)

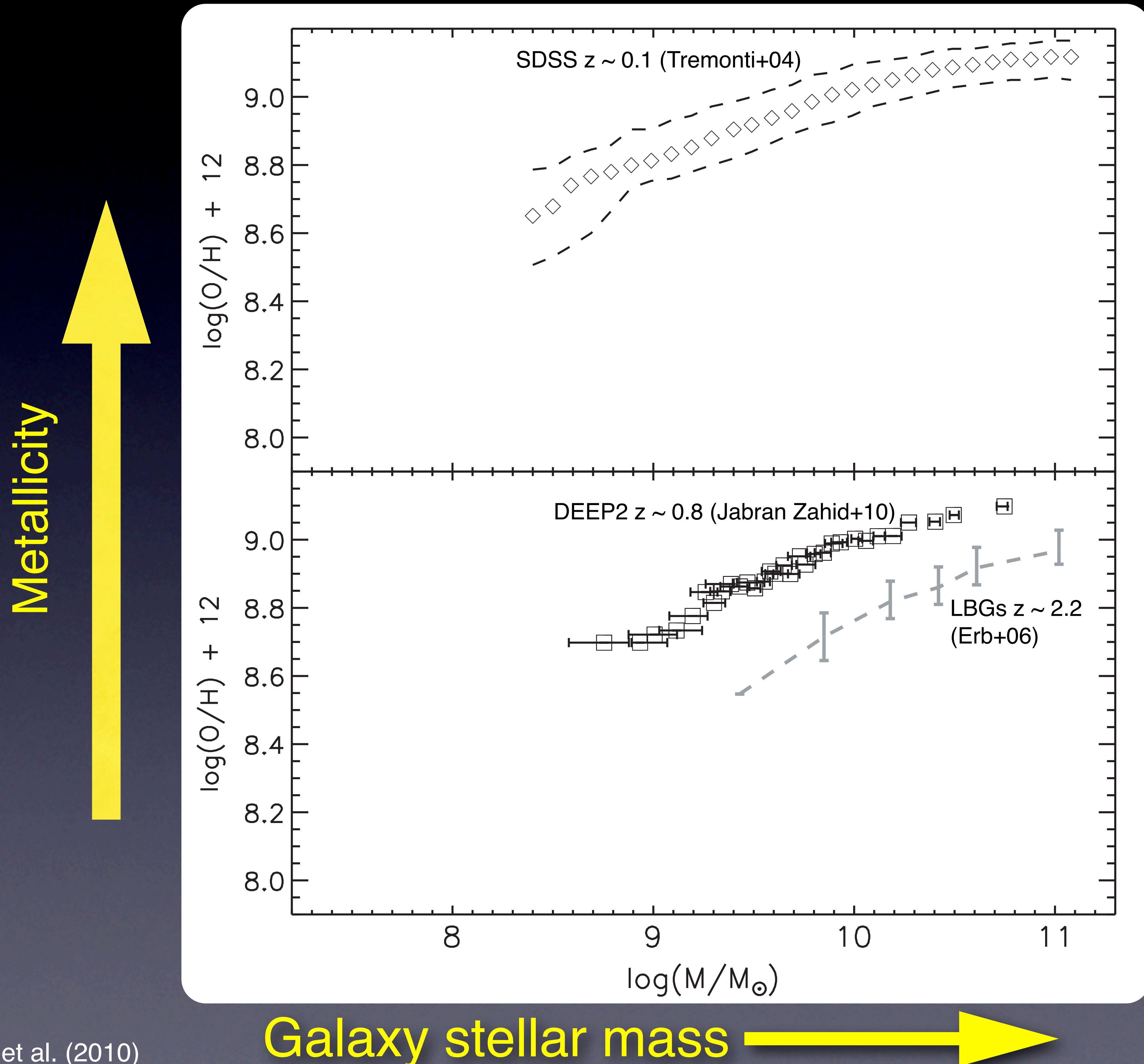


Savaglio et al. (2005)

GRB hosts $0 < z < 2.4$

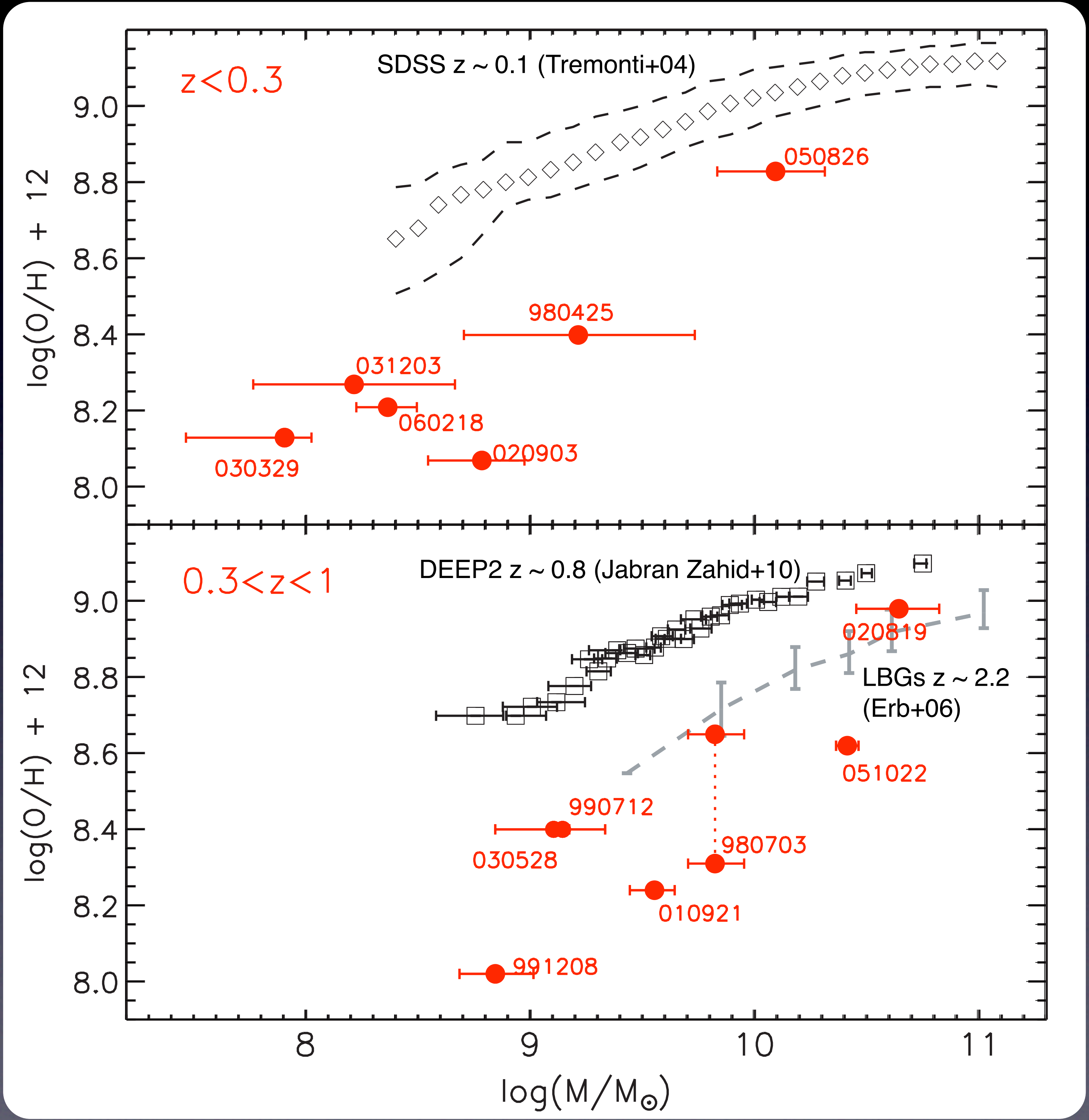
(Savaglio, Glazebrook, Le Borgne 2009)

Mass-Metallicity relation



Levesque et al. (2010)

Mass-Metallicity relation

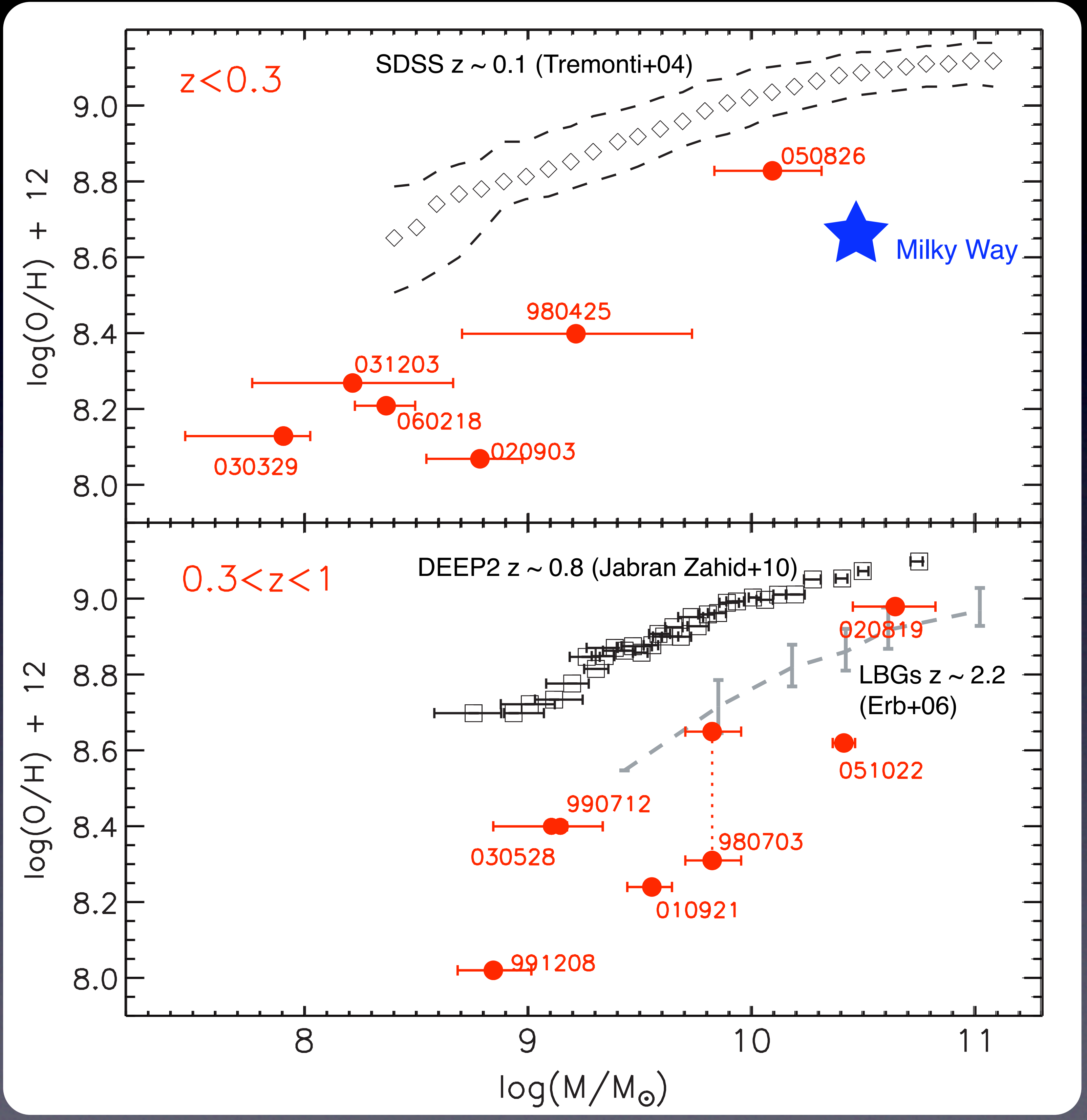


Metallicity

Galaxy stellar mass

Levesque et al. (2010)

Mass-Metallicity relation



Metallicity

Galaxy stellar mass

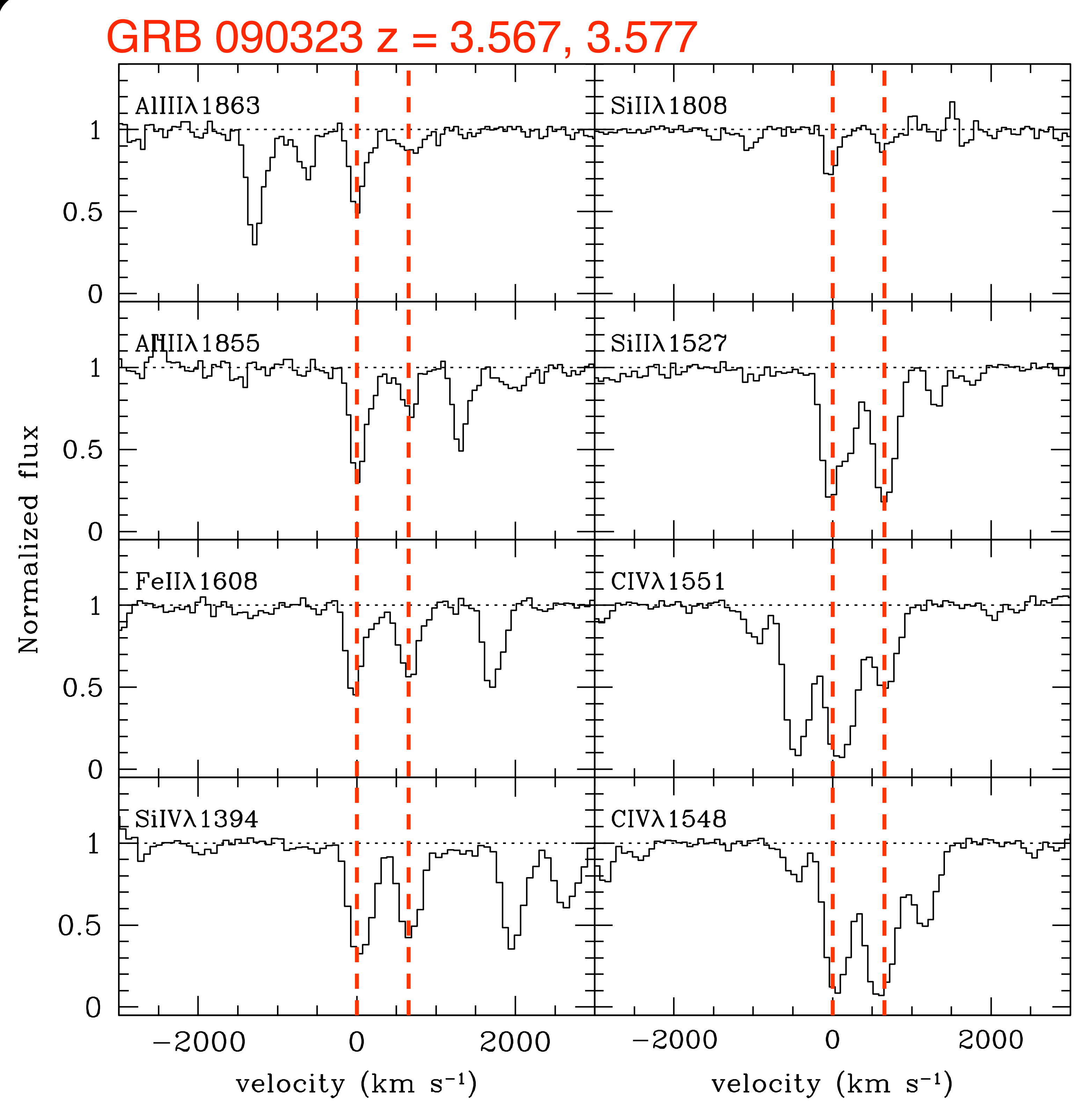
Levesque et al. (2010)

Related publications:

Campisi, M. A., De Lucia, G., Li, L., Mao, S., & Kang, X. 2009, MNRAS, 400, 1613
Chen, H.-W. et al. 2009, ApJ, 691, 152
Chisari, N. E., Tissera, P. B., & Pellizza, L. J. 2010, MNRAS, submitted arXiv:1005.4036
Fynbo, J. P. U.; Prochaska J. X.; Sommer-Larsen J.; Dessauges-Zavadsky, M., Møller P. 2008, ApJ, 683, 321
Han, X. H., Hammer, F., Liang, Y. C., Flores, H., Rodrigues, M., Hou, J. L., Wei, J. Y. 2010, A&A, 514, 24
Kocevski, D., West, A. A., & Modjaz, M. 2009, ApJ, 702, 377
Kretchmer, C., & Ravindranath, S. 2007, ApJ, 654, 172
Levesque, E. M., Kewley, L. J., Graham, J. F., & Fruchter, A. S. 2010, ApJ, 712, L26
Modjaz, M., et al. 2008, AJ, 135, 1136
Niino, Y., et al. 2010, submitted, arXiv:1006.5033

Is there a connection between sub-mm galaxies and GRB hosts ?

Double absorbers in GRB afterglows



Savaglio, Rau, Greiner, Krühler et al. (Science, sub.)

Double absorbers in GRB afterglows

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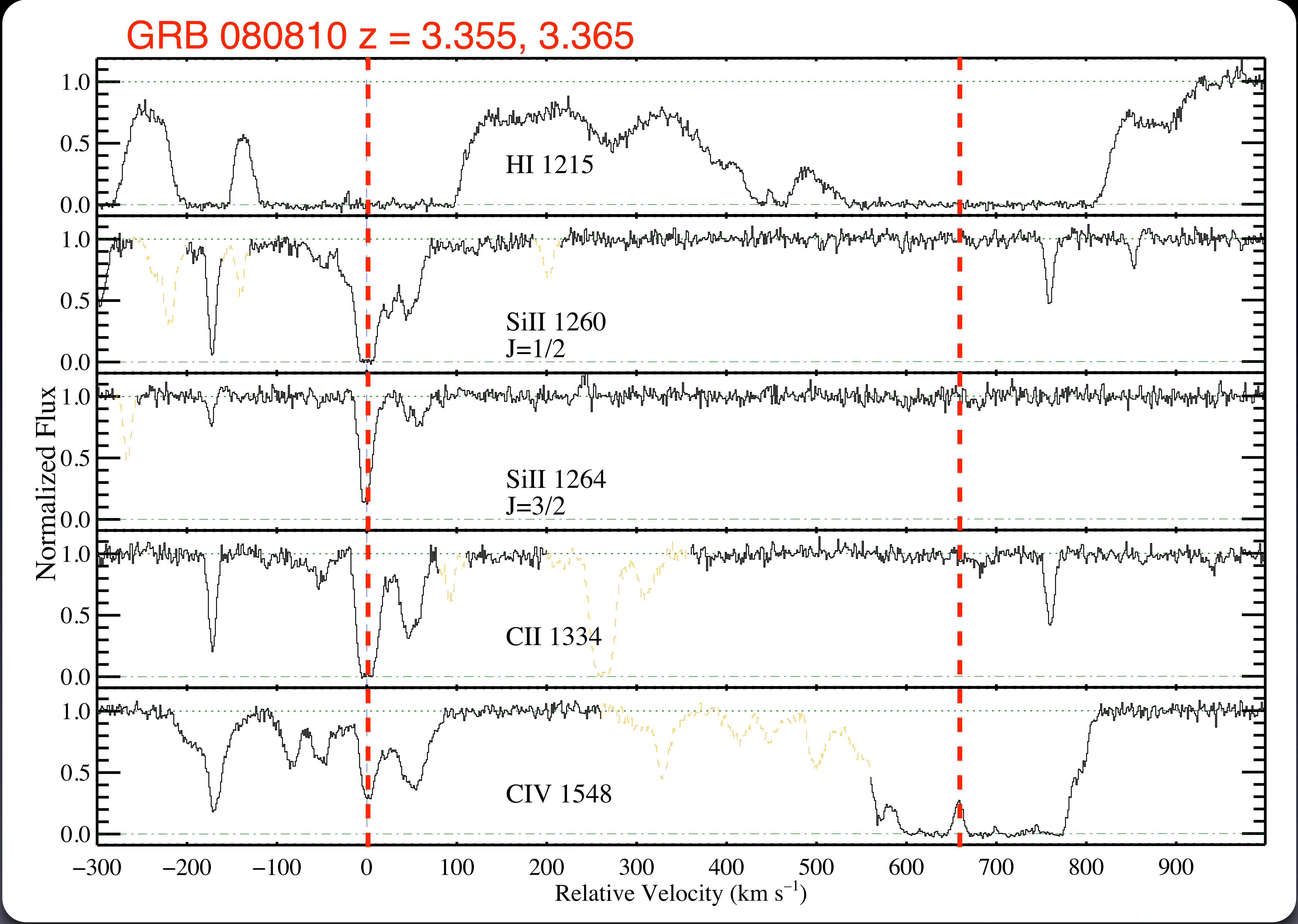

Page et al. (2009)

Double absorbers in GRB afterglows

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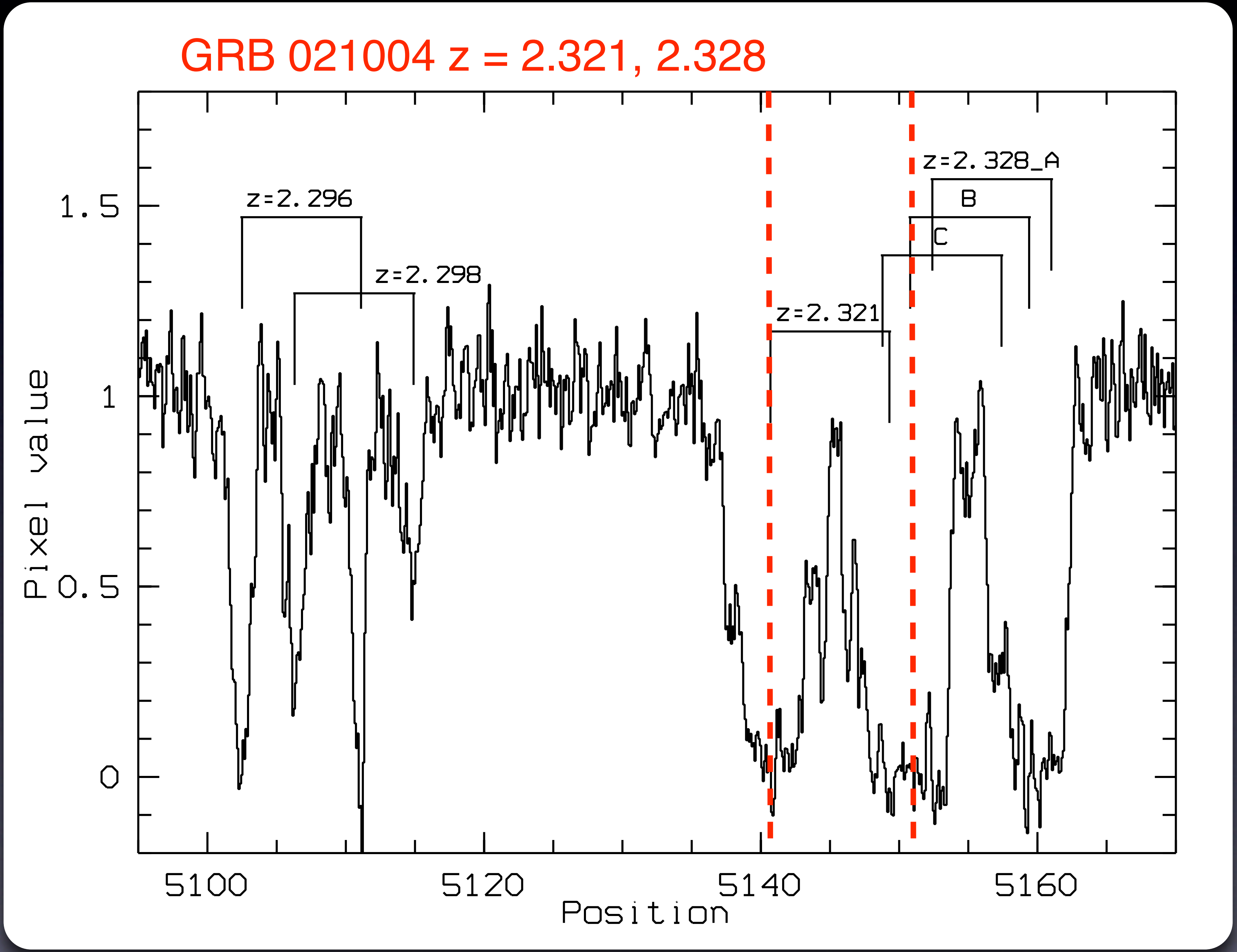
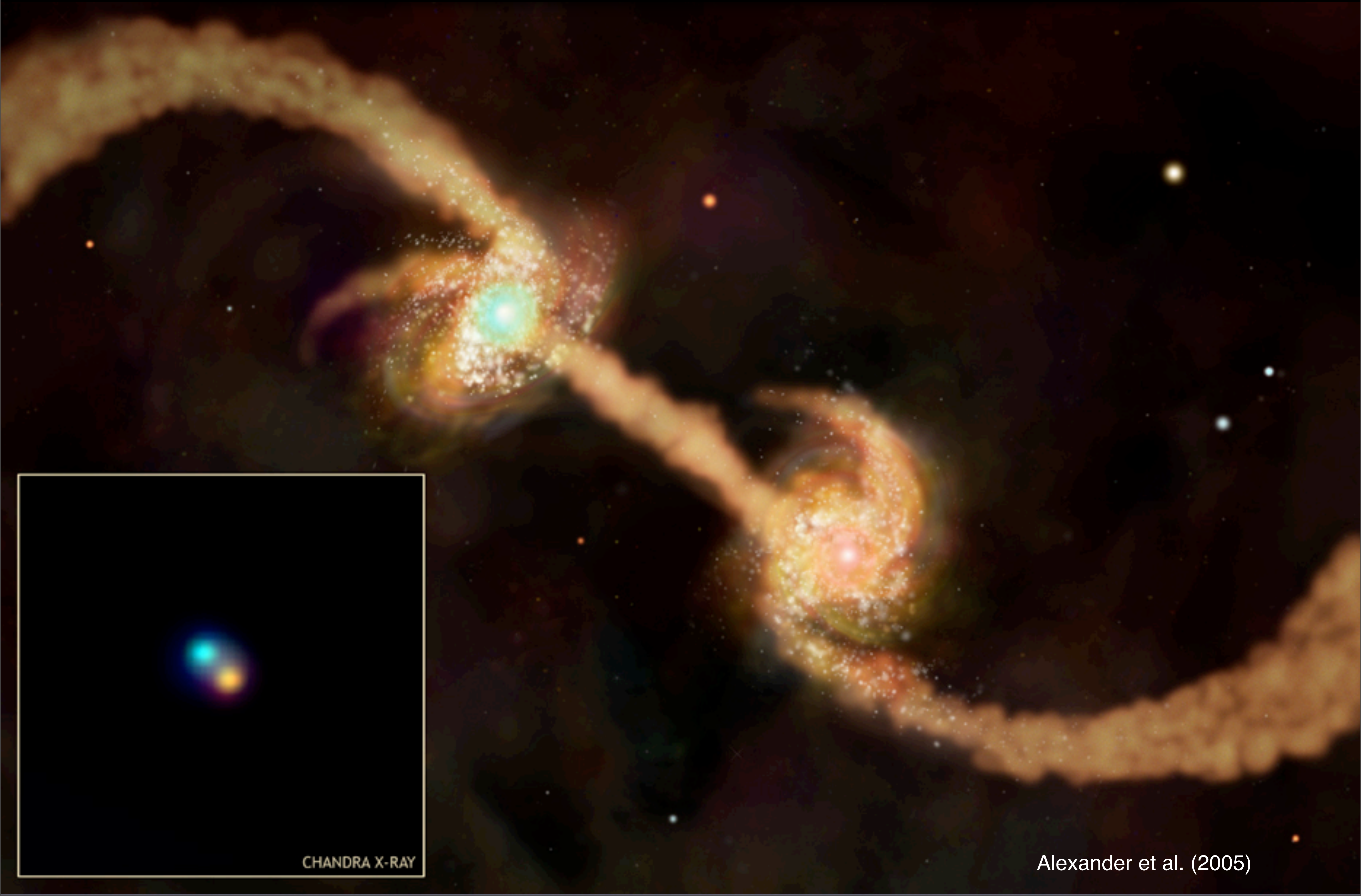


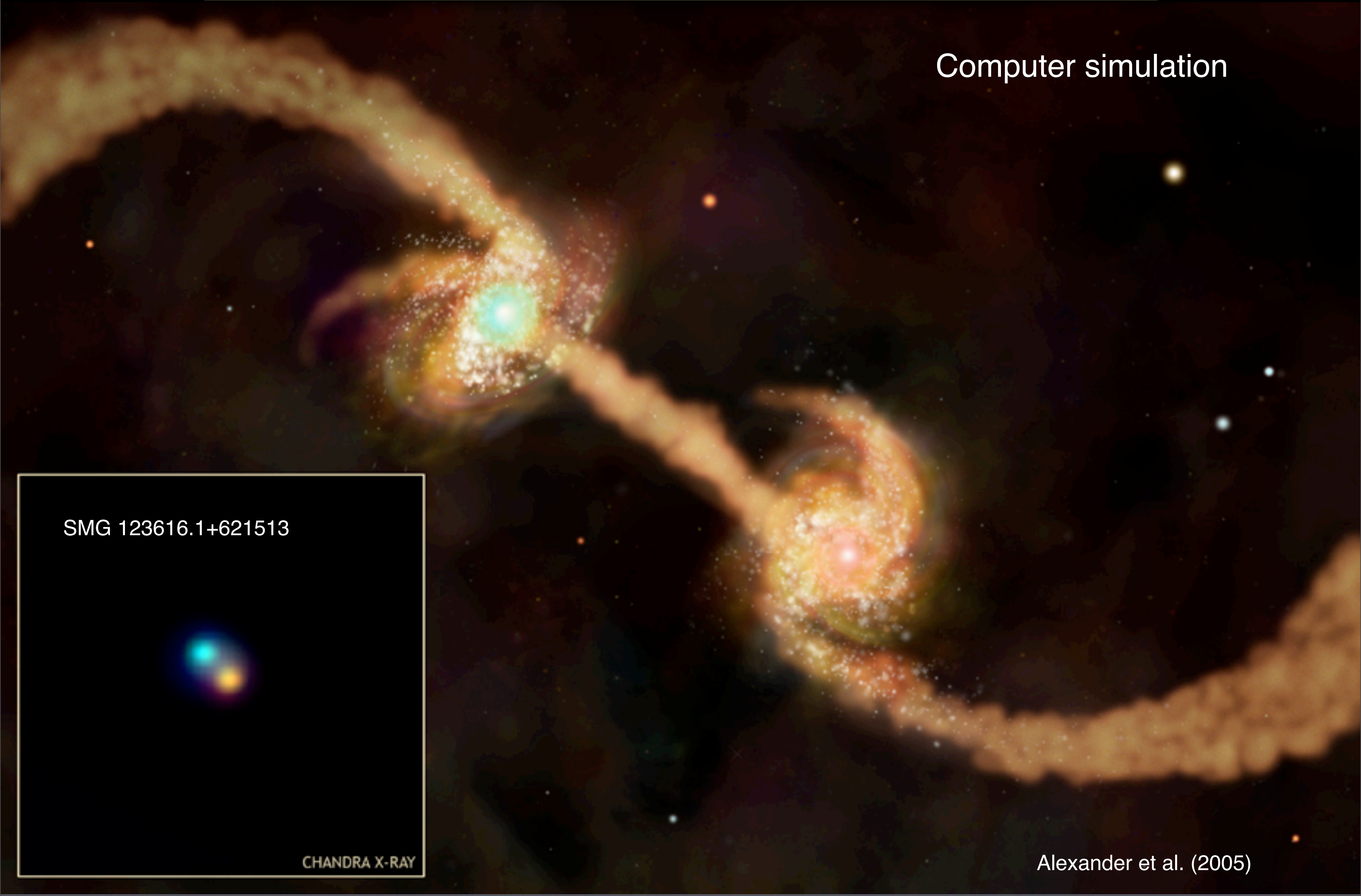
Fiore et al. (2005)

Sub-millimeter Galaxies

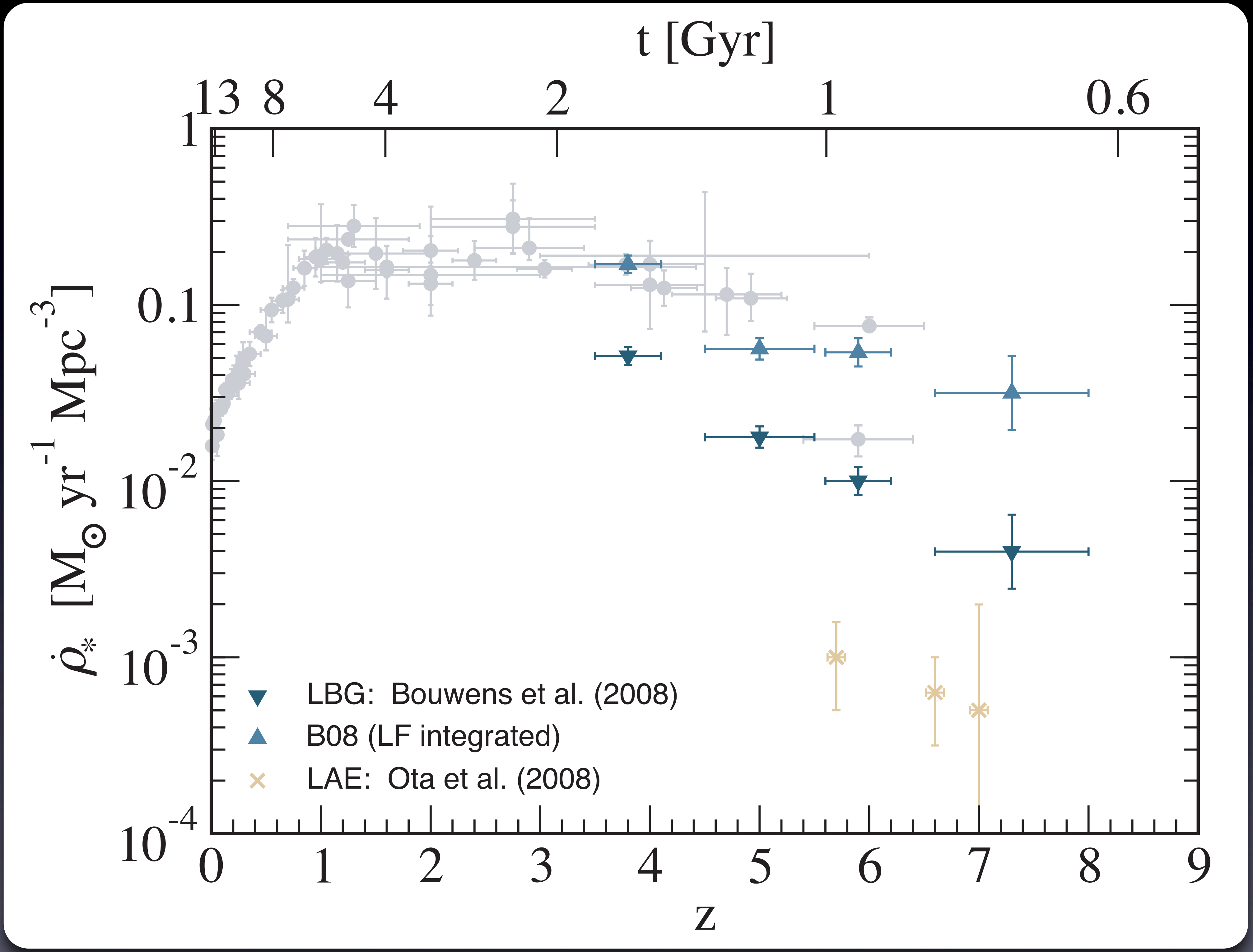


Alexander et al. (2005)

Sub-millimeter Galaxies



Star Formation Rate Density of the Universe



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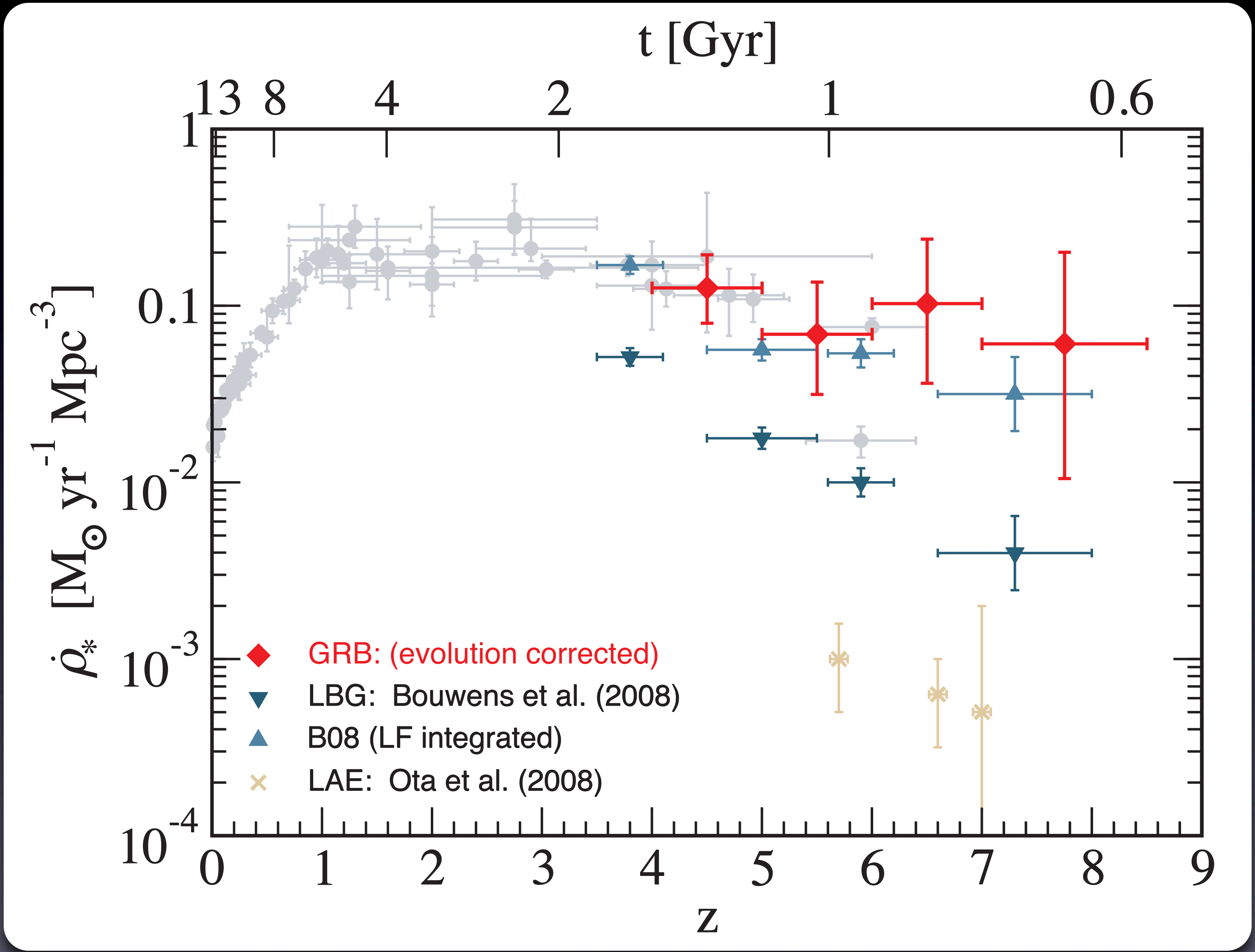
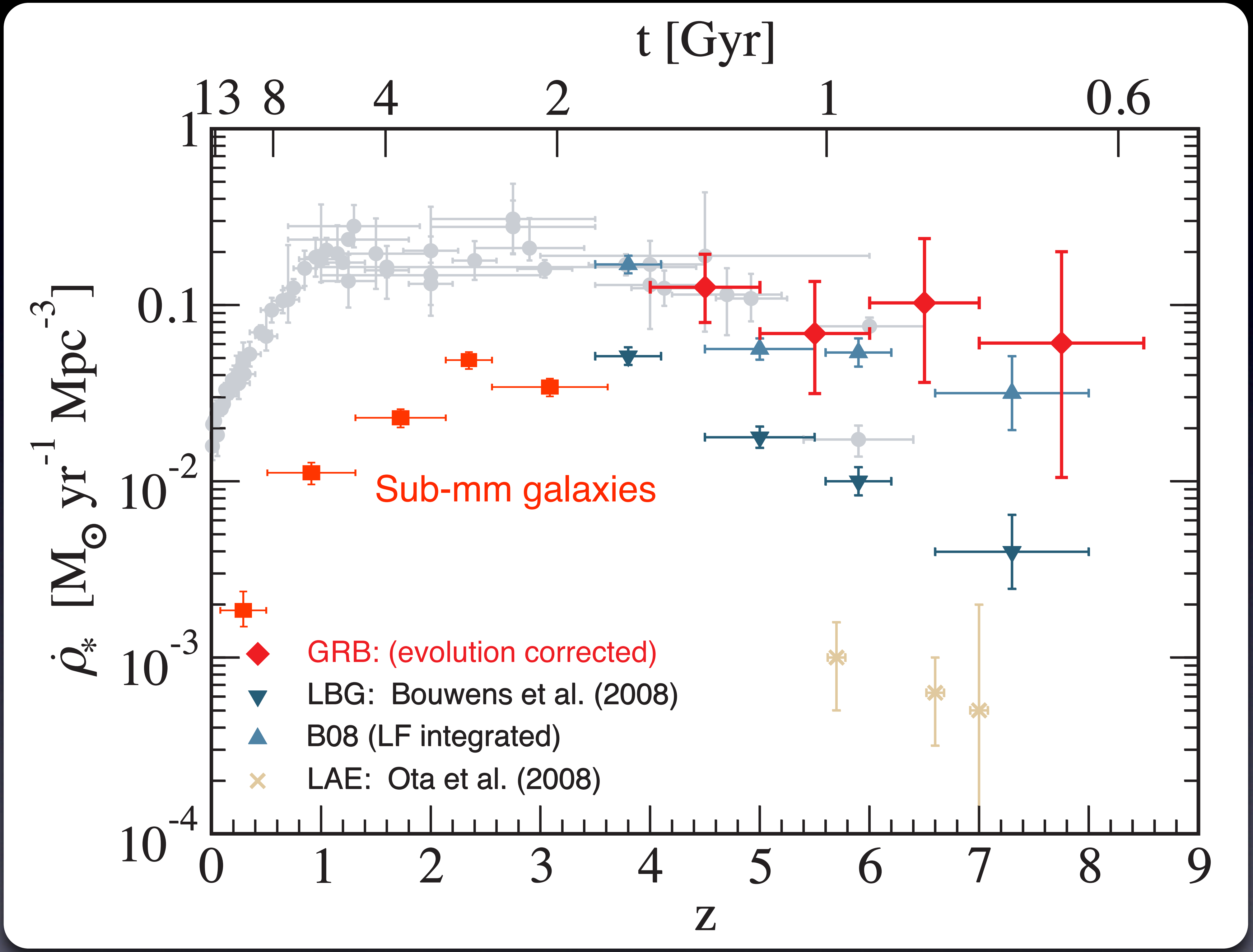


Chary, Berger, & Cowie (2007)
Yüksel, Kistler, Beacom, & Hopkins (2008)
Kistler et al. (2009)

Star Formation Rate Density of the Universe



Chary, Berger, & Cowie (2007)
Yüksel, Kistler, Beacom, & Hopkins (2008)
Kistler et al. (2009)

Michałowski, Hjorth & Watson (2009)

Conclusions

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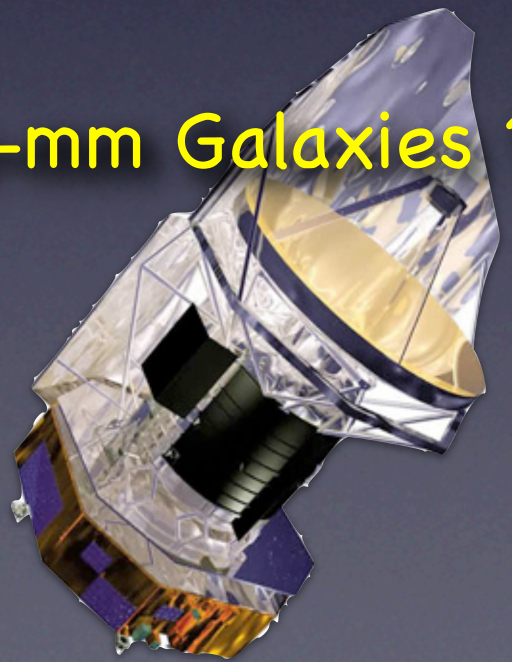

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