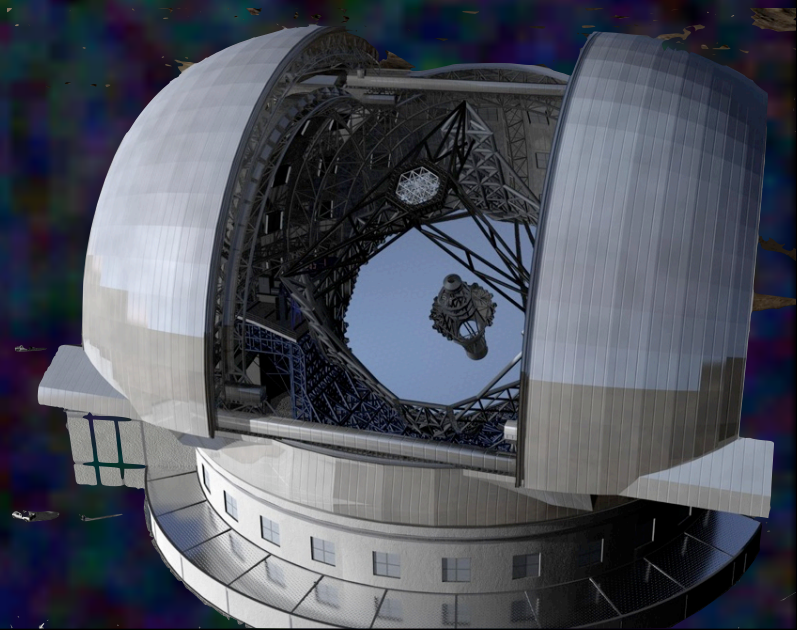
The Future of z > 7 Astronomy with Gamma-Ray Bursts

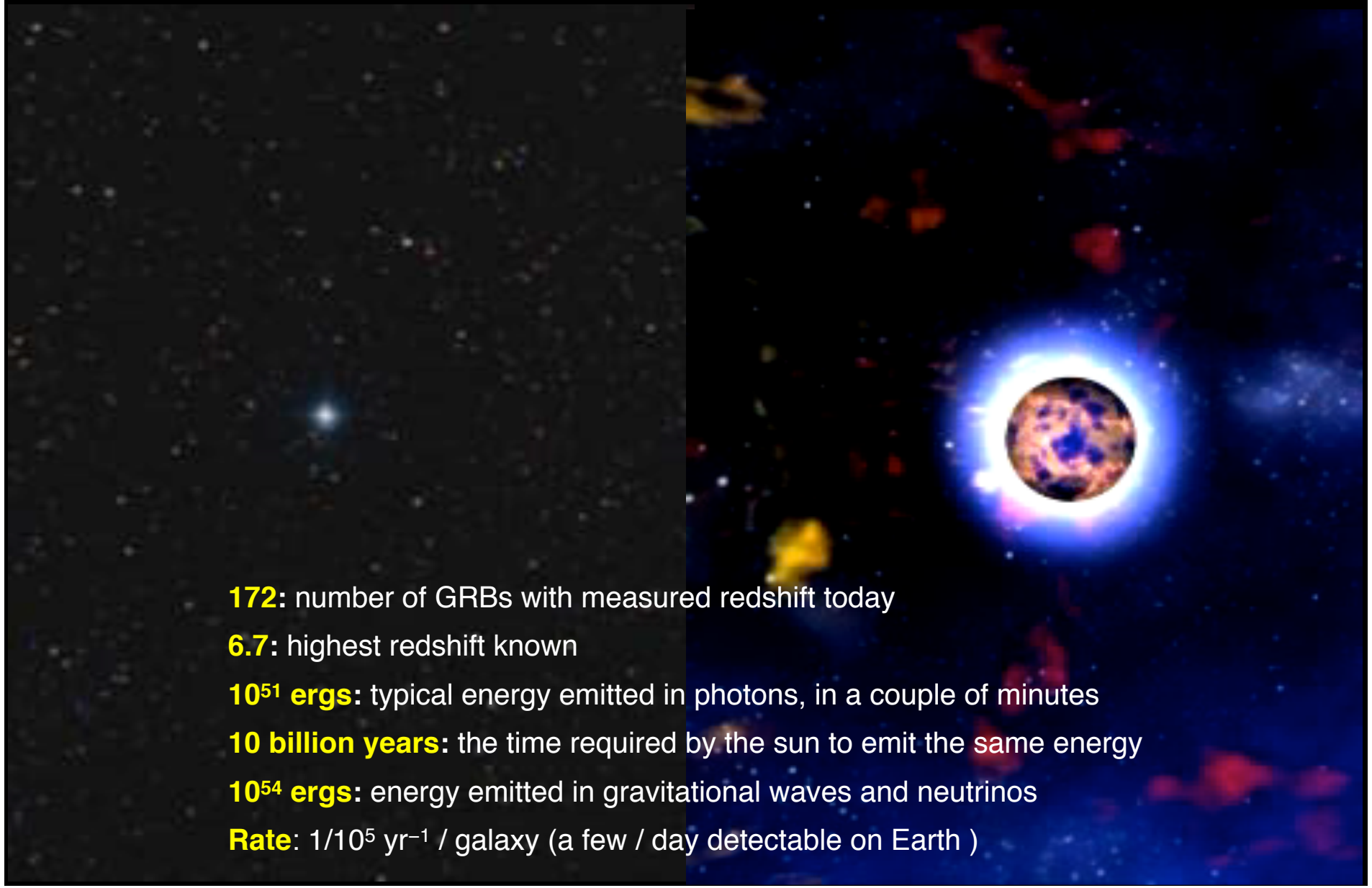
Sandra Savaglio
Max-Planck Institute for Extraterrestrial Physics



GRB 011121
redshift z = 0.362
3.98 Gyr ago

Long-duration Gamma-Ray Burst:
Core Collapse SN

Short-duration Gamma-Ray Burst:
Merger of Neutron Stars/Black Holes



172: number of GRBs with measured redshift today

6.7: highest redshift known

10^{51} ergs: typical energy emitted in photons, in a couple of minutes

10 billion years: the time required by the sun to emit the same energy

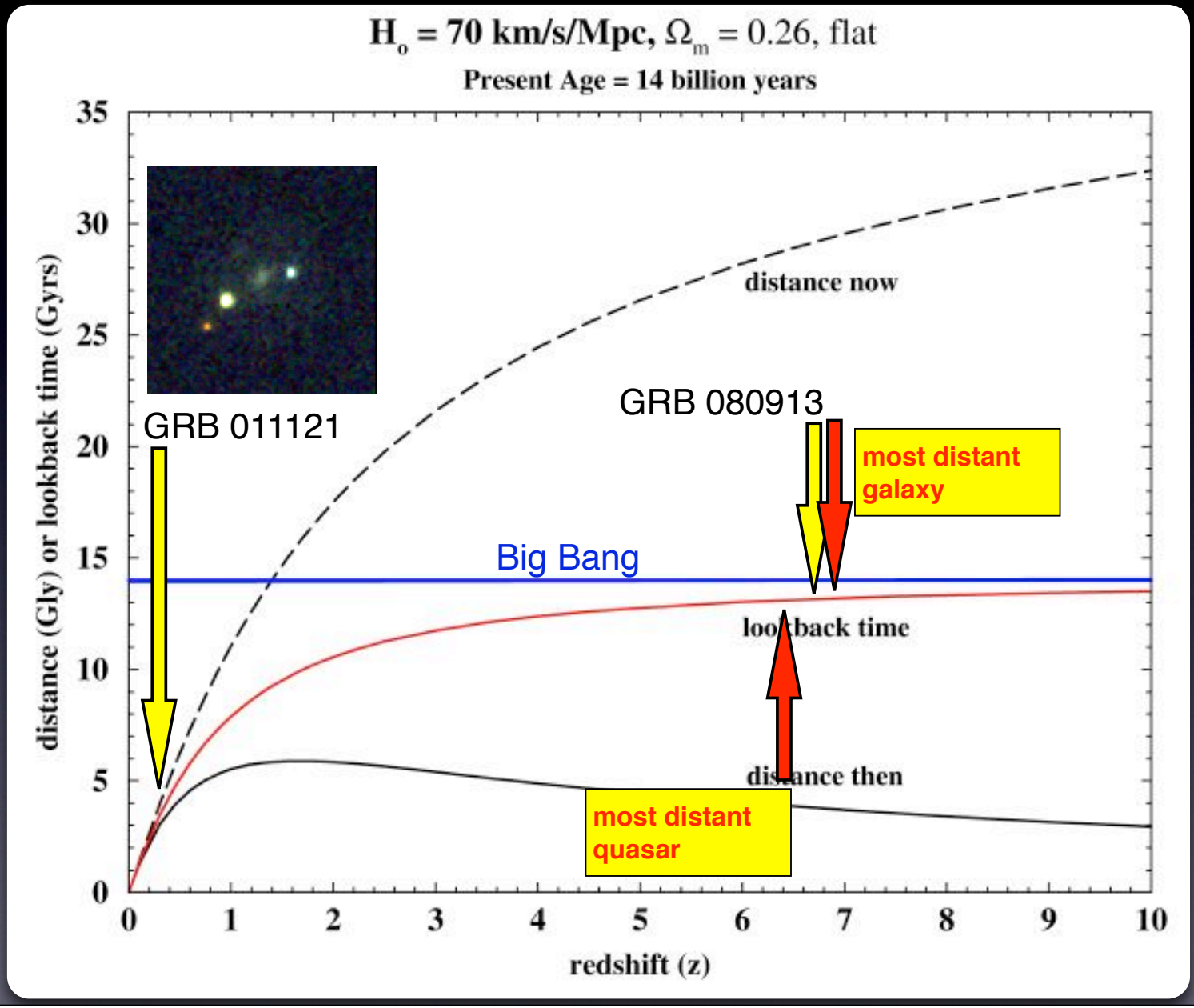
10^{54} ergs: energy emitted in gravitational waves and neutrinos

Rate: $1/10^5$ yr^{-1} / galaxy (a few / day detectable on Earth)

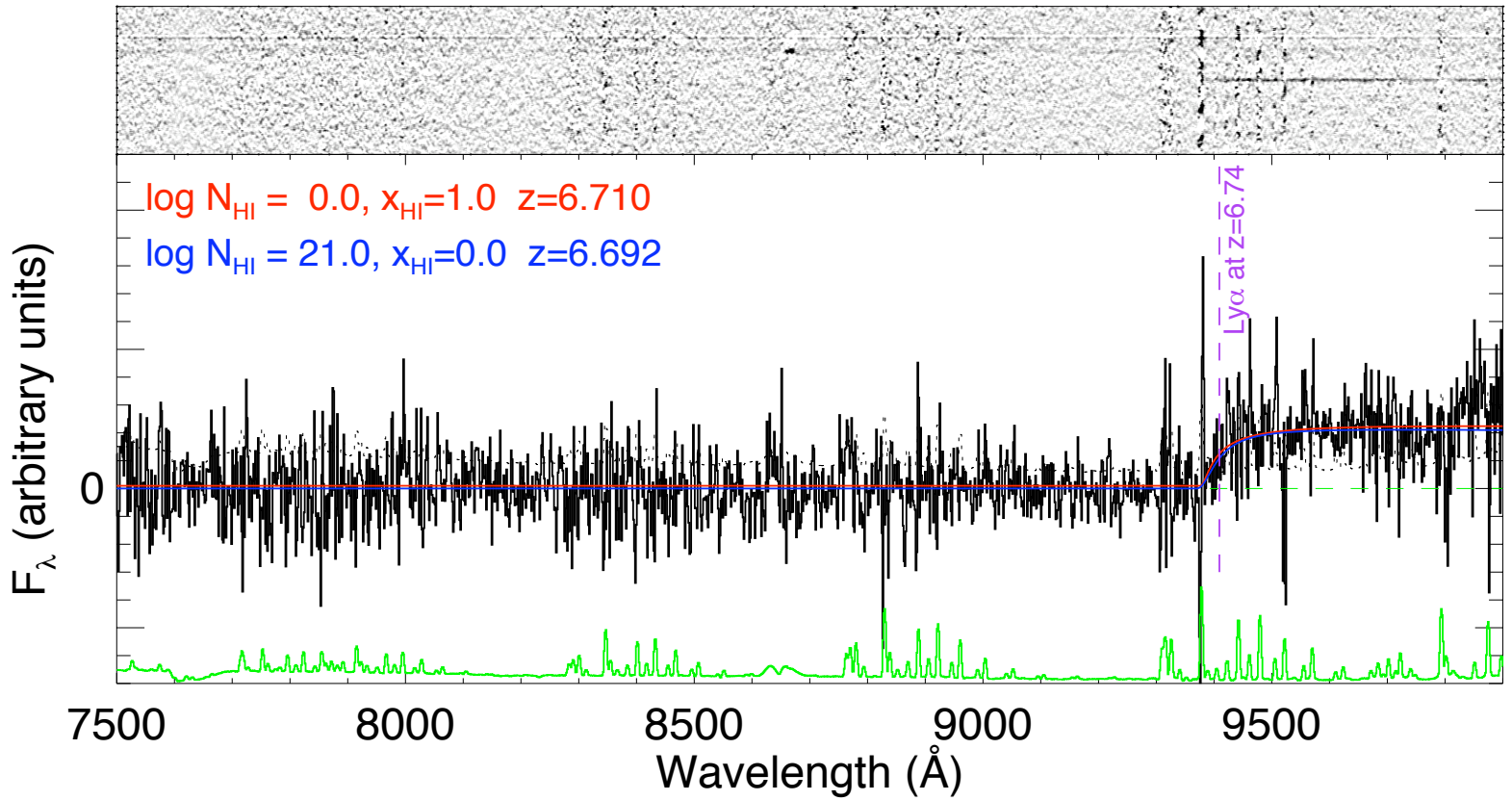
What can we investigate? A partial view....

1. *Star formation under extreme conditions*
2. *Massive stars (supernovae, WR)*
3. *Black Holes*
4. *Reionization of the universe*
5. *Cosmic chemical evolution*
6. *SFR history of the universe*
7. *Small galaxies at high redshift*
8. *First stars at z>7*
9. *Cosmology*

GRBs as cosmological probes



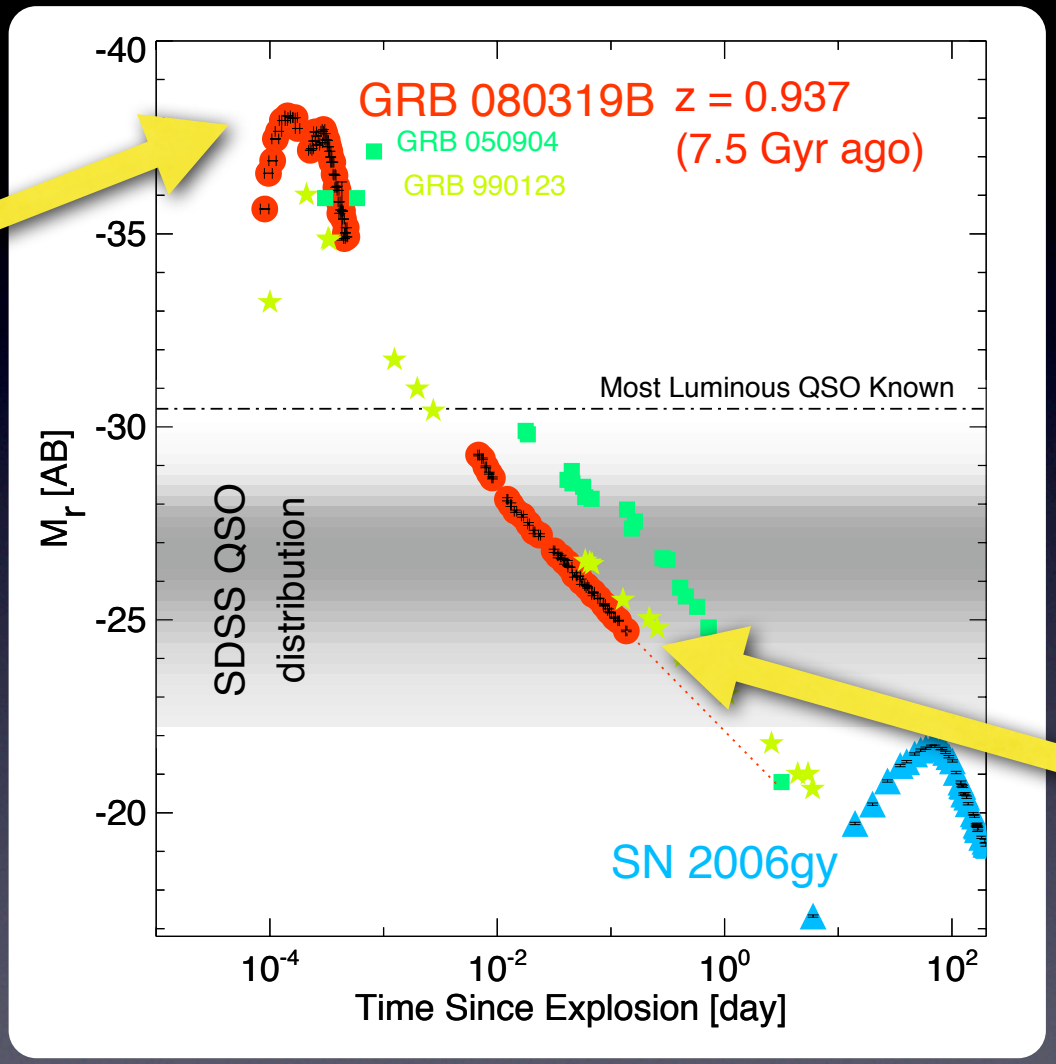
GRB redshift record holder: GRB 080913 (z = 6.7)



J. Greiner, T. Kruehler, J.P.U. Fynbo, A. Rossi, R. Schwarz, S. Klose, S. Savaglio, N.R. Tanvir, S. McBreen, T. Totani, B.B. Zhang, X.F. Wu, D. Watson, S.D. Barthelmy, A.P. Beardmore, P. Ferrero, N. Gehrels, D.A. Kann, N. Kawai, A. Kuepcue Yoldas, P. Meszaros, B. Milvang-Jensen, S.R. Oates, D. Pierini, P. Schady, K. Toma, P.M. Vreeswijk, A. Yoldas, B. Zhang, P. Afonso, K. Aoki, D.N. Burrows, C. Clemens, R. Filgas, Z. Haiman, D.H. Hartmann, G. Hasinger, J. Hjorth, E. Jehin, A.J. Levan, E.W. Liang, D. Malesani, T.-S. Pyo, S. Schulze, G. Szokoly, H. Terada, K. Wiersema (2009)

GRB 080319B: the brightest source recorded by humanity

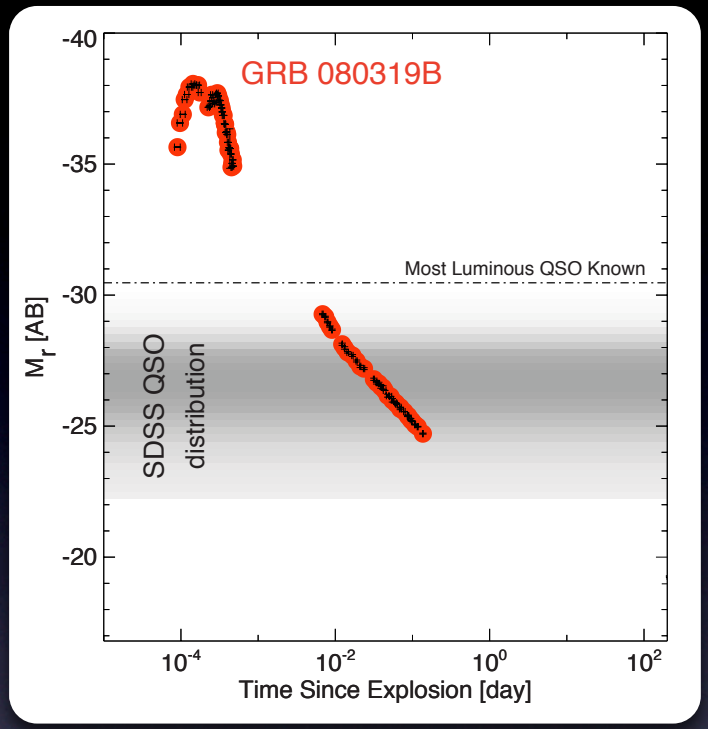
Visual magnitude m=5.6



6.7 hours after m=19.1

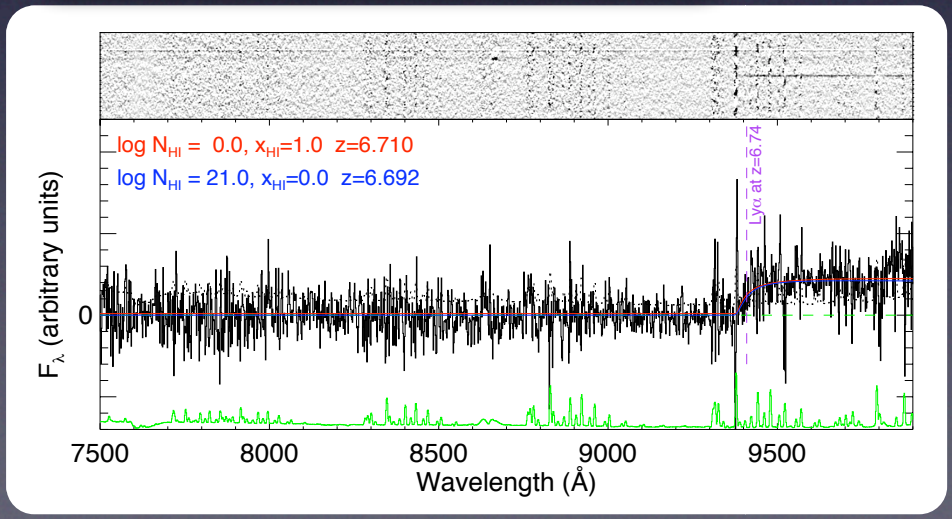
Bloom et al. (2008 March 24, ApJ Submitted, 42 pages)

2008: the Year of Gamma-Ray Bursts



GRB 080319B

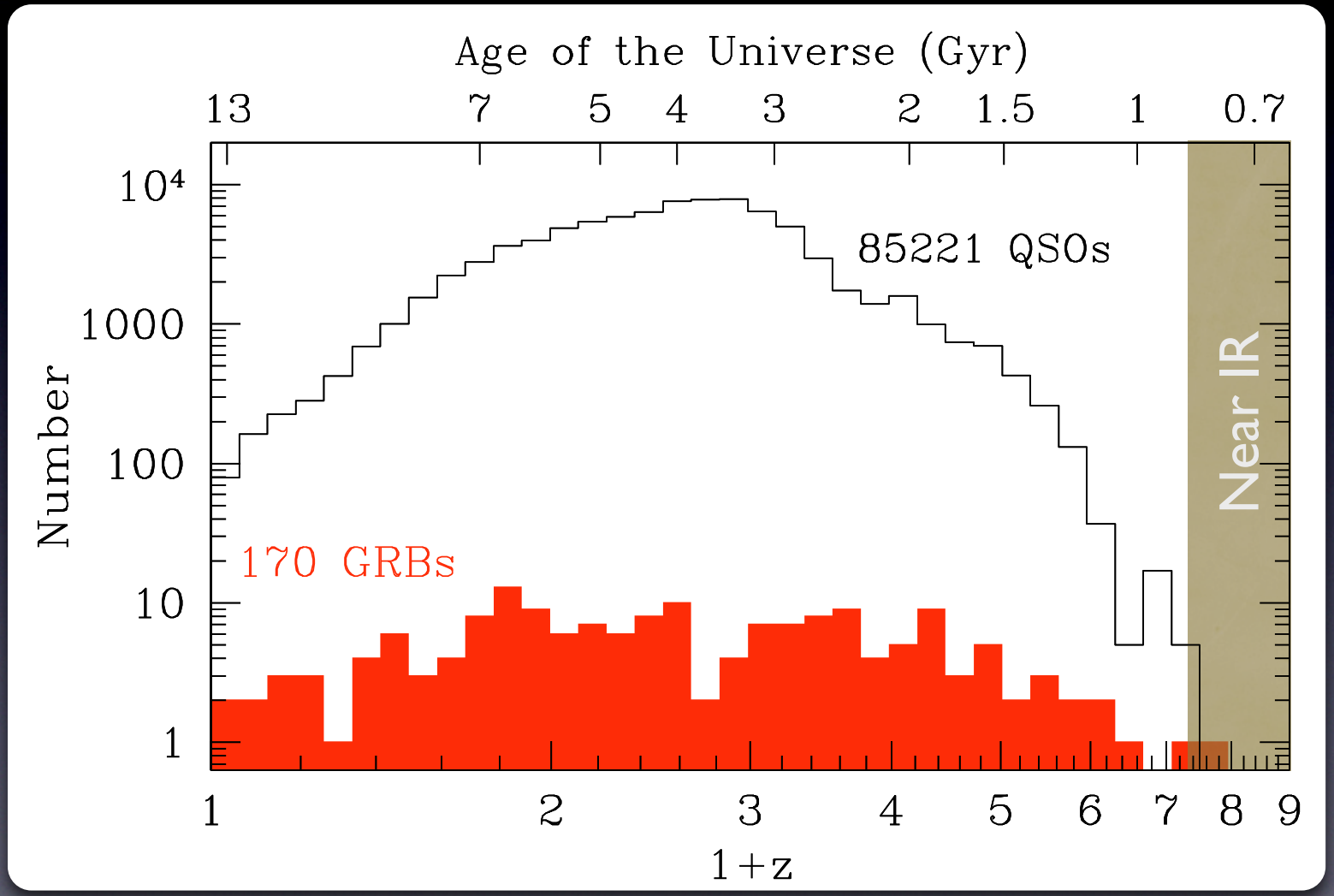
Brightest source recorded by humanity



GRB 080913

Second most distant object known

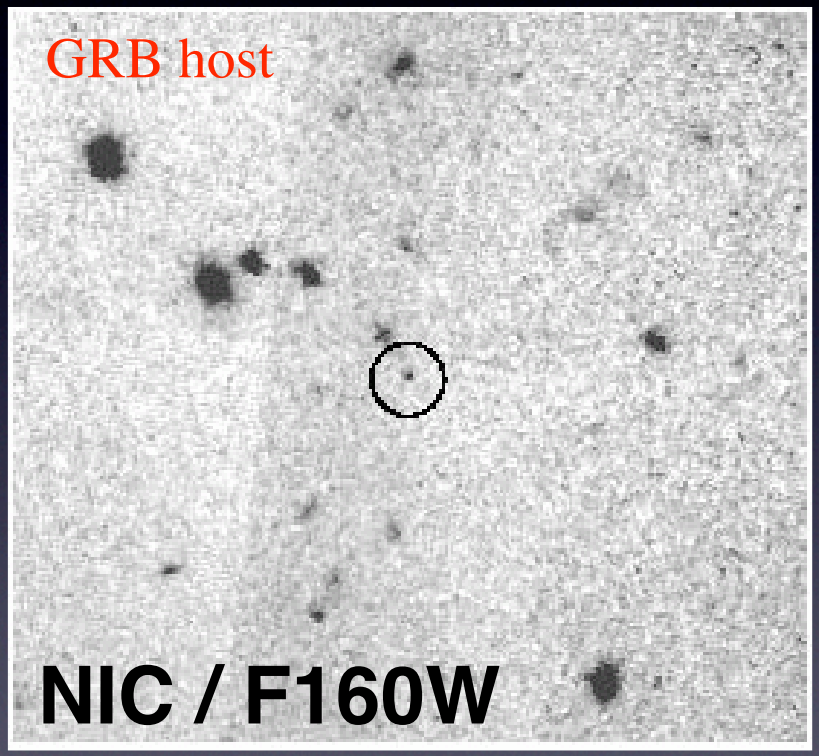
GRB redshift distribution



Only seen with GRBs

Smallest spectroscopically confirmed galaxy at z > 5

GRB 050904 z = 6.3

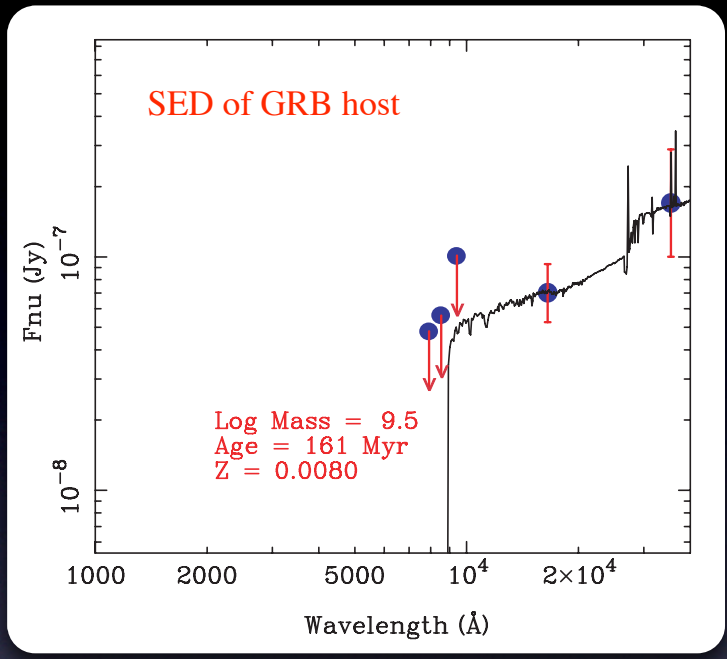


Berger et al. (2007)

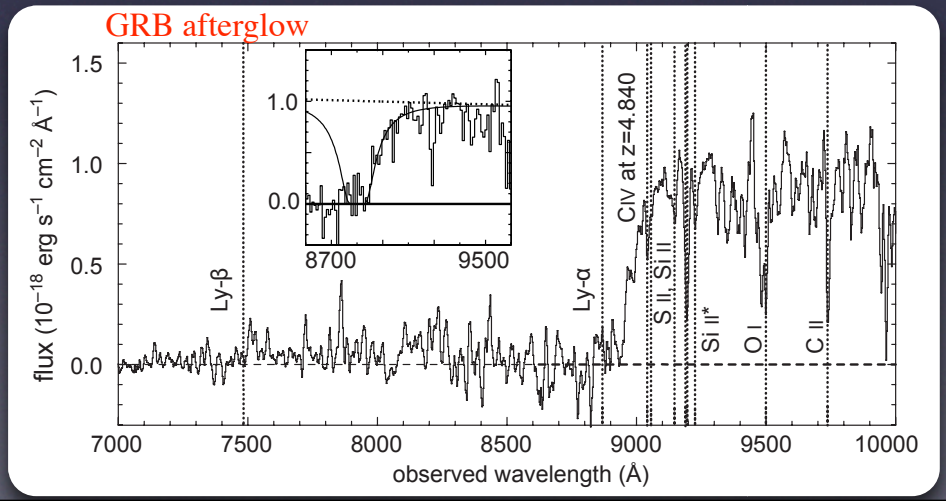
$M_* \sim 10^{9.5}\, M_\odot$

$Z/Z_\odot \sim 1/6$

Savaglio. Glazebrook & Le Borgne (2009)

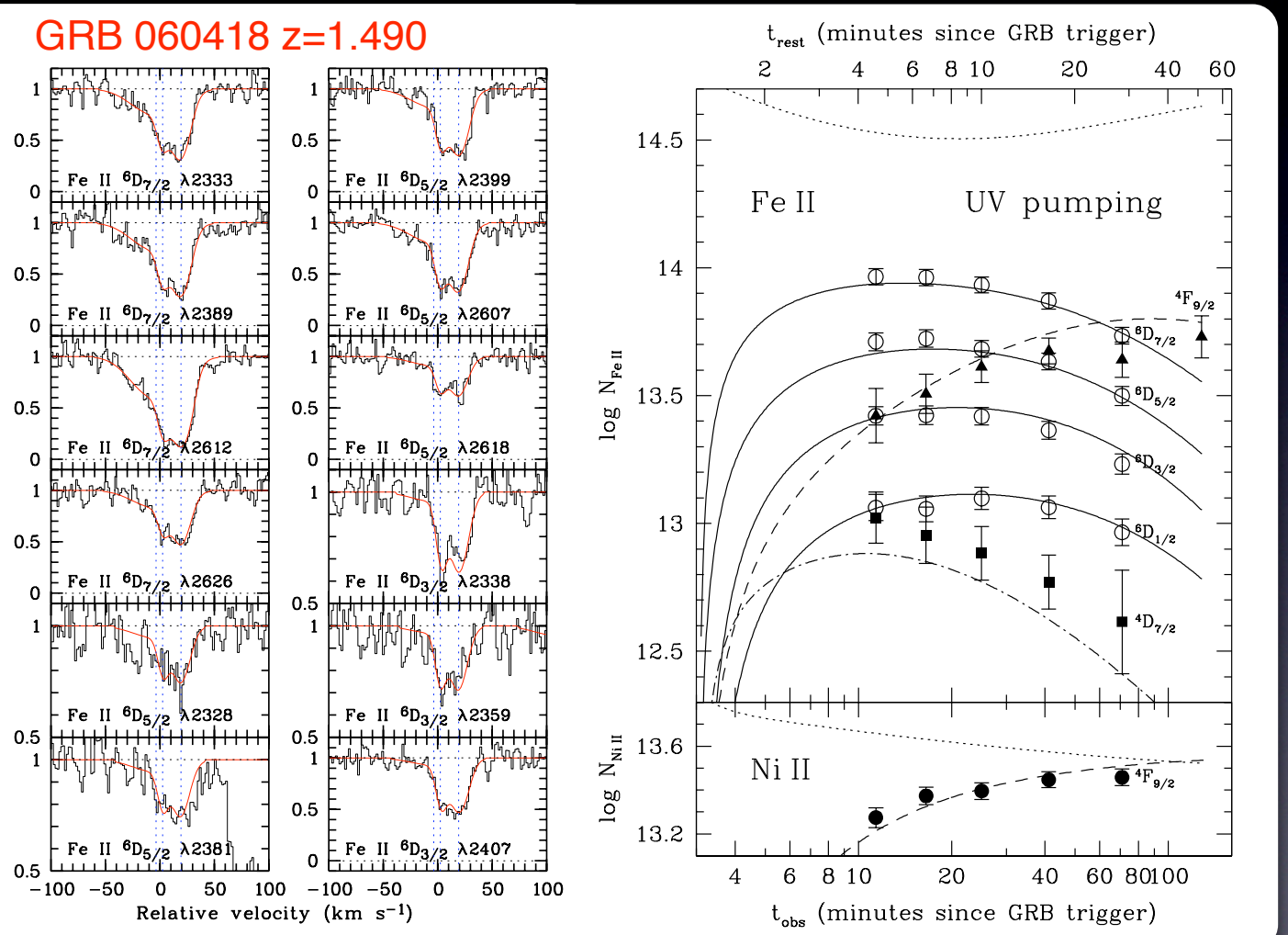


Totani et al. (2006)



Only seen with GRBs

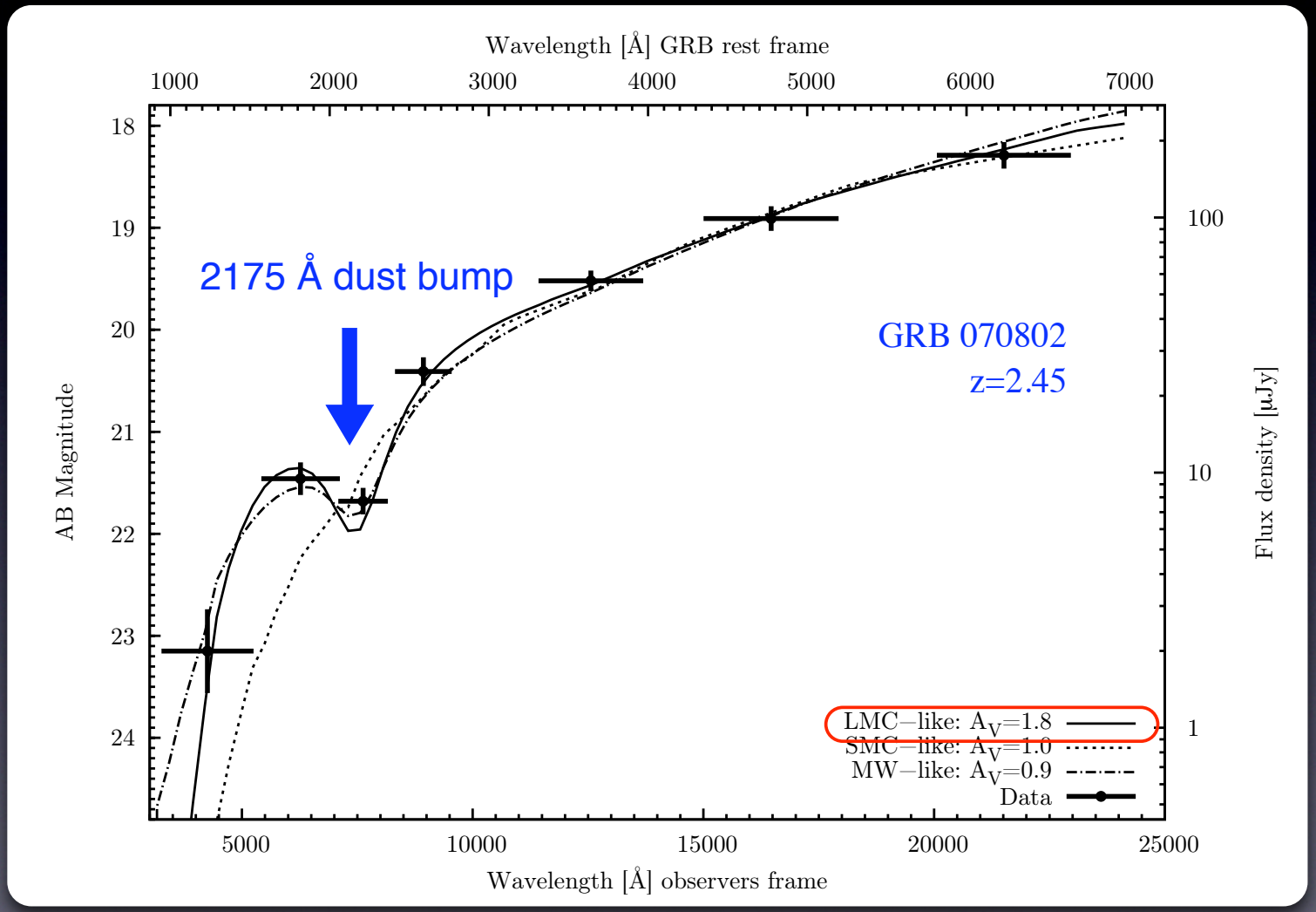
Fine structure lines in ISM out of Milky Way



Vreeswijk, Ledoux, Smette, Ellison, Jaunsen, Andersen, Fruchter, Fynbo, Hjorth, Kaufer, Møller, Petitjean, Savaglio, Wijers (2007)

Only seen with GRBs

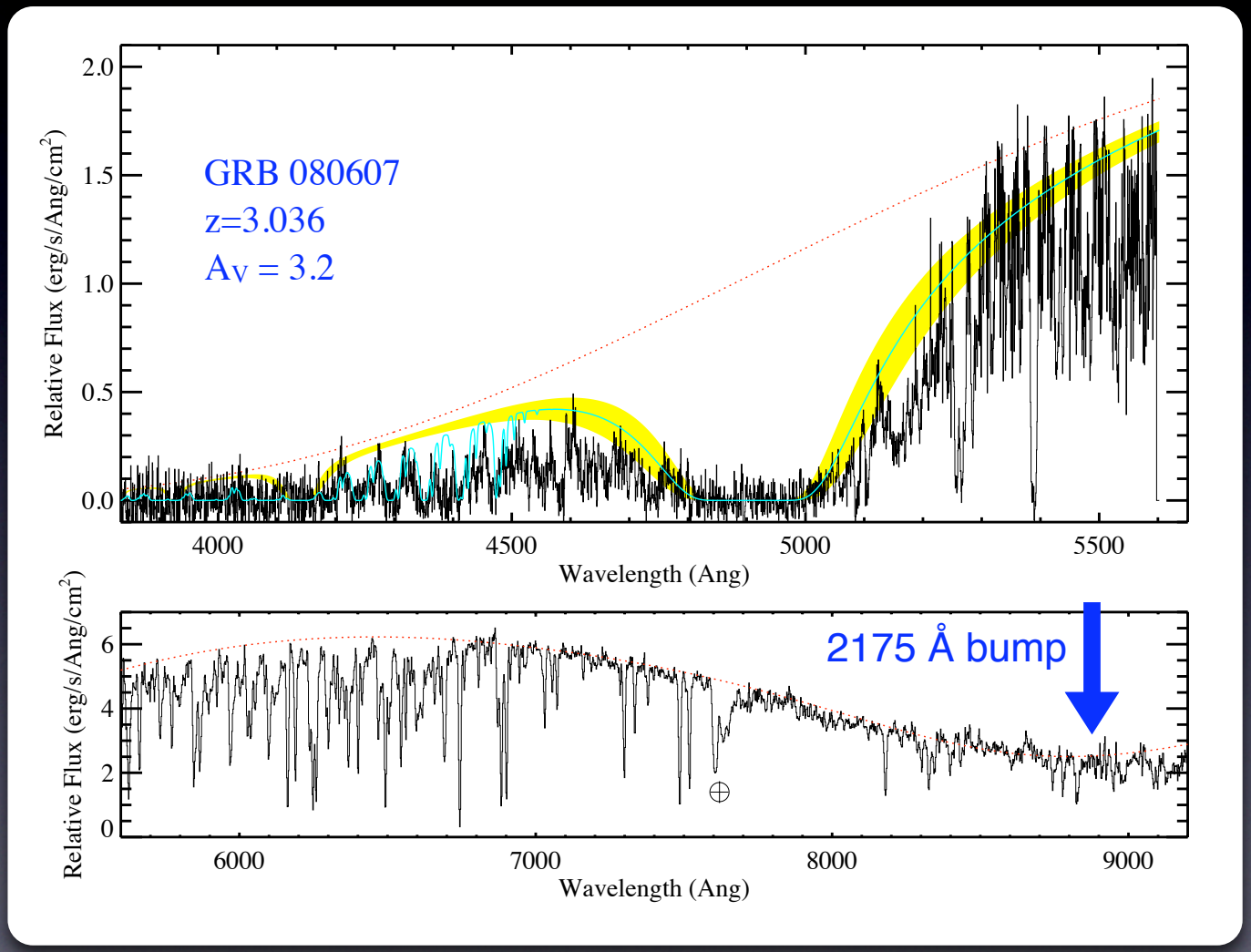
2175 Å dust bump at high redshift



Krühler, Küpcü Yoldaş, Greiner, Clemens, McBreen, Primak, Savaglio, Yoldaş, Szokoly, Klose (2008)

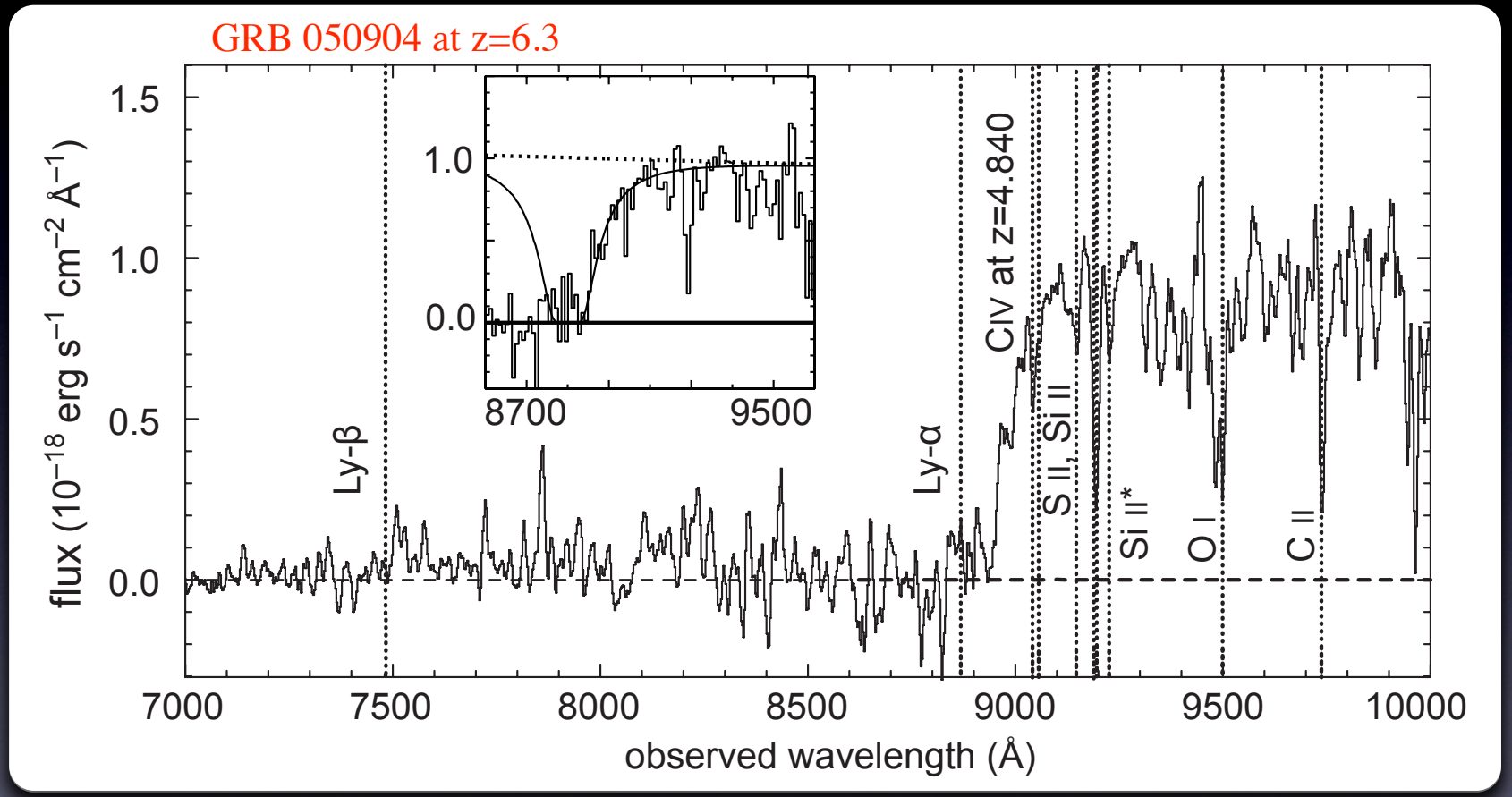
Only seen with GRBs

2175 Å dust bump at high redshift



Prochaska et al. (2009)

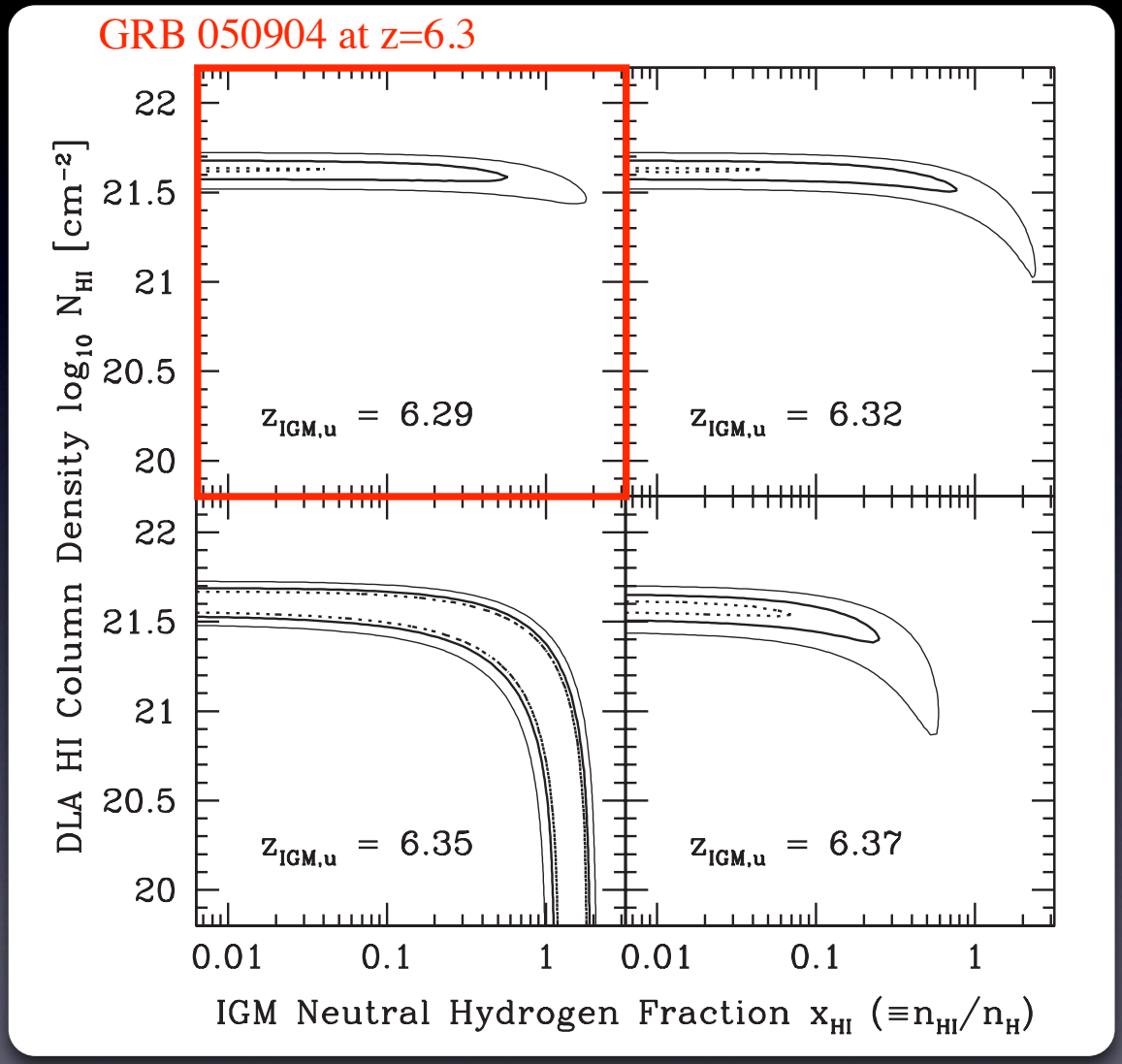
Reionization of the universe



Totani et al. (2006)

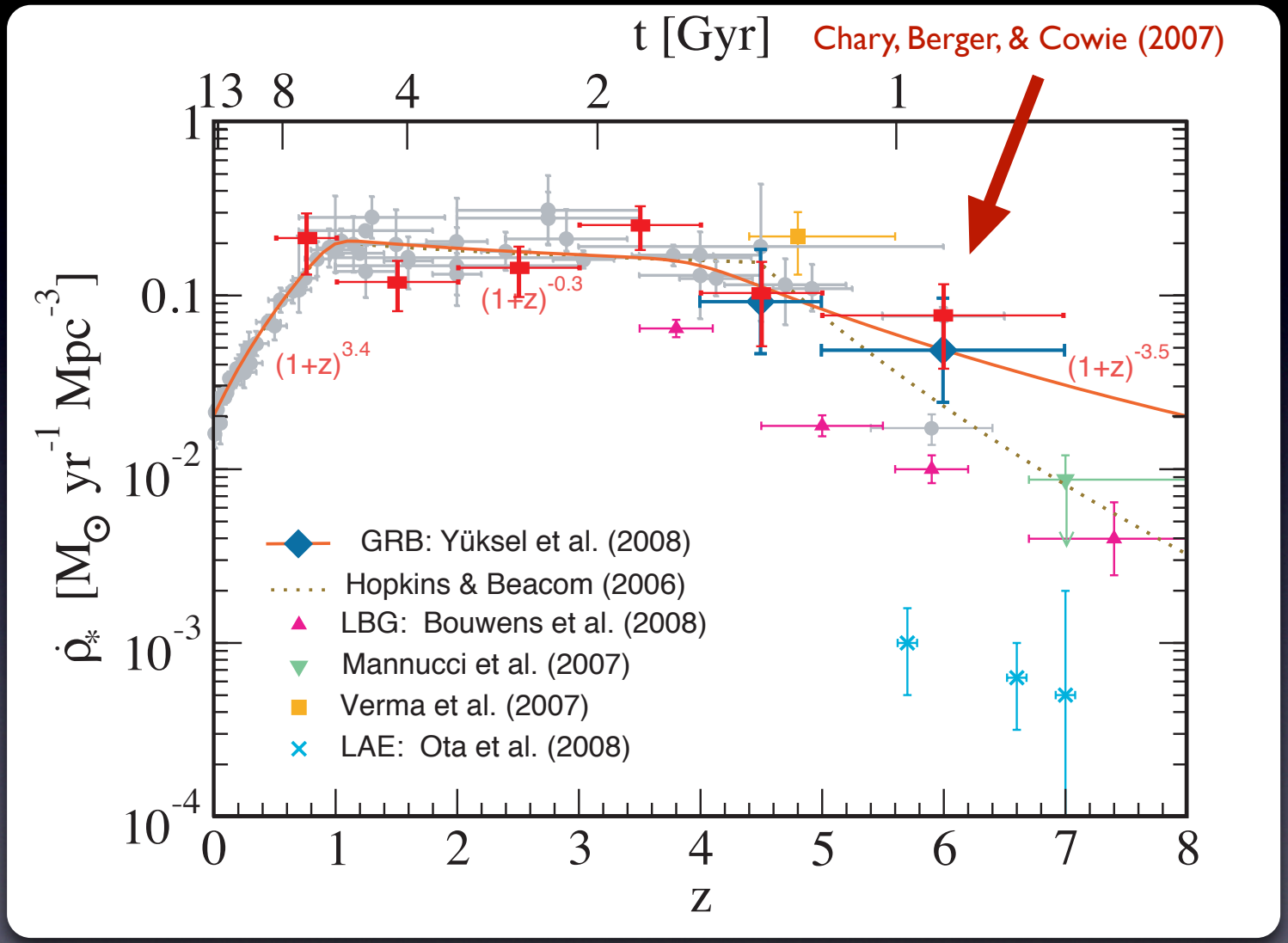
Reionization of the universe

IGM largely ionized by z = 6.3



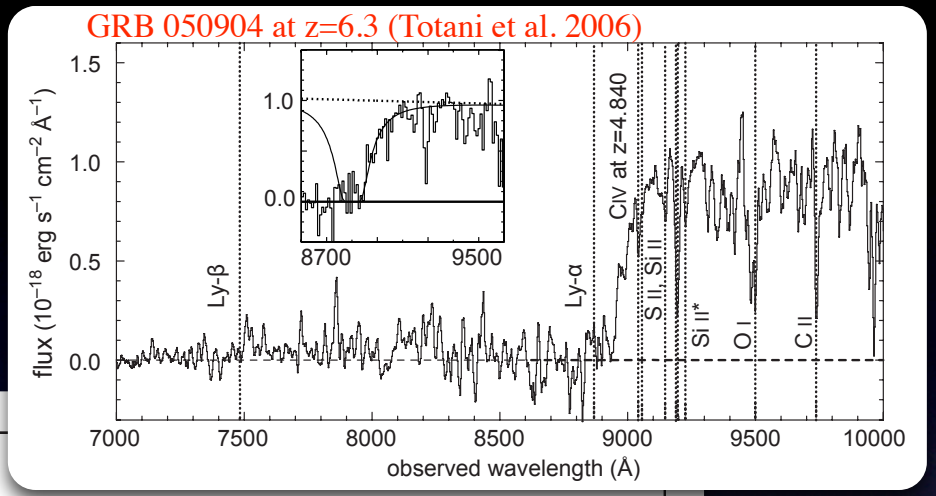
Totani et al. (2006)

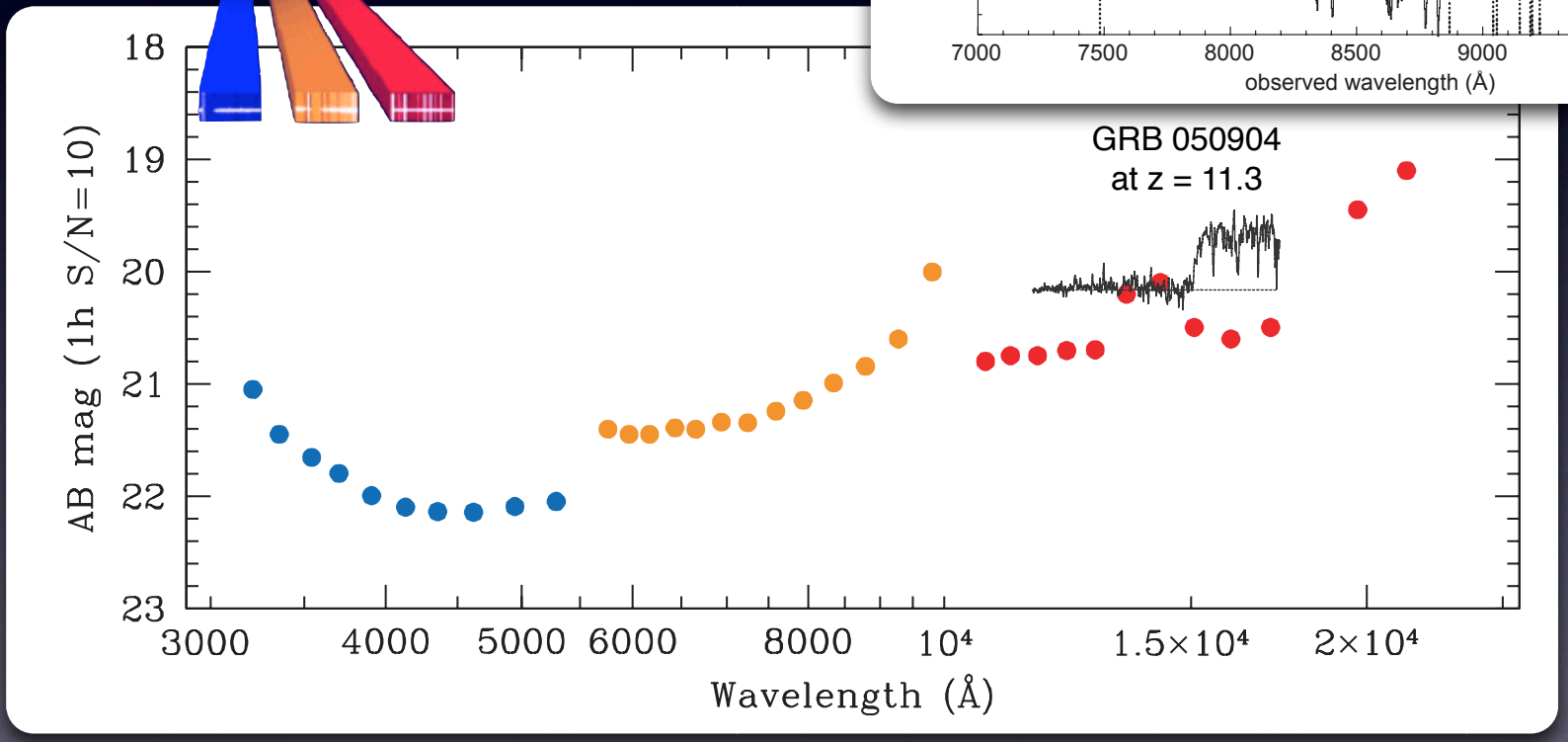
Star formation rate density of the universe



Yüksel, Kistler, Beacom, & Hopkins (2008)

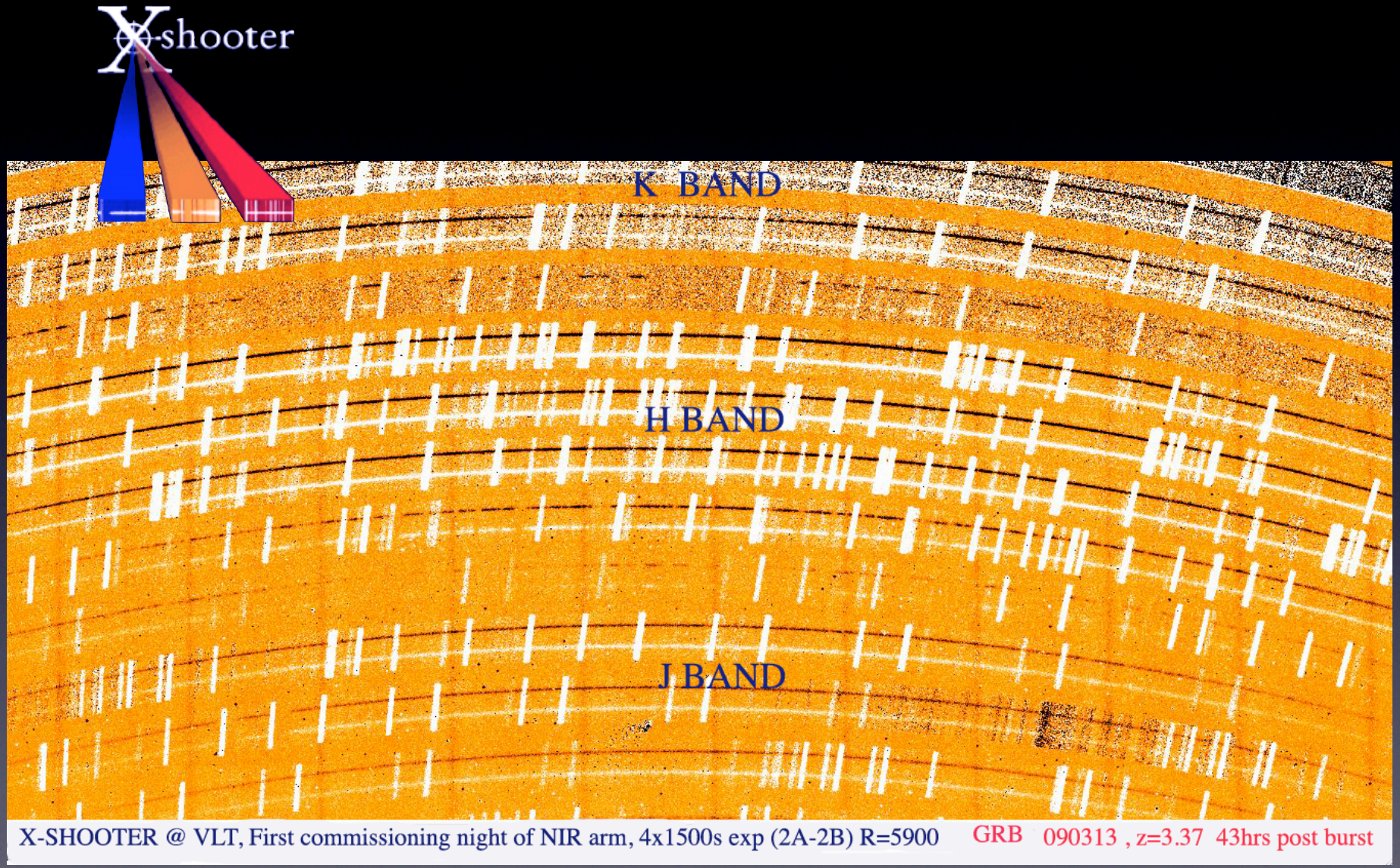
Prototype instrument for ELT





P.I. Board: S. D'Odorico (ESO), F. Hammer (GEPI), L. Kaper (Univ. Amsterdam), R. Pallavicini (INAF), P. Kjaergaard Rasmussen (NBI)

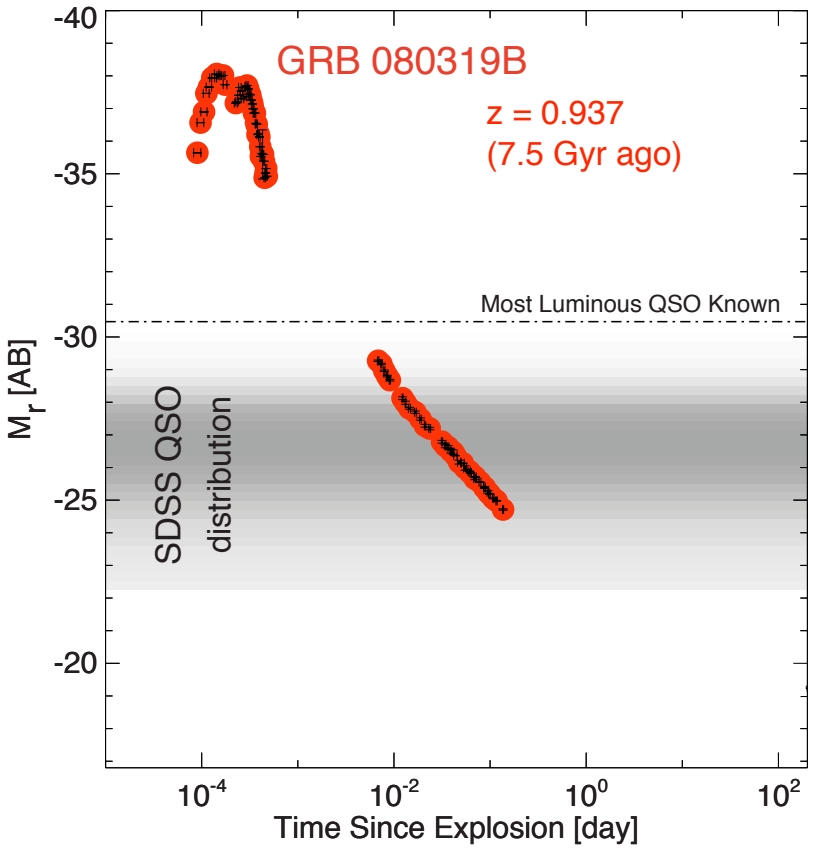
Prototype instrument for ELT

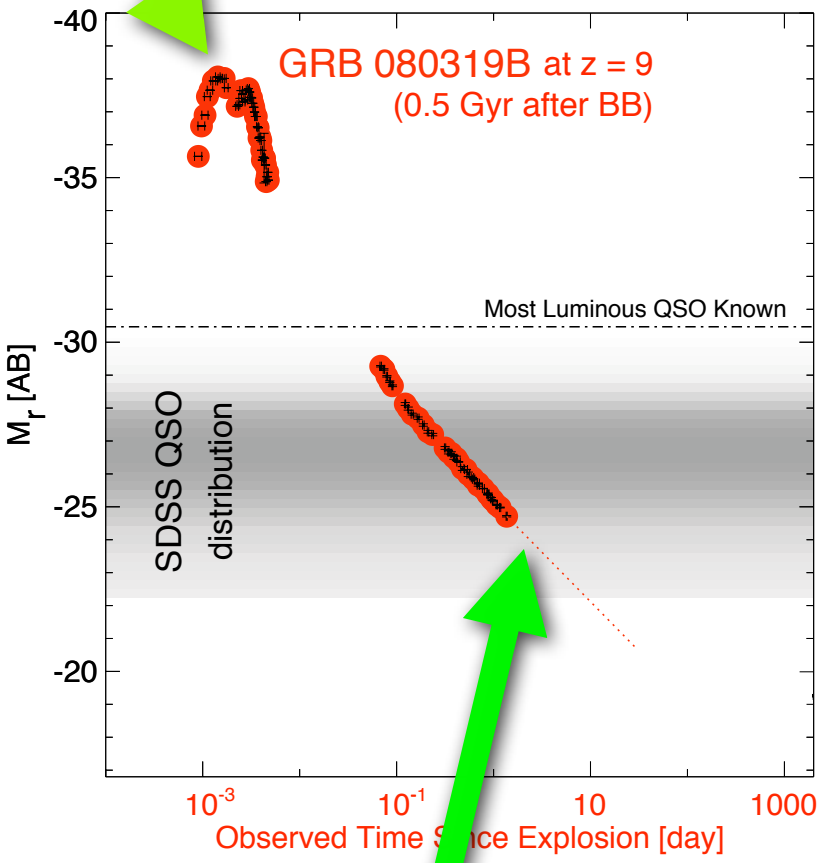


(S. D'Odorico, private communication)

GRB 080319B at z = 9 with ELT

NIR magnitude
m = 11.5





34.7 hours after
m = 25.0

Conclusions

❶ GRBs shining through a universe hard to see in other ways

❷ GRBs very promising probes of z > 7 universe

❸ Ideal targets for ELTs