



Star-forming Galaxies Unveiled by GRB Afterglows

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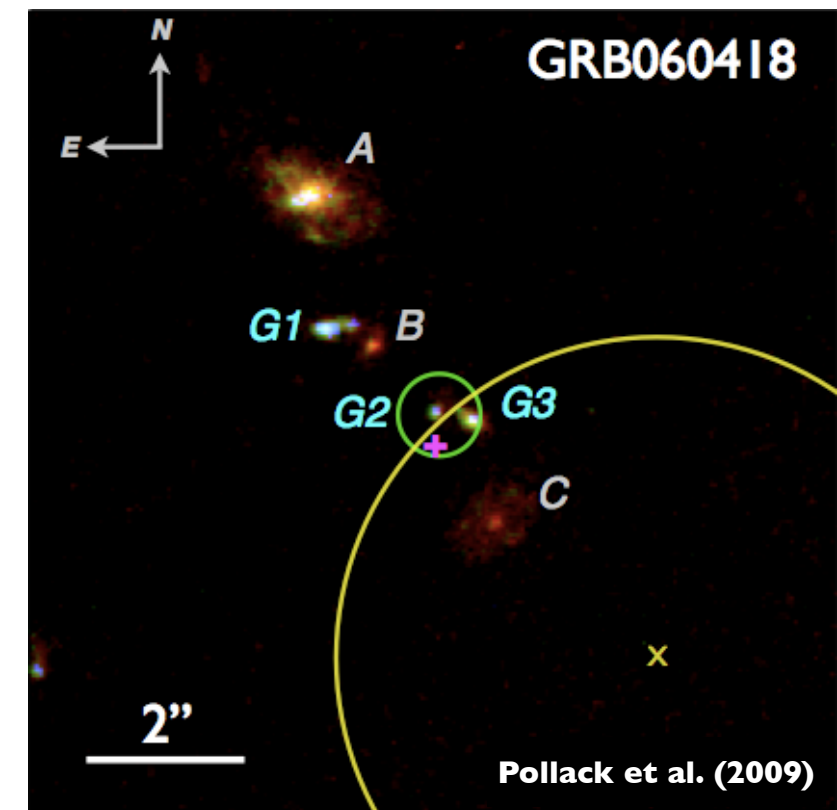
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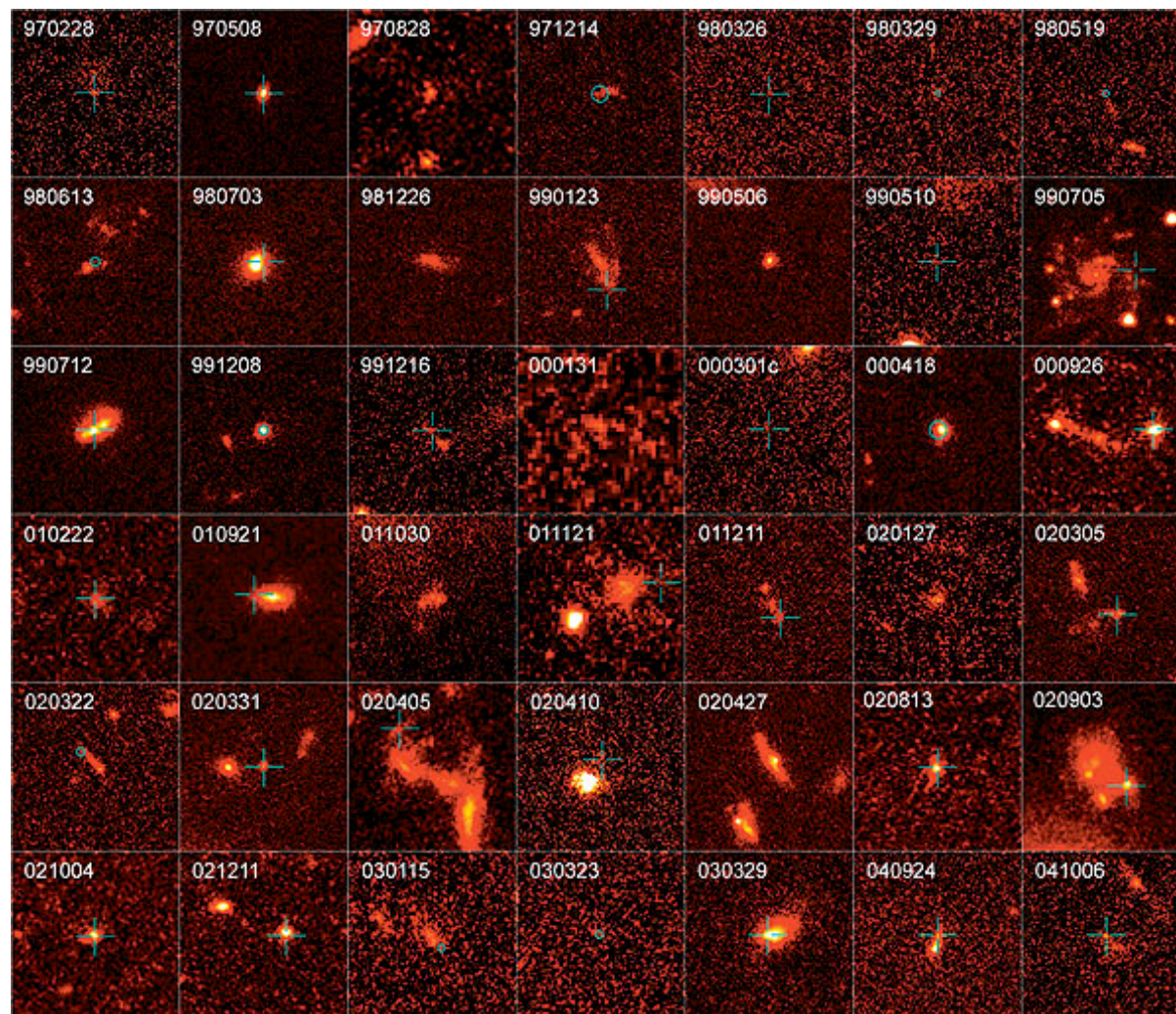


Outline

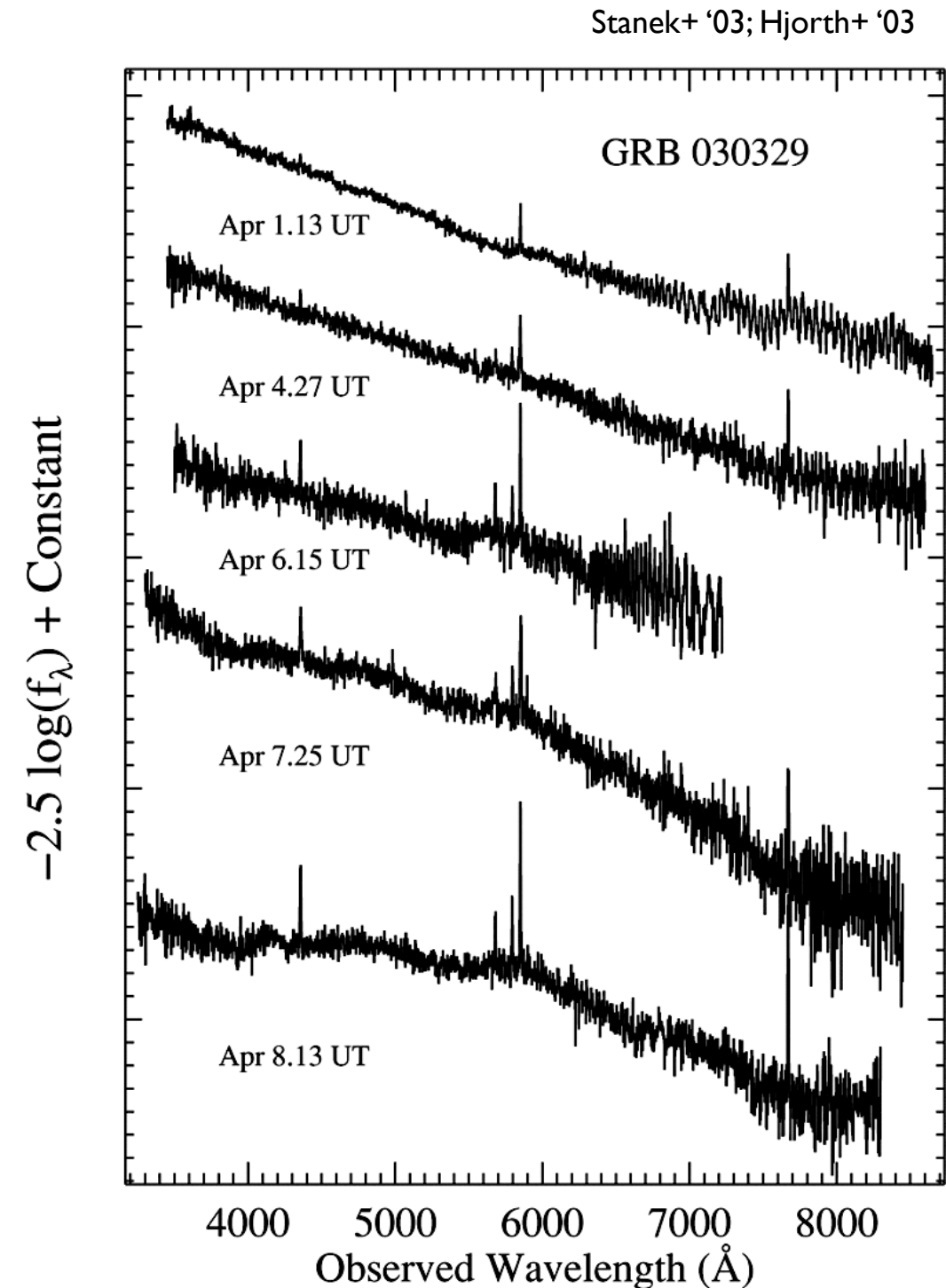
- ✦ **The origin of long-duration GRBs**
- ✦ **Known ISM properties from afterglow absorption-line studies**
- ✦ **The nature of the GRB host galaxy population from late-time imaging follow-ups**

Long-duration GRBs are Signposts of Distant Star-forming Regions

- **Association with core-collapse Ic SNe**
(e.g. Woosley & Bloom '06)
- **Spatial coincidence with UV light in late-type host galaxies at $z \lesssim 1$**
(e.g. Bloom+ '02, Fruchter+ '06)

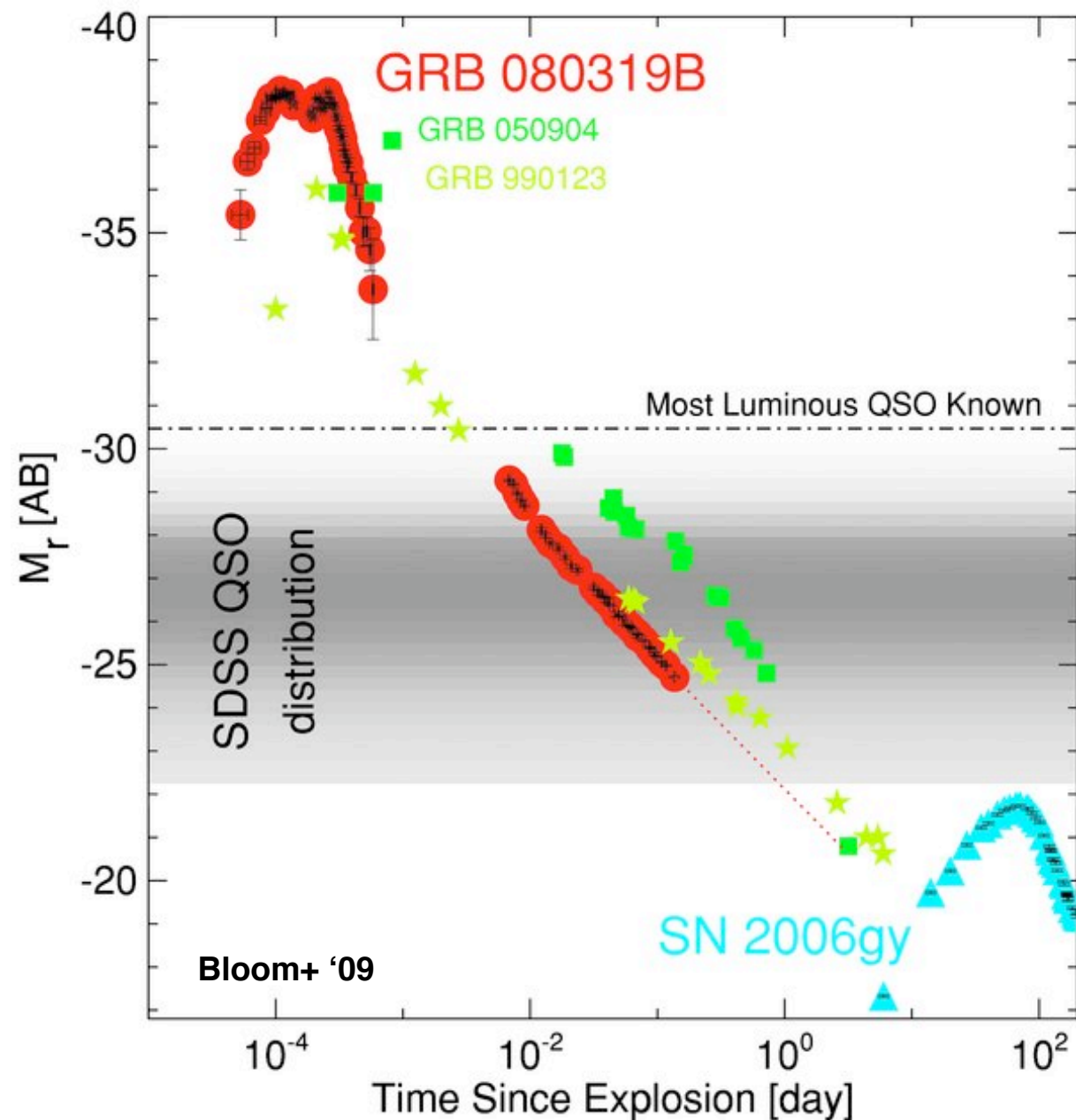


Fruchter et al. (2006)

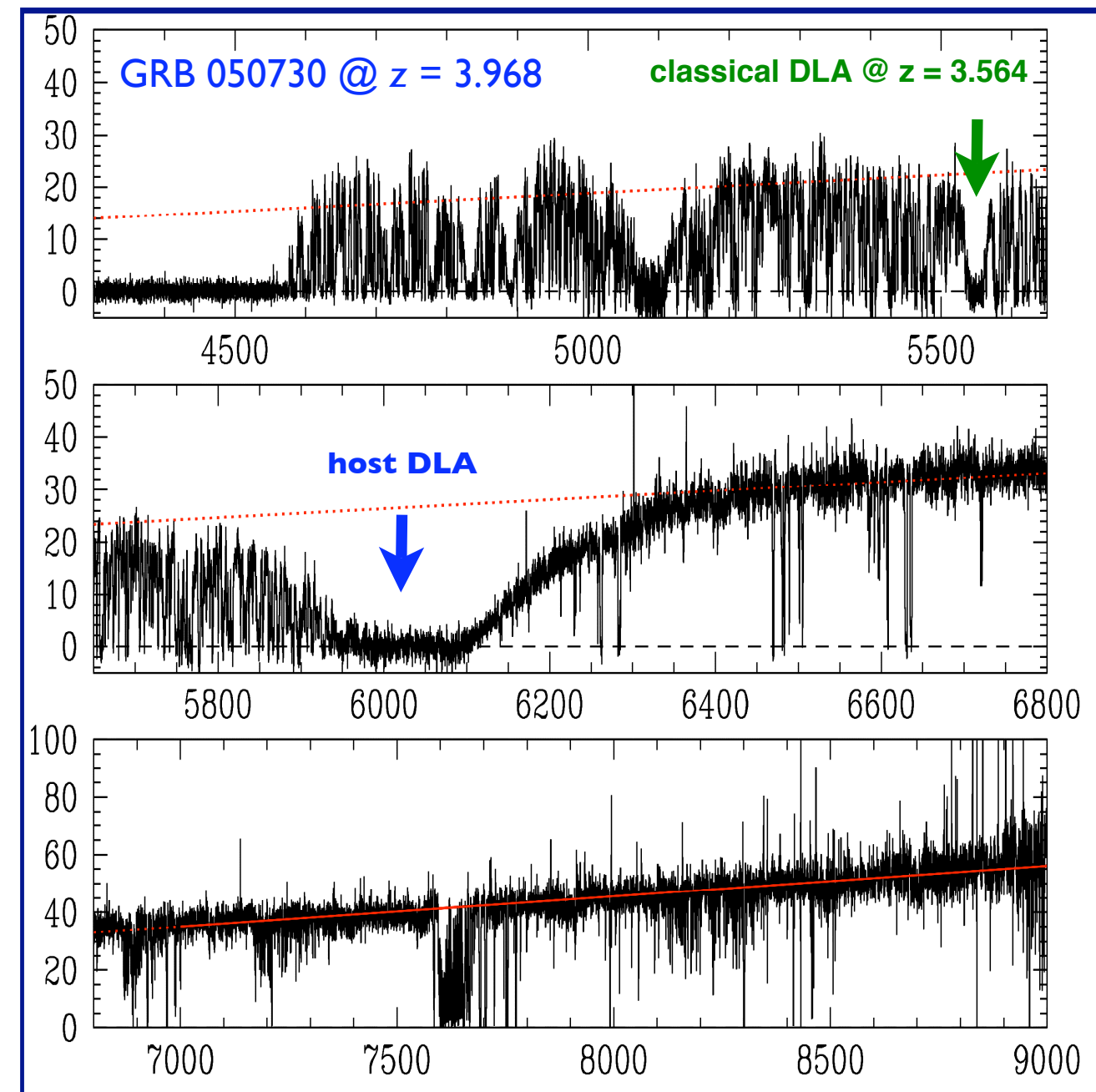


GRB Afterglows as a Probe of Distant Universe

- Extreme rest-frame luminosity



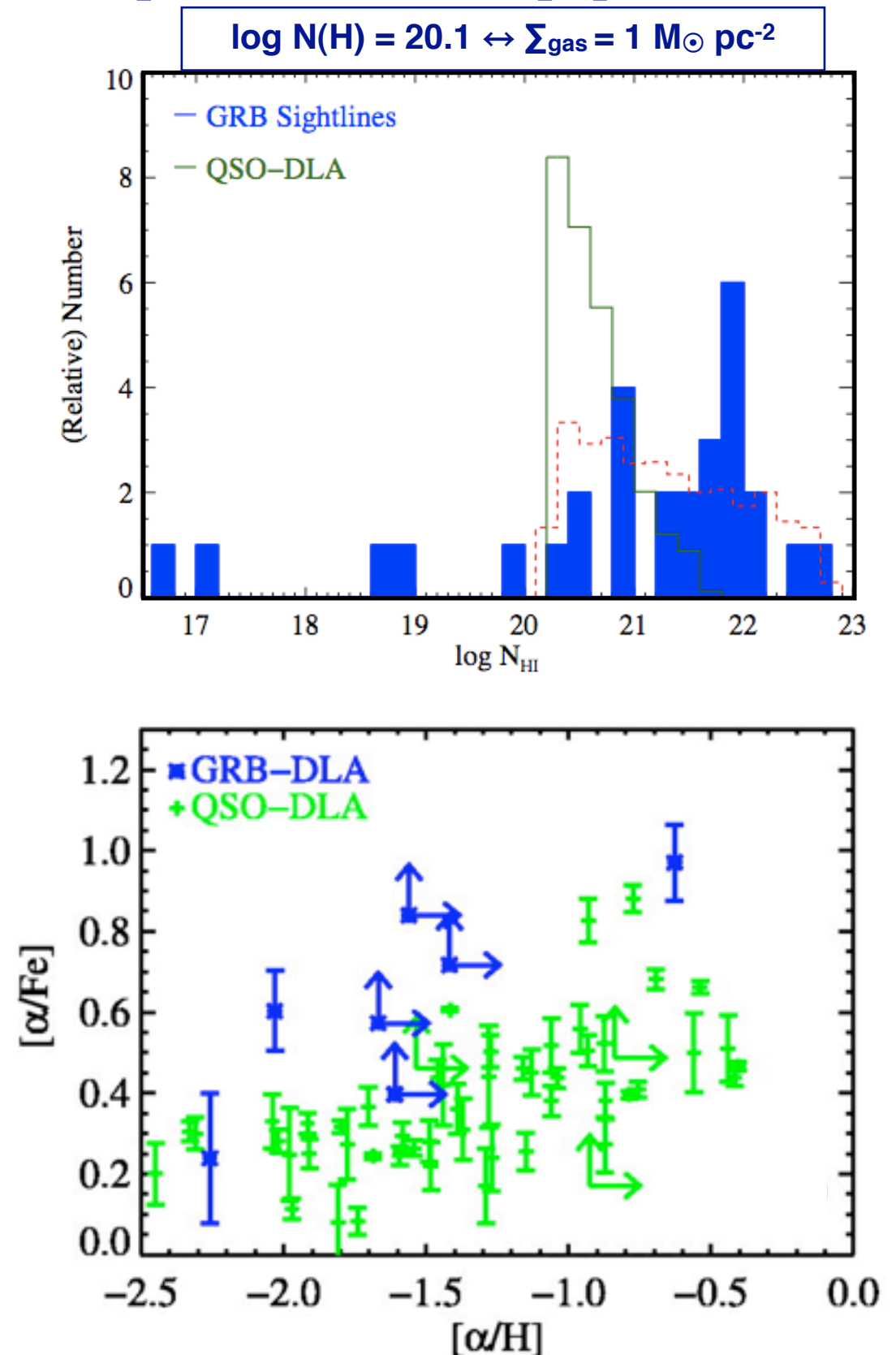
- Simple spectral shape



Chen, Prochaska, Bloom, & Thompson (2005)

ISM Properties of GRB Host Galaxies from Early-time Afterglow Spectroscopy

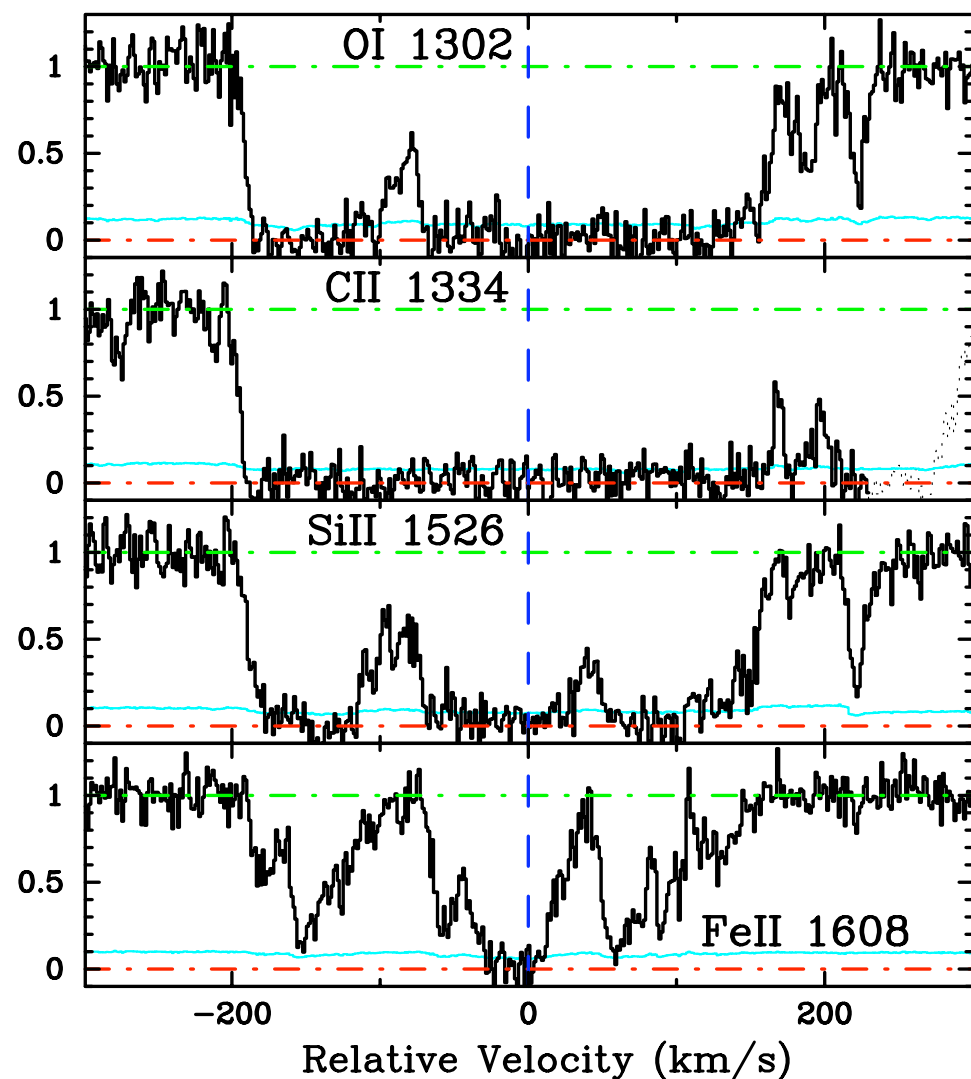
- ◆ large neutral gas column, > 50% have $\log N(\text{HI}) > 21$, *c.f.* <15% of classical DLAs have such high $N(\text{HI})$ (Jakobsson+ '06)
- ◆ a broad range of metallicity from 1/100 solar to 1/2 solar
(Fynbo+ '06; Savaglio '06; Prochaska+ '07)
- ◆ UV pumped O^0 , Si^+ , and Fe^+ are commonly seen in GRB host galaxies, allowing distance estimates of 0.1-1 kpc
(Prochaska+ '06; Vreeswijk+ '07; D'Elia+ '08)



ISM Properties of GRB Host Galaxies from Early-time Afterglow Spectroscopy (cont'd)

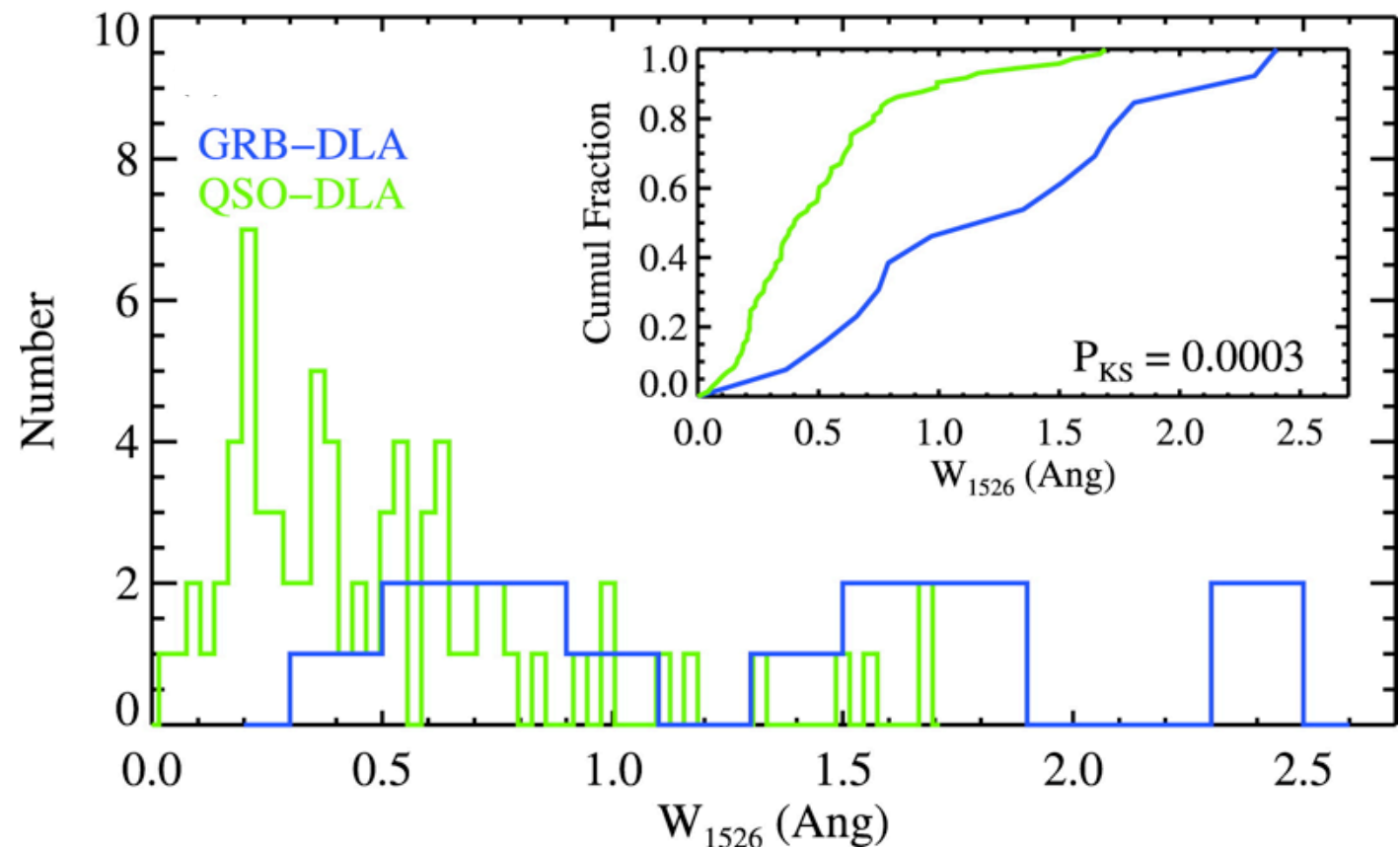
◆ Complex absorption profiles revealing a turbulent velocity field

(Prochaska, Chen, Wolfe, Dessauges-Zavadsky, & Bloom 2008)



SiII 1526 is saturated.

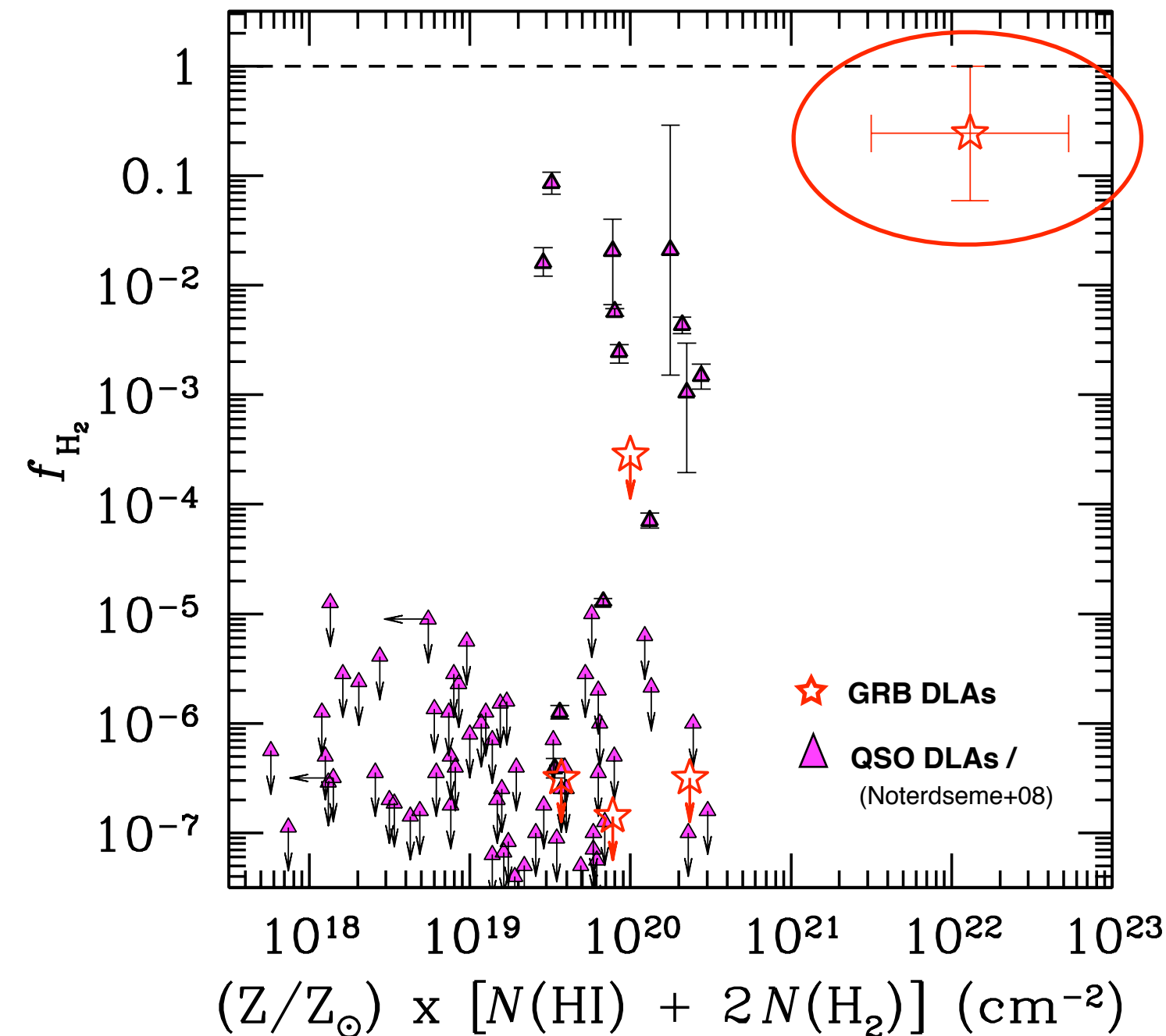
W_{1526} serves as a measure of the underlying gas kinematics.



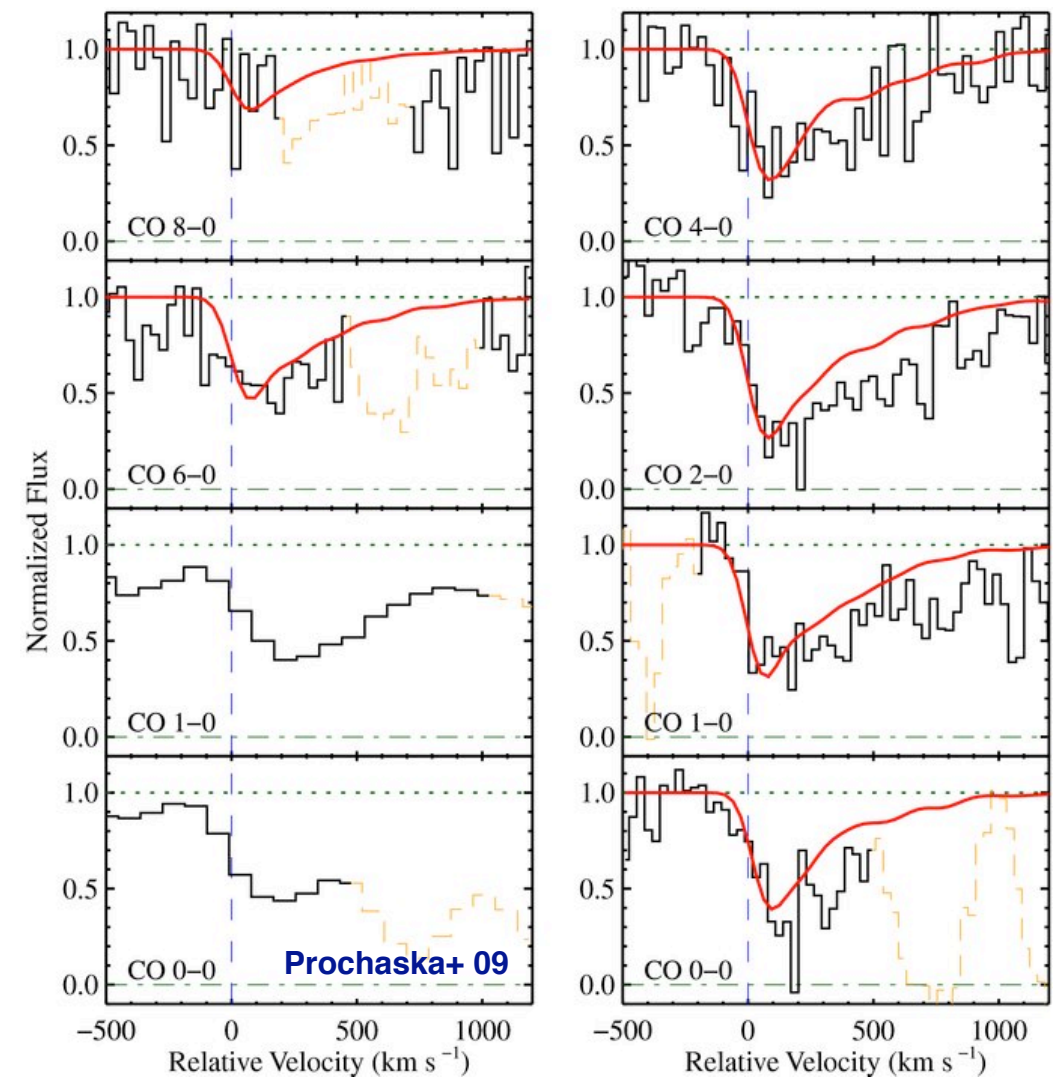
ISM Properties of GRB Host Galaxies from Early-time Afterglow Spectroscopy (cont'd)

◆ large atomic gas column but little molecular gas content

(Fynbo+ '06; Tumlinson+ '07; Prochaska+ '09)

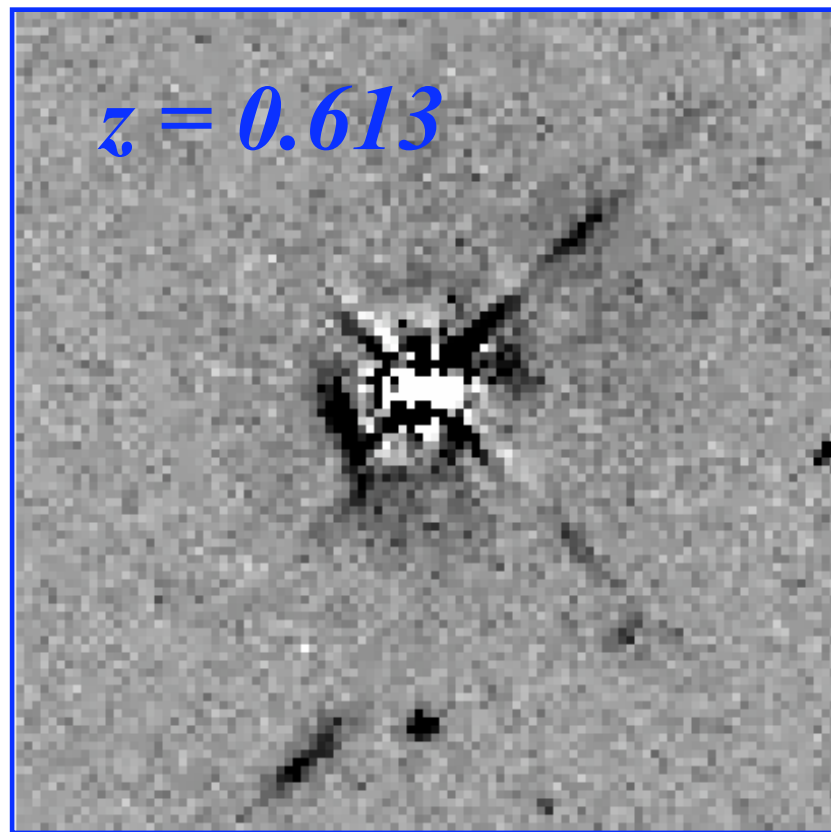


GRB080607 at $z=3.04$



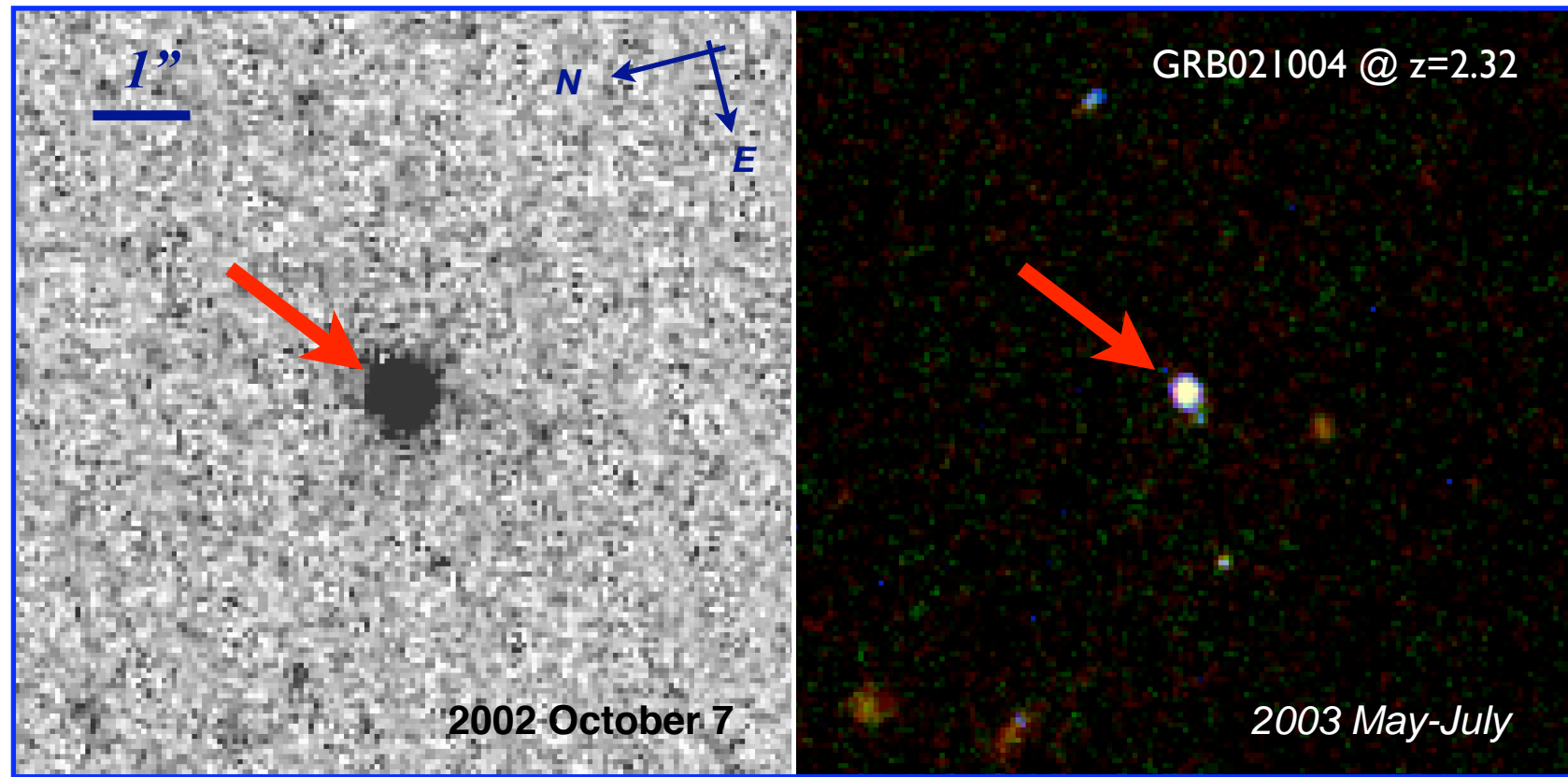
Connecting Absorption Properties with Stellar Light at $z > 2$

QSO sightline



The glare of the background QSO makes it challenging to observe foreground DLA galaxies

GRB sightline



The transient nature of GRB afterglows allows late-time imaging search of faint galaxies along the sightline

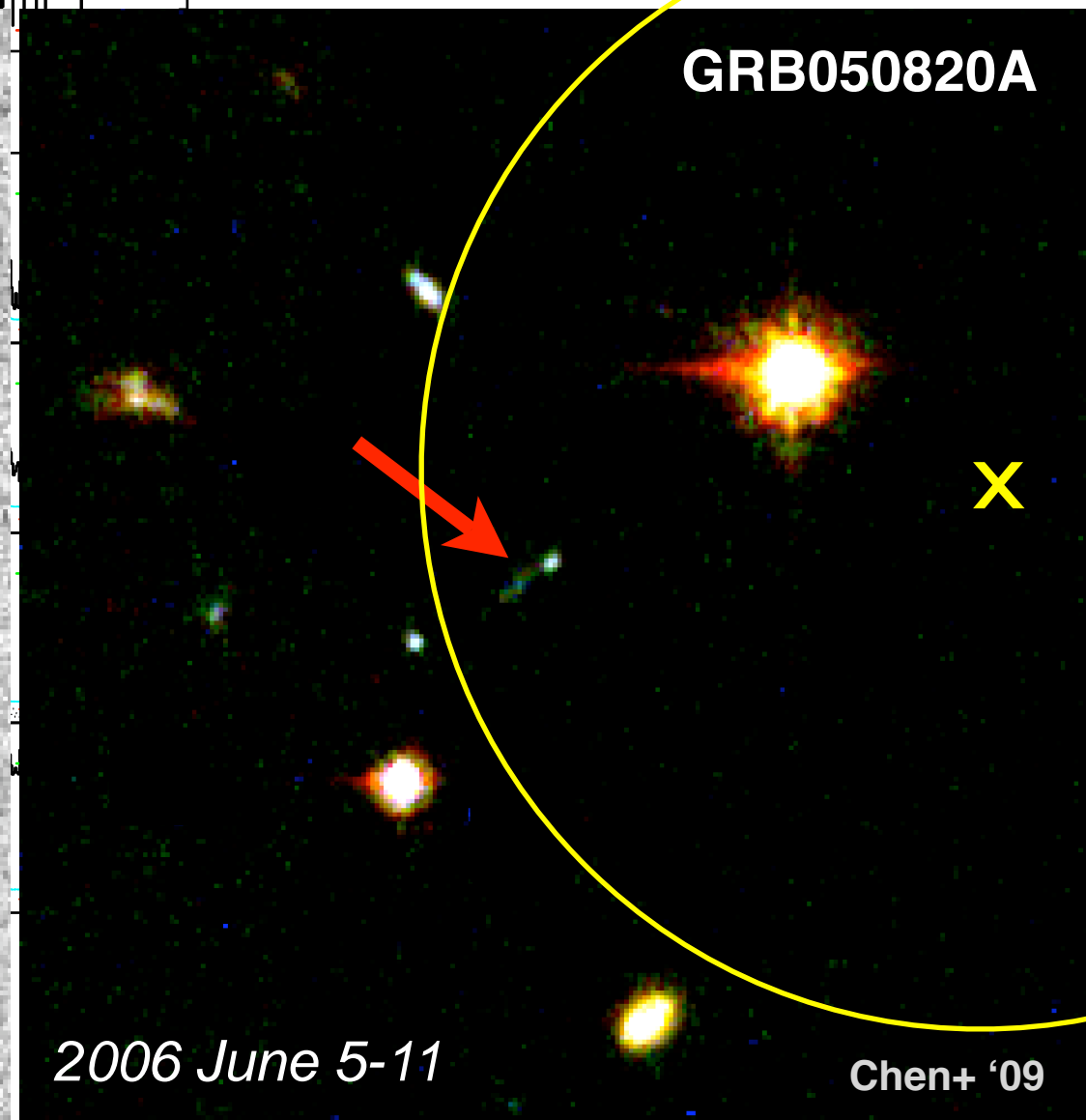
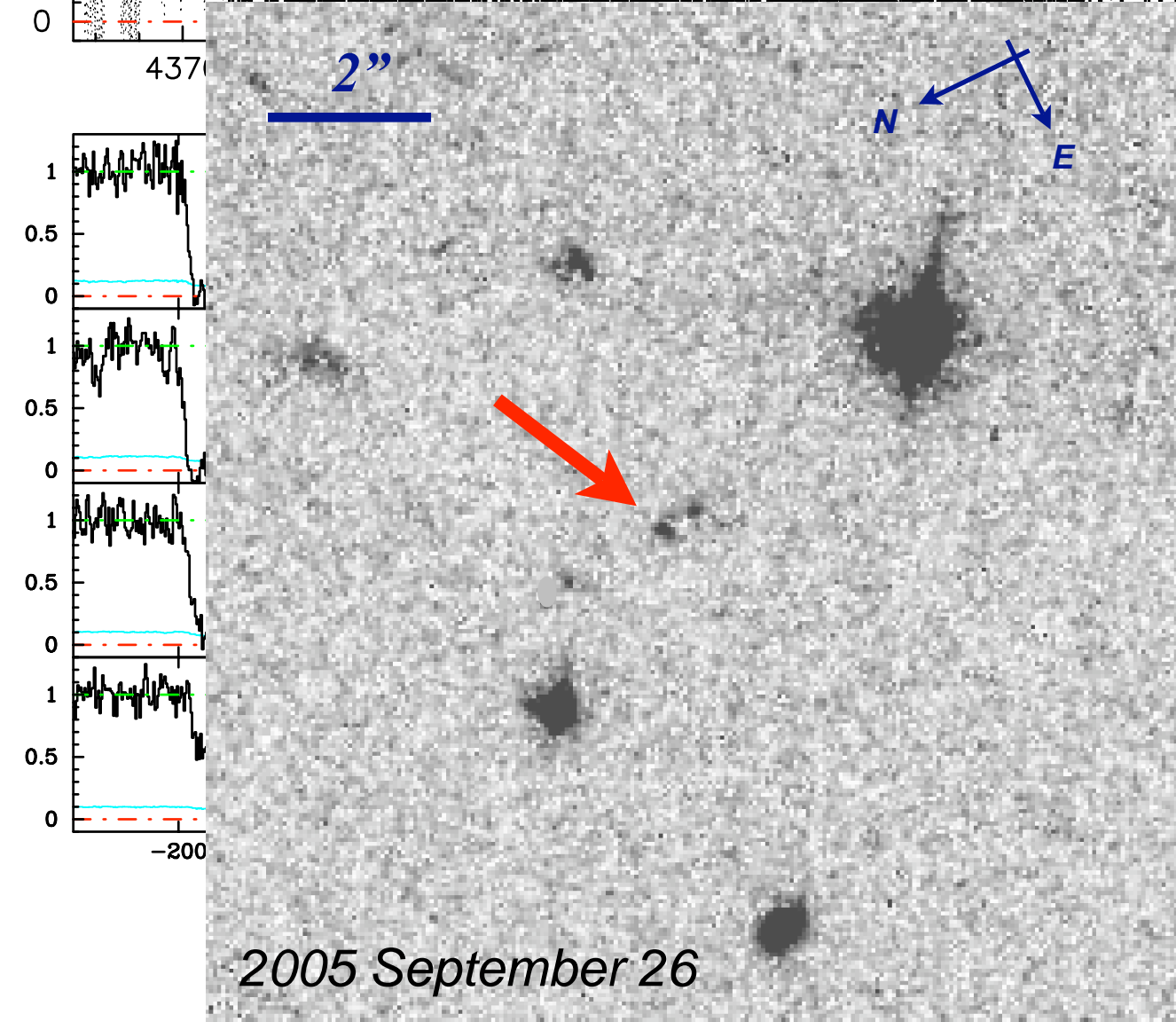
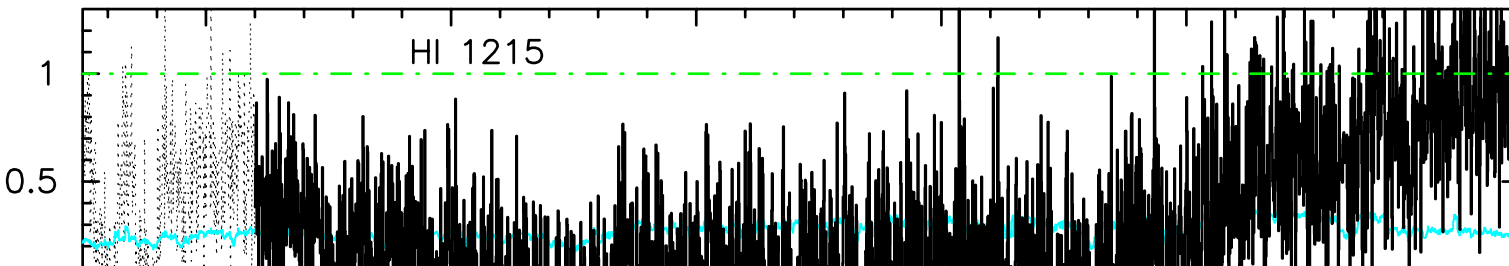
A Survey of GRB Host Galaxies at $z > 2$

GRB050820A @ $z = 2.61$

- $\log N(\text{HI}) = 21.0 \pm 0.1$
- $A_V = 0.08$
- $[\text{S}/\text{H}] = -0.63 \pm 0.11$
- $f_{\text{H}_2} < 10^{-6.5}$
- $[\text{Fe}/\text{H}] = -1.6 \pm 0.1$
- $\Sigma_{\text{SFR}} \sim 0.27 \text{ M}_\odot/\text{yr}/\text{kpc}^2$

- $M_{AB}(2000) - 5 \log h = -18.5 \pm 0.1$

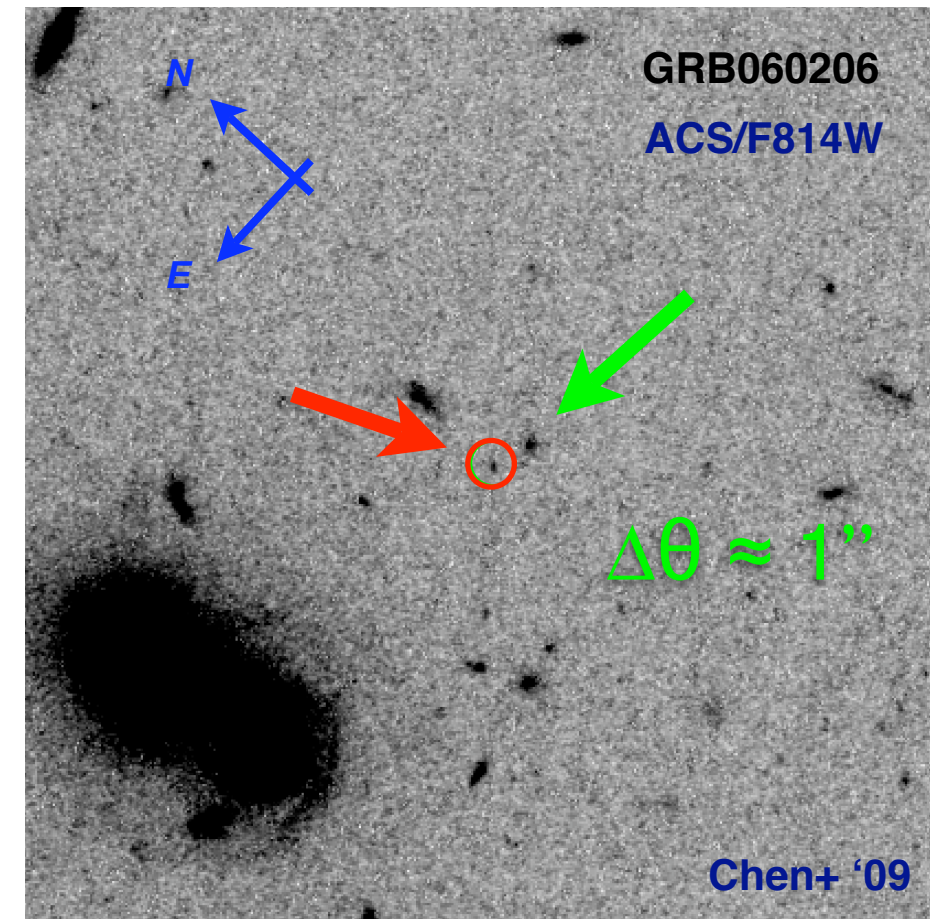
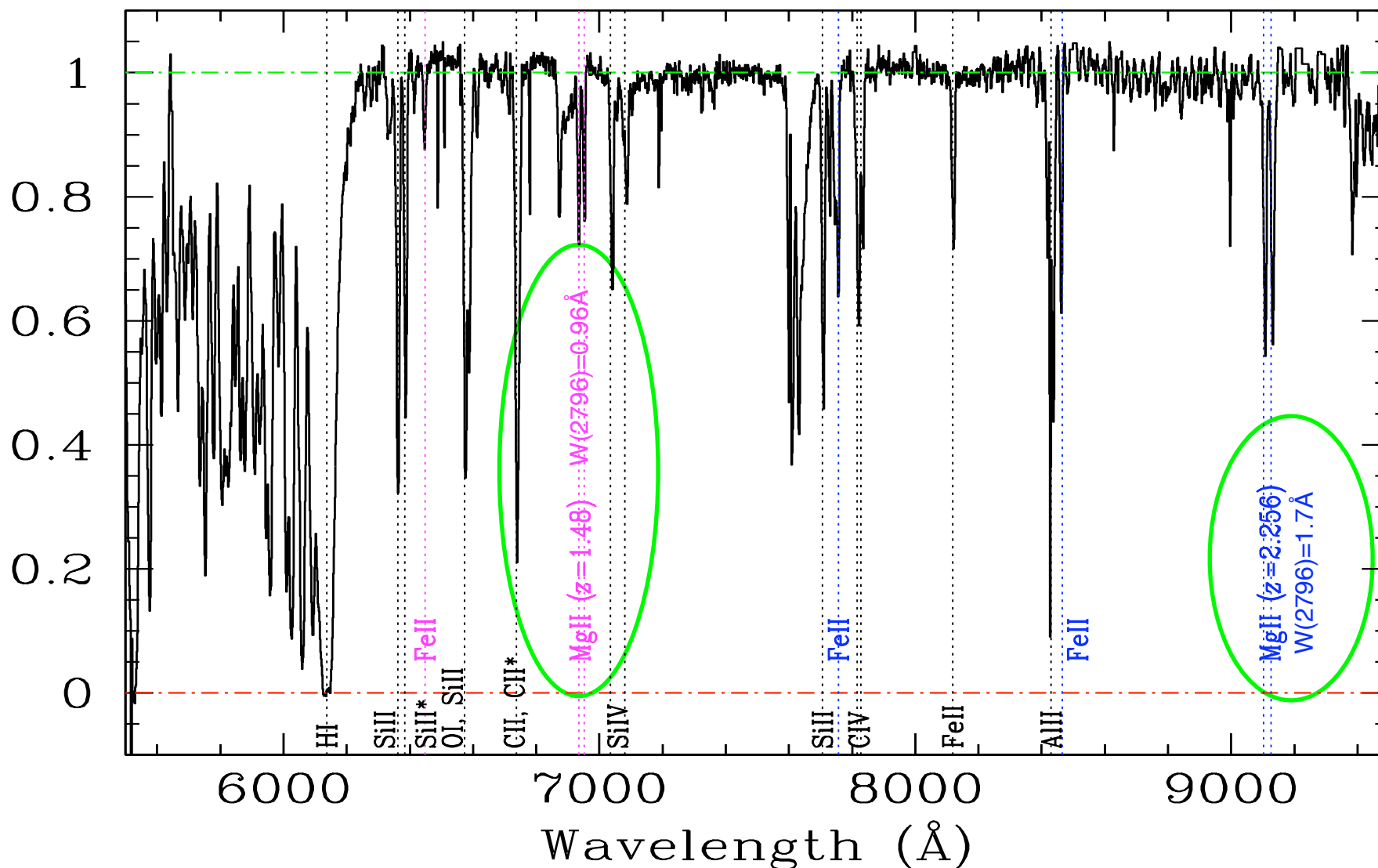
- $M_* = (0.9 \pm 1.0) \times 10^9 h^2 \text{ M}_\odot$



A Survey of GRB Host Galaxies at $z > 2$

GRB060206 @ $z = 4.048$

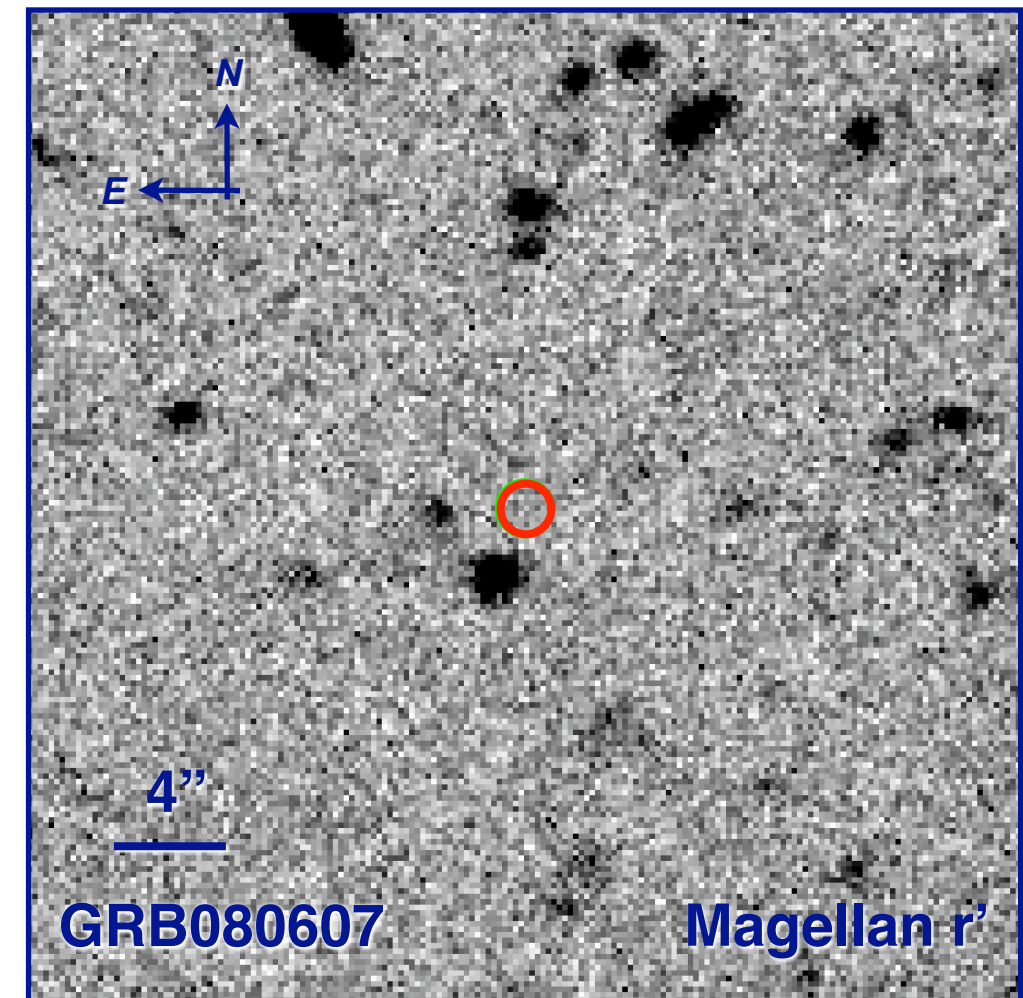
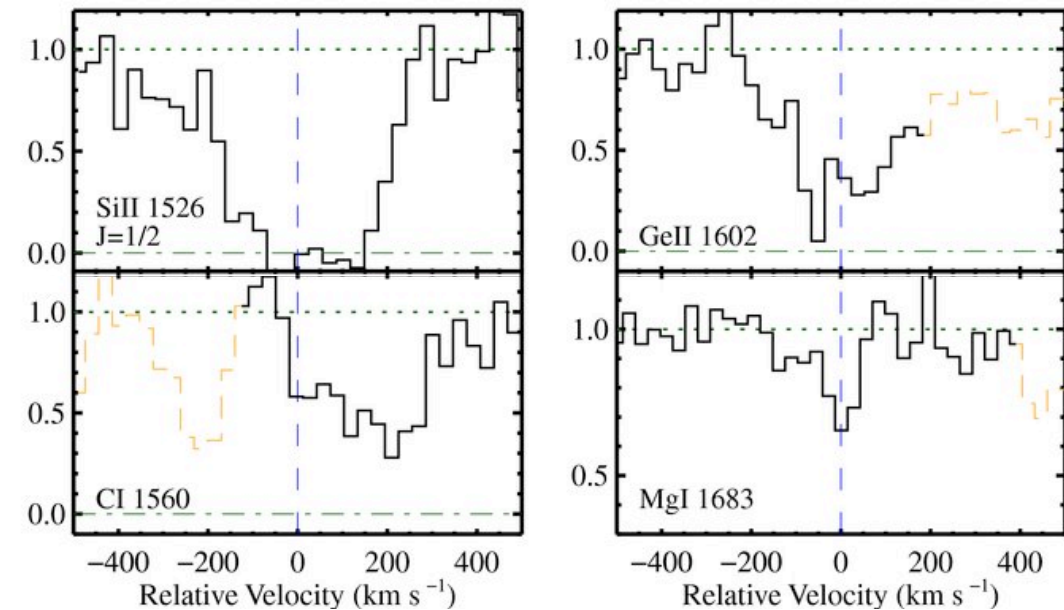
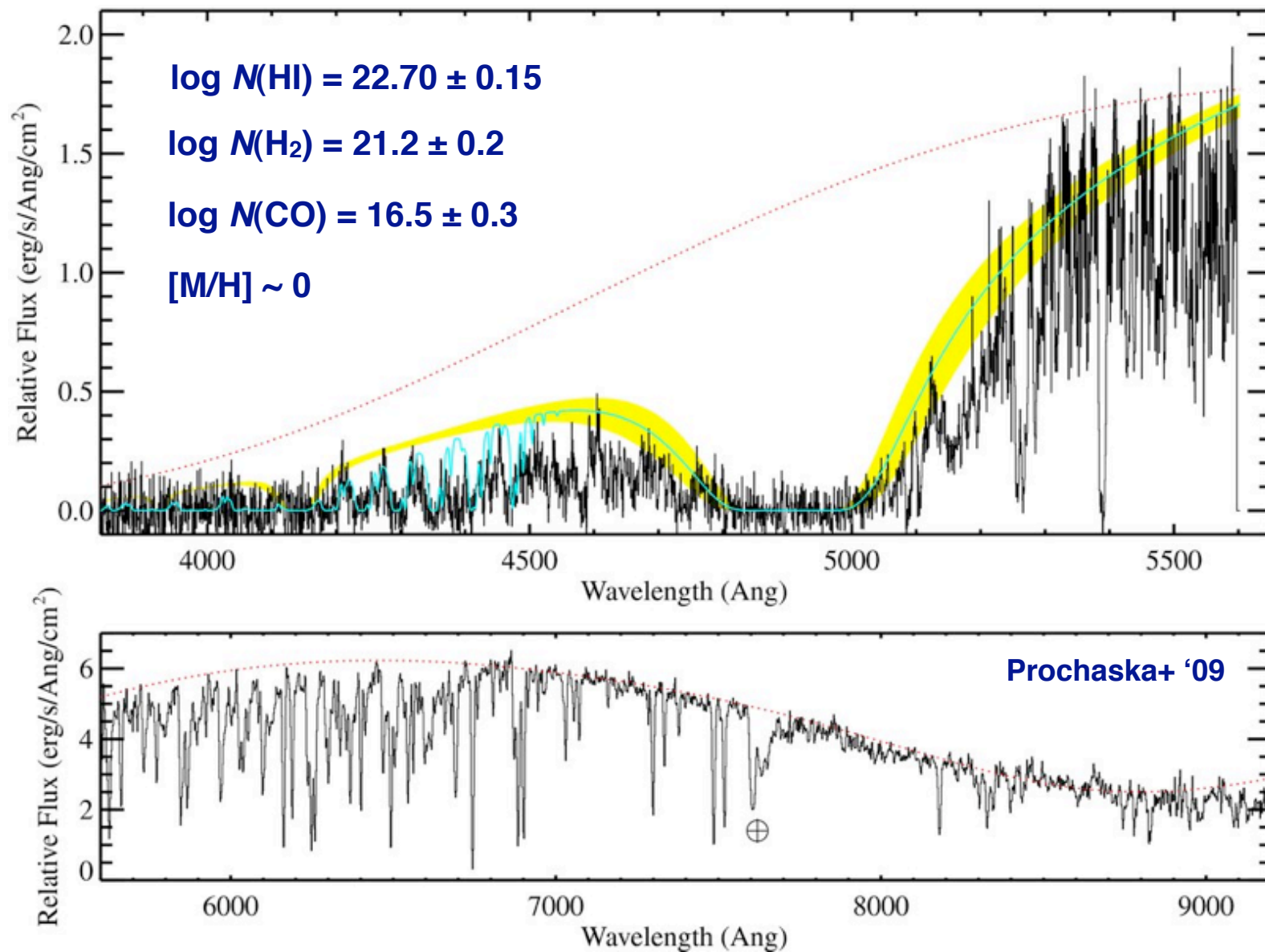
- $\log N(\text{HI}) = 20.85 \pm 0.10$
- $[\text{S}/\text{H}] = -0.85 \pm 0.15$ (Thöne+ '08)
- $f_{\text{H}_2} < 10^{-3.6}$ (Fynbo+ '06)
- $M_{\text{AB}}(1600) - 5 \log h = -17.7 \pm 0.1$



- $\Sigma_{\text{SFR}} \sim 0.56 \text{ M}_{\odot}/\text{yr}/\text{kpc}^2$

A Survey of GRB Host Galaxies at $z > 2$

GRB080607 @ $z = 3.0363$

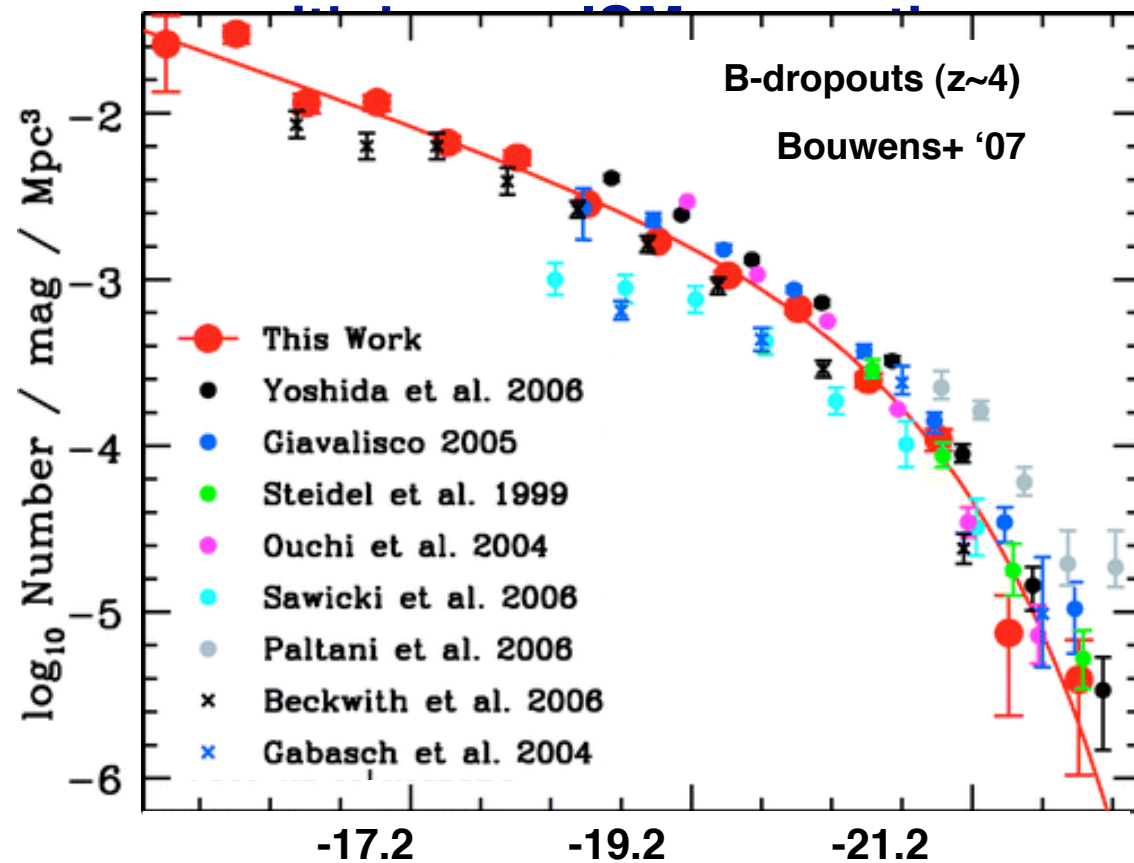


- $r' > 27.5$
- $M_{AB}(2000) - 5 \log h > -17.3$

Connecting Absorption Properties with Stellar Light at $z > 2$

◆ The luminosity distribution function

A sample of 15 GRB hosts at $z > 2$

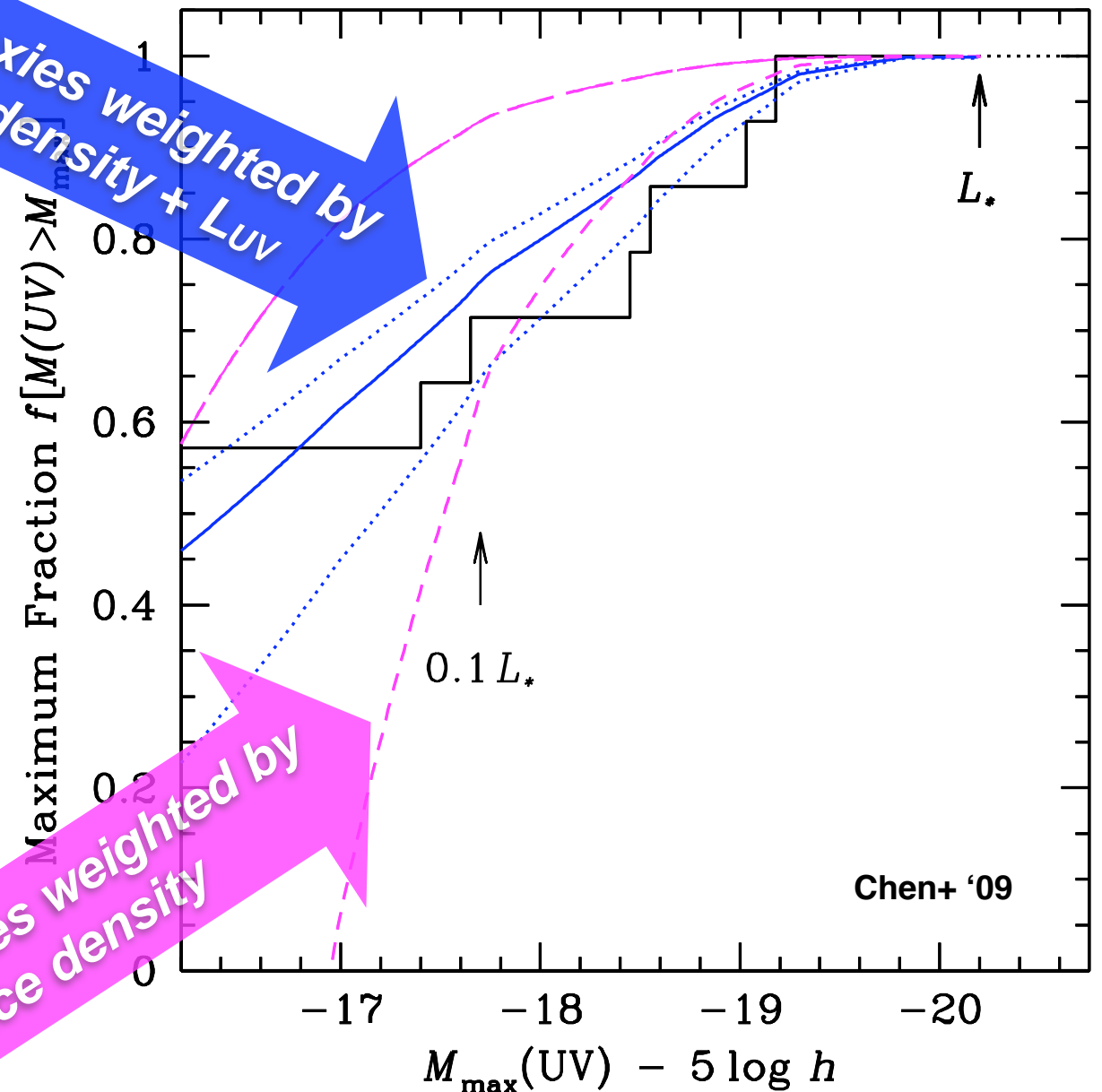


UV luminosity distribution of GRB host galaxies is consistent with a SFR weighted galaxy population

7 detections + 8 upper limits

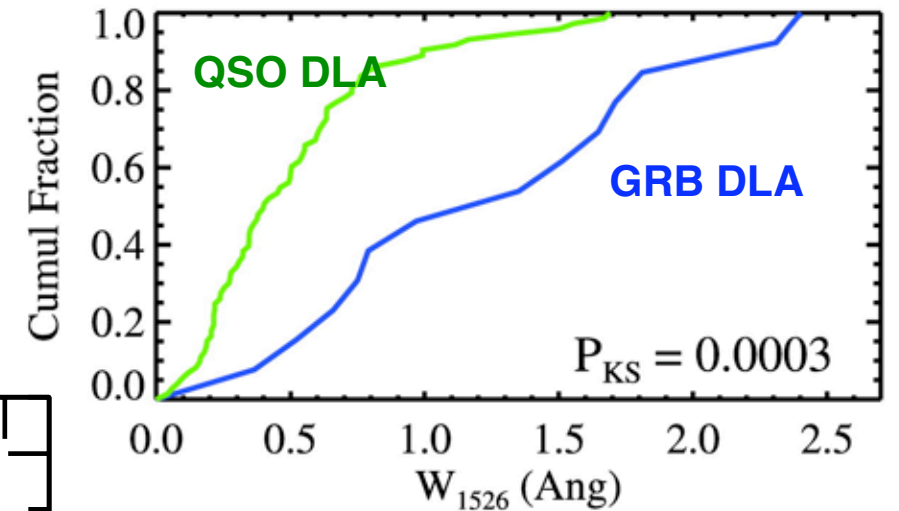
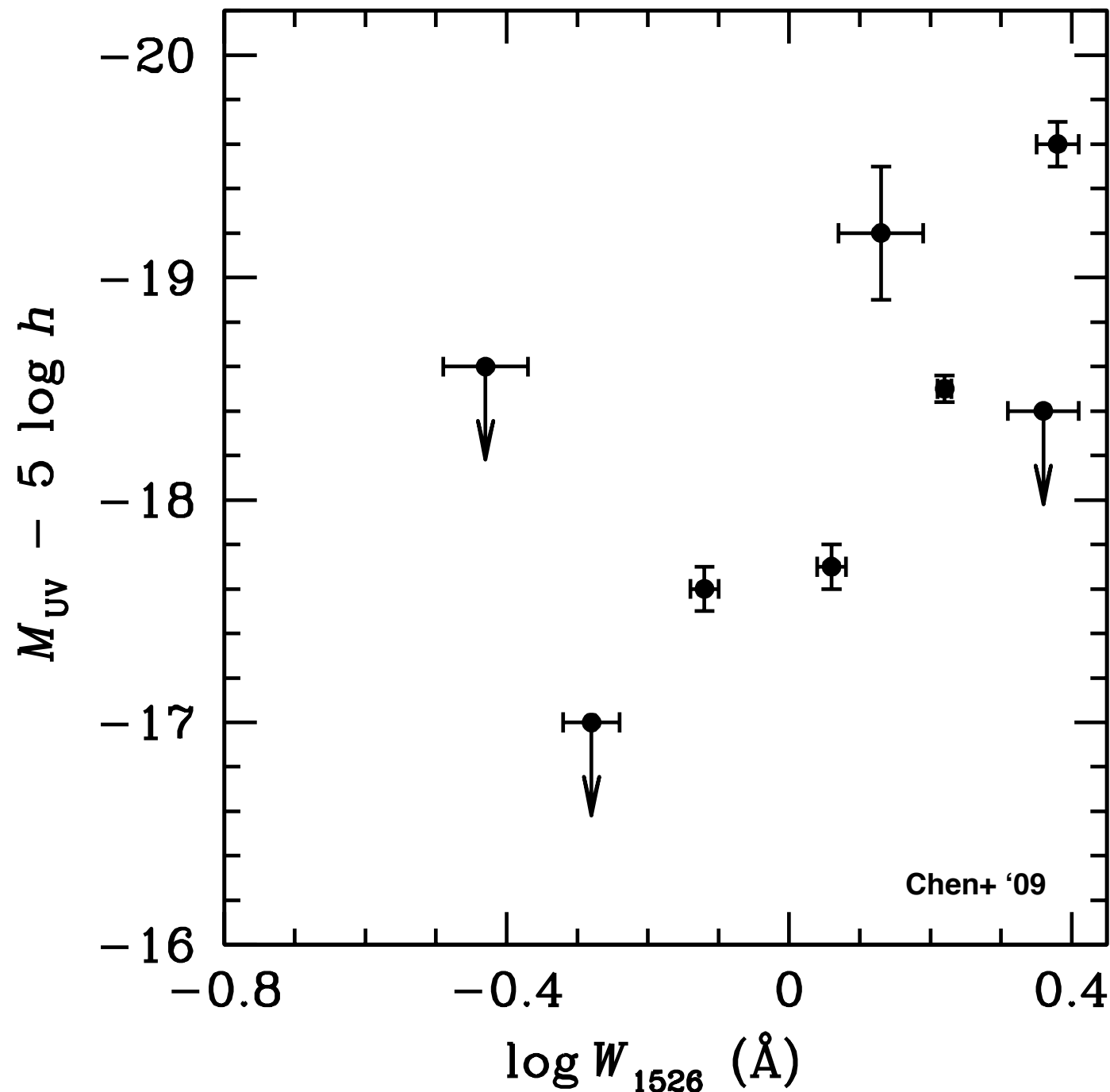
field galaxies weighted by space density + L_{UV}

field galaxies weighted by space density



Connecting Absorption Properties with Stellar Light at $z > 2$

◆ Correlation between W_{1526} and L_{UV}

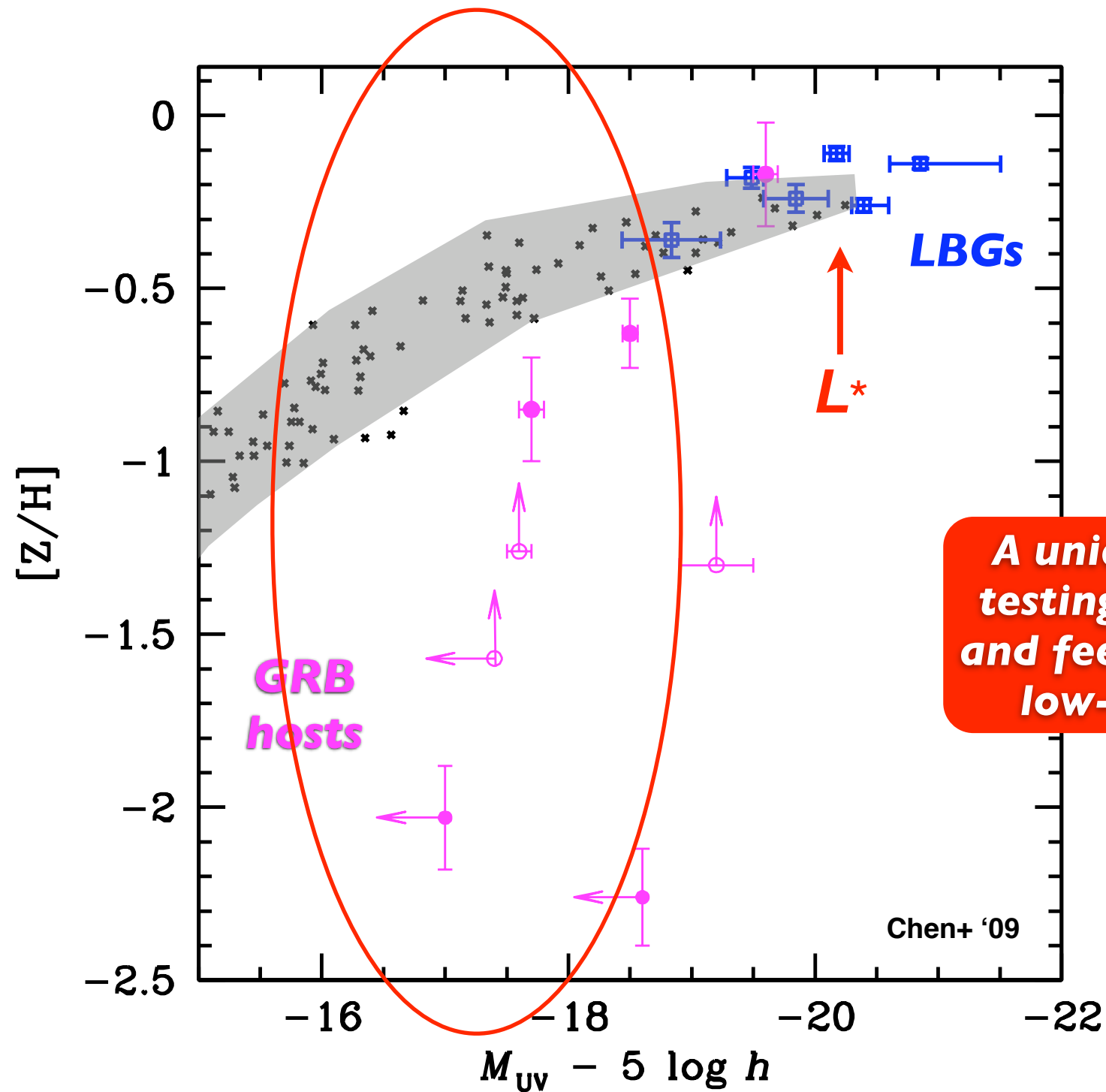


starburst outflow or gravity driven velocity field ?

near-IR spectra of the host galaxies are needed!

Connecting Absorption Properties with Stellar Light at $z > 2$

◆ Correlation between metallicity and L_{UV}



■ LBGs from Erb et al. (2006)

x Simulations of LBGs from
Sommer-Larsen & Fynbo (2008)

Summary

- ✦ The sample of long-duration GRB host galaxies is best described as a *SFR weighted field galaxy population* with a median luminosity of $0.1 L^*$.
- ✦ *UV luminosity* of GRB hosts appears to be *correlated with the velocity spread* of absorption gas clumps. Follow-up near-IR spectroscopy of the hosts is necessary to determine the origin of the velocity field.
- ✦ The *luminosity-metallicity relation* observed in GRB hosts offers a unique window for testing star formation and feedback recipes in distant low mass galaxies.