

# GRBs AS TRACERS OF (SFR) AND THE DISTANT ISM

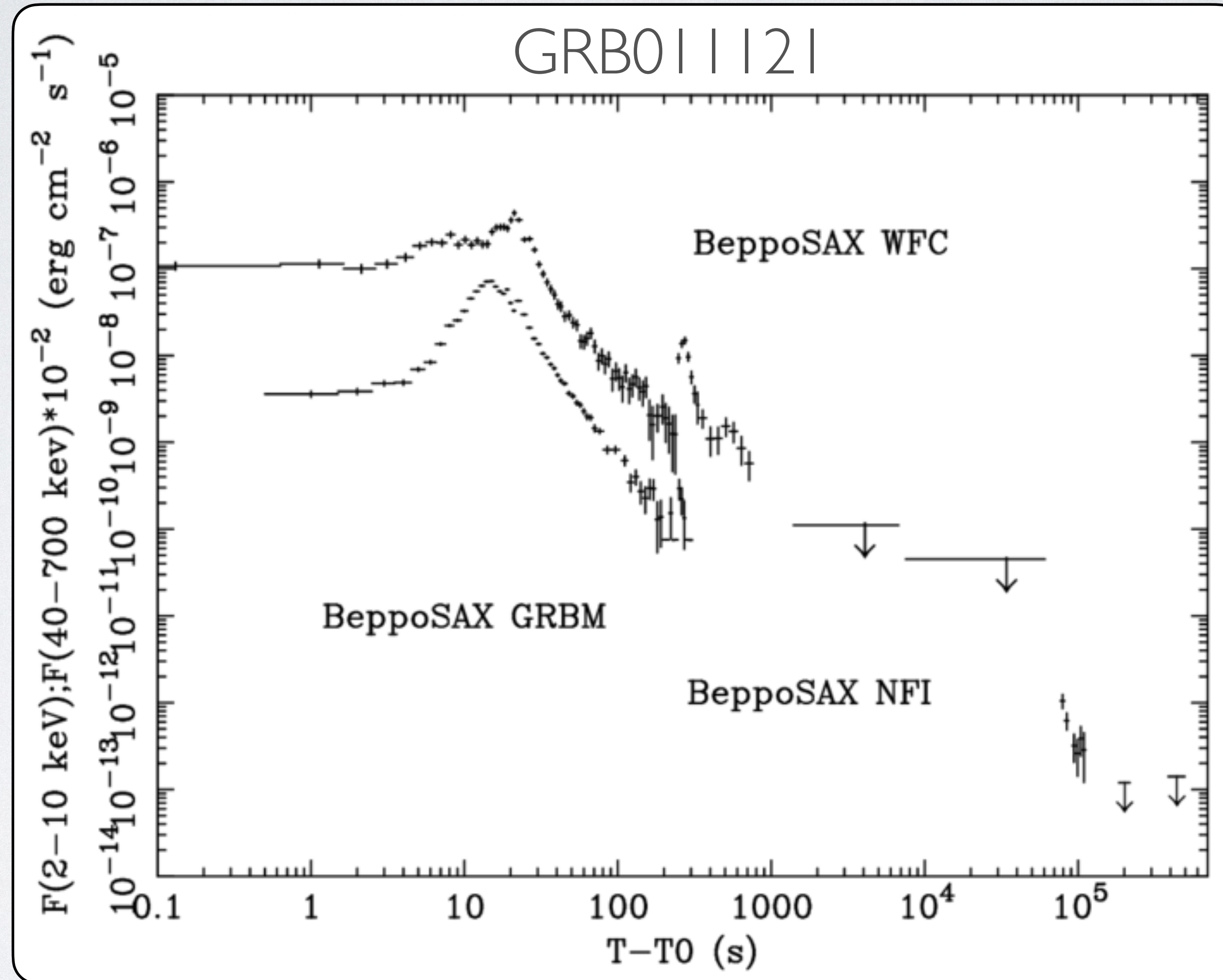
Patricia Schady, Lise Christensen, Rob Yates, Annalise De Cia, Kasper Heintz, **Anne Inkenhaag**, Tanmoy Laskar, Nial Tanvir, **Berk Topçu** and STARGATE collaboration



UNIVERSITY OF  
**BATH**



# Closing the time gap with

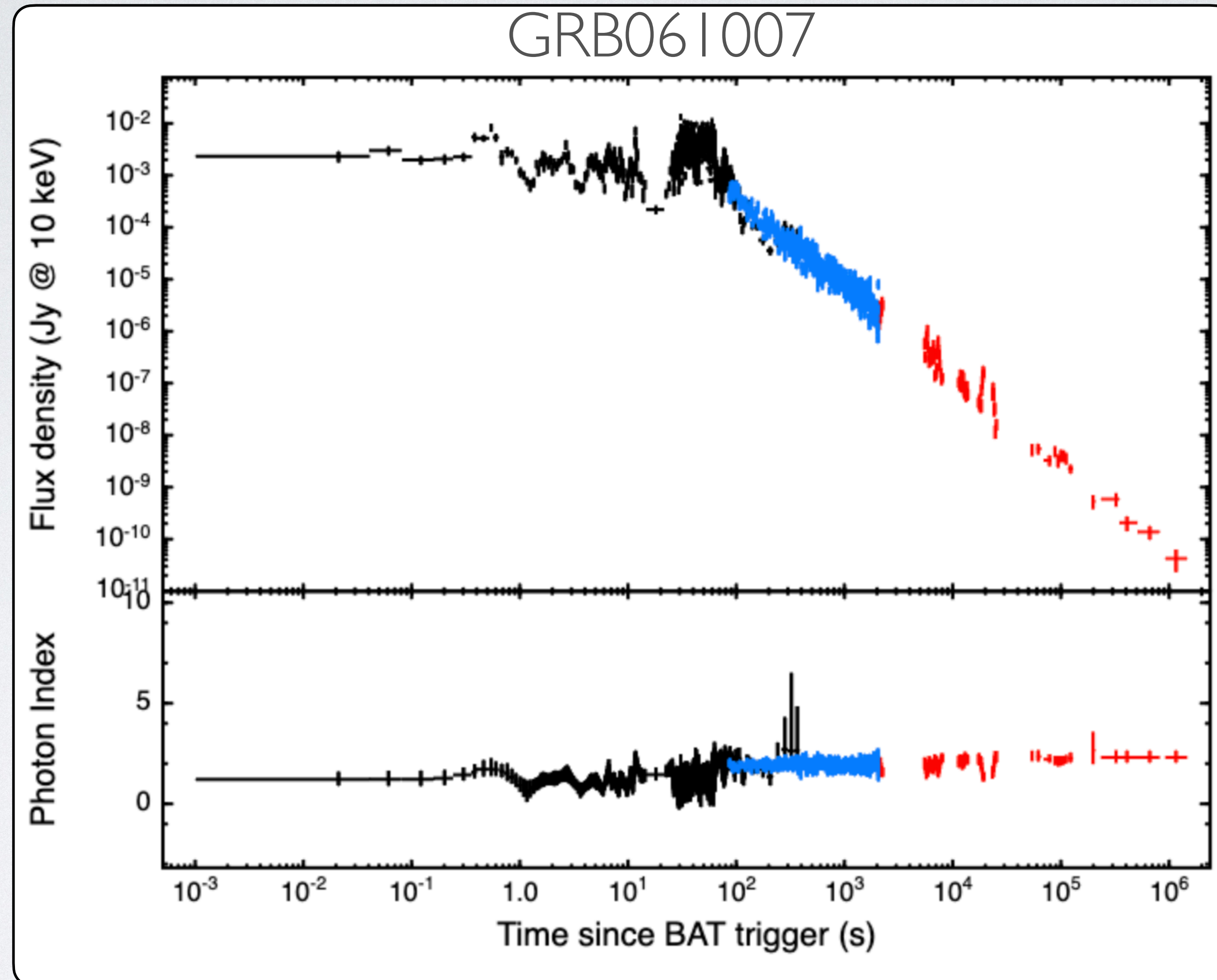


Piro+05





# Closing the time gap with

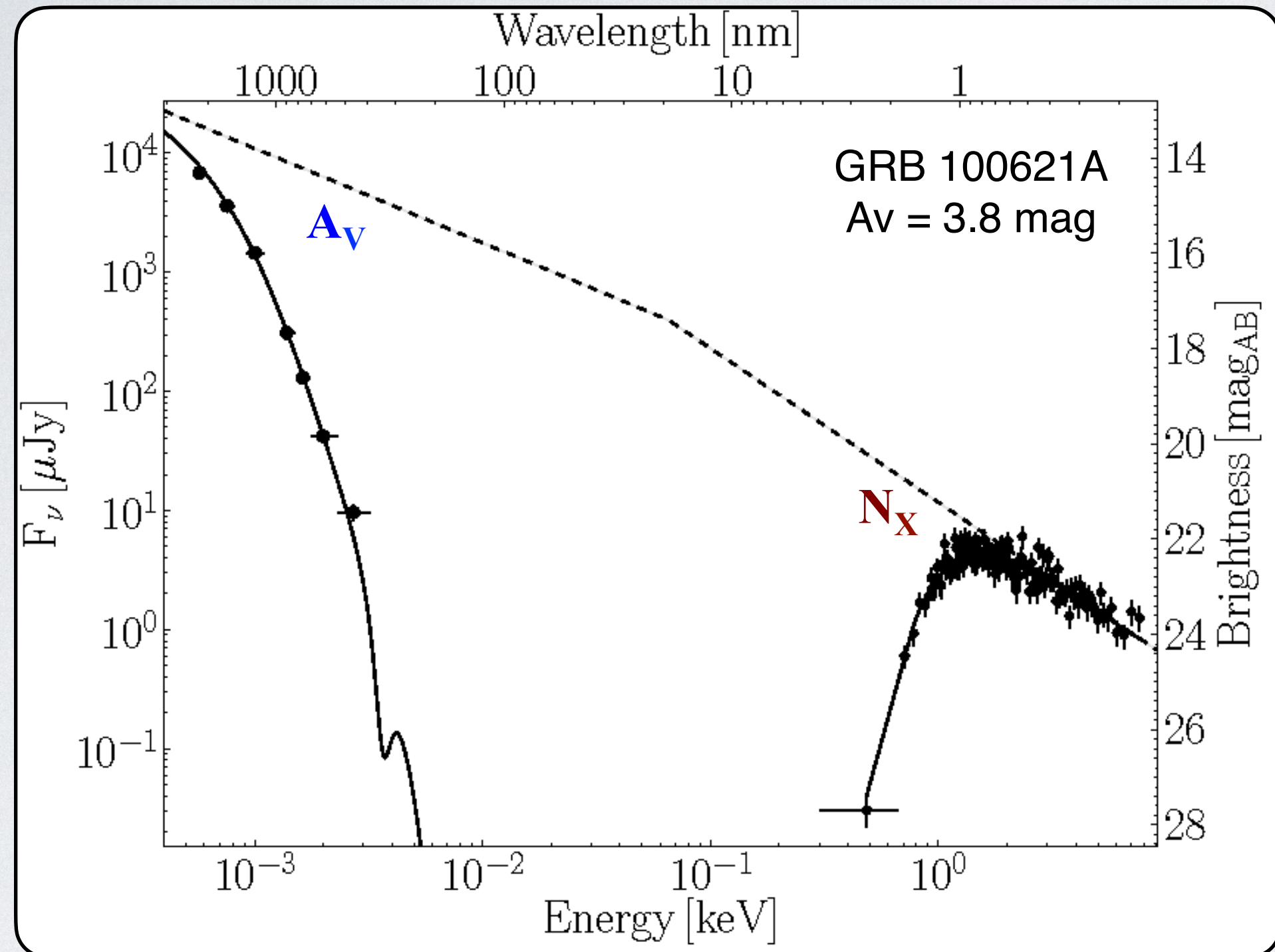


Leicester Swift-XRT GRB lightcurve repository

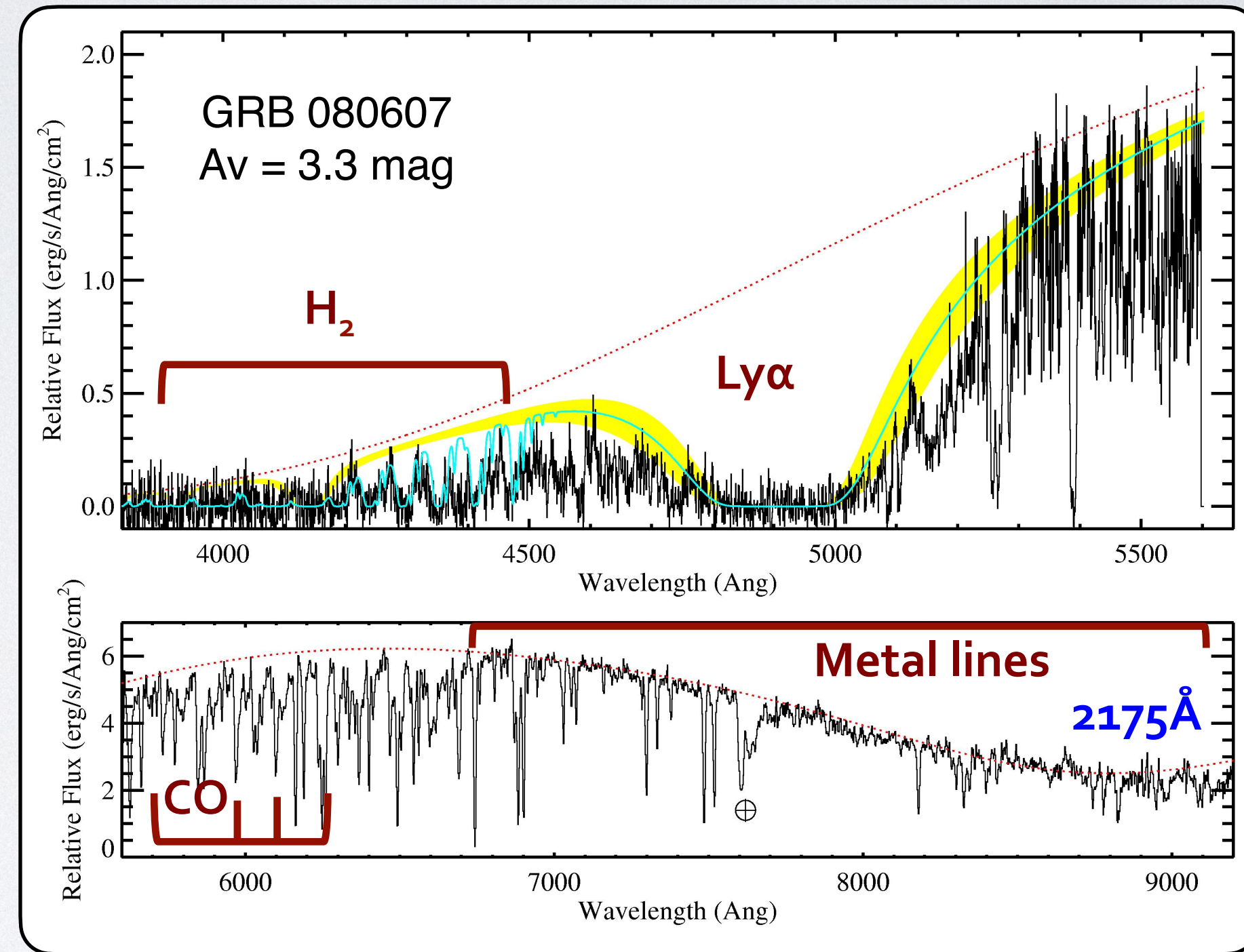




# Probes of ISM in high-z galaxies



Krühler+11



Prochaska+09

High quality GRB afterglow data provide wealth of information on host ISM

Dust-to-metals ratio (Schady+07,+10; De Cia+13, 16, 18; Wiseman+17, Zafar+13)

ISM metallicity and ionisation state (Fox+08; Cucchiara+15; Heintz+23, Schady+11)

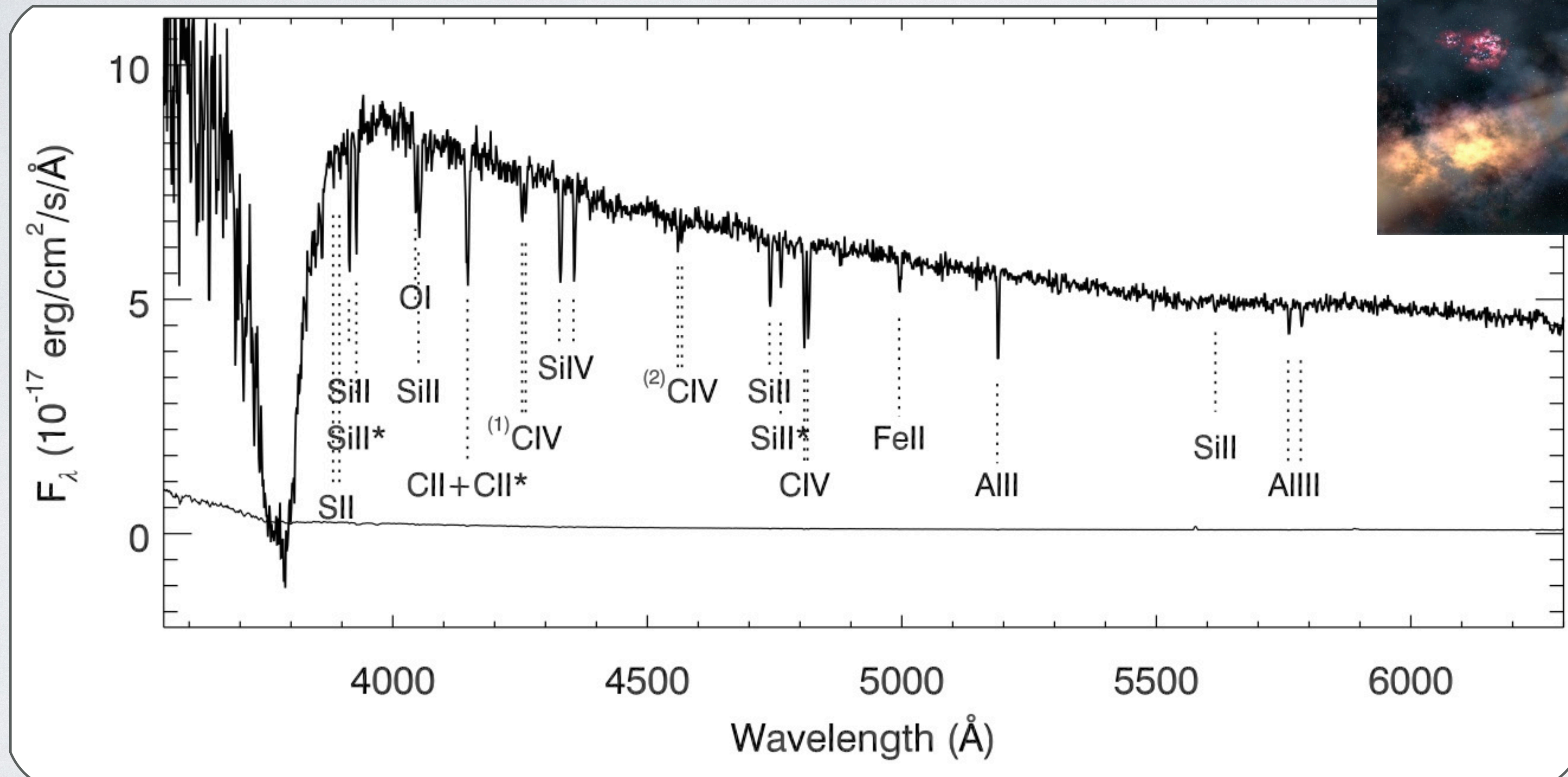
Dust extinction curves and depletion (Bolmer+18; Schady+12; Zafar+11, 12, 18)

Molecular gas fraction at high-z (Bolmer+19; Heintz+21; Ledoux+09; Tanga+15)





# PROBES OF NEUTRAL GAS METALLICITY

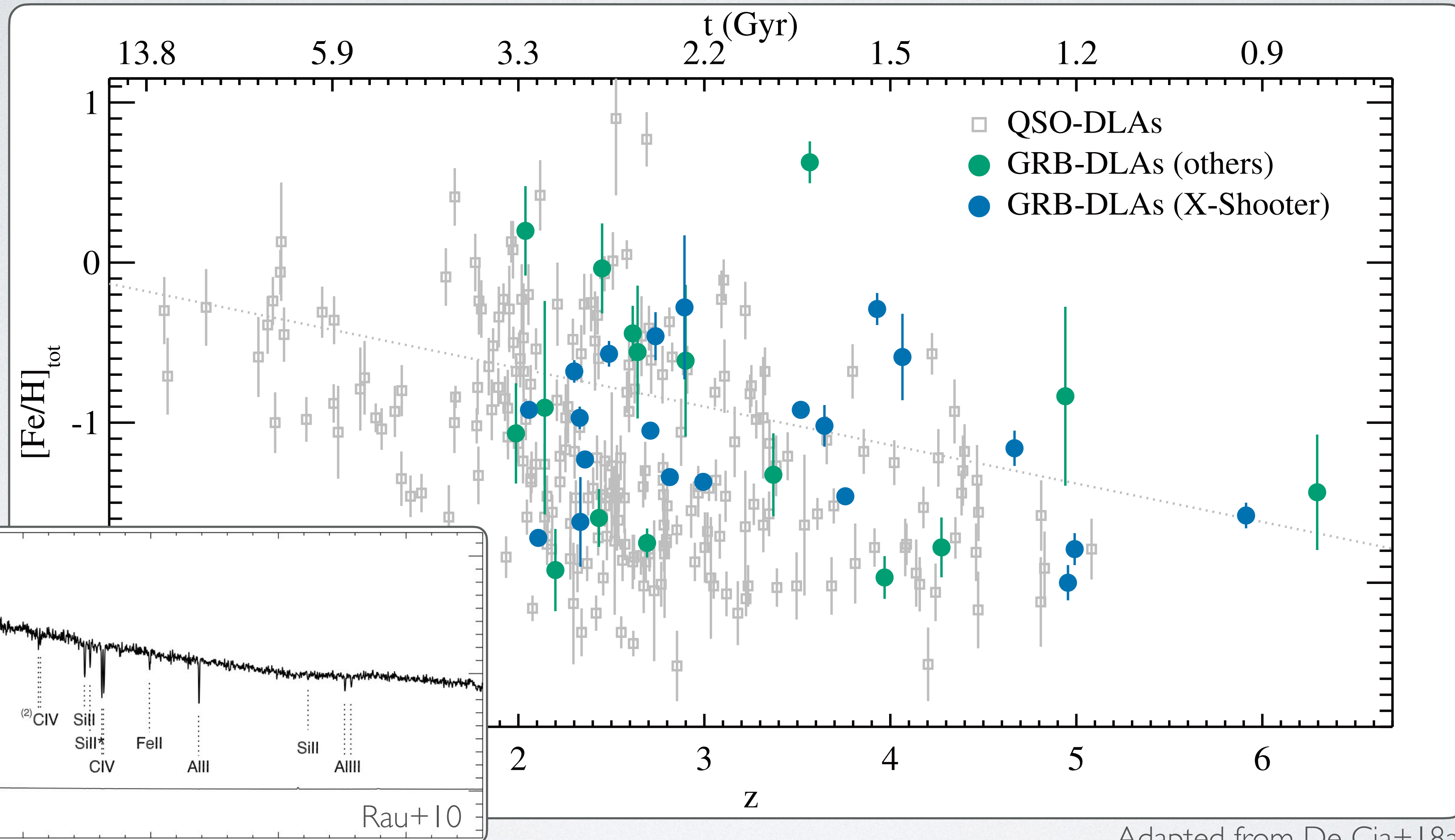


Rau+10





# ABSORPTION METALLICITY EVOLUTION

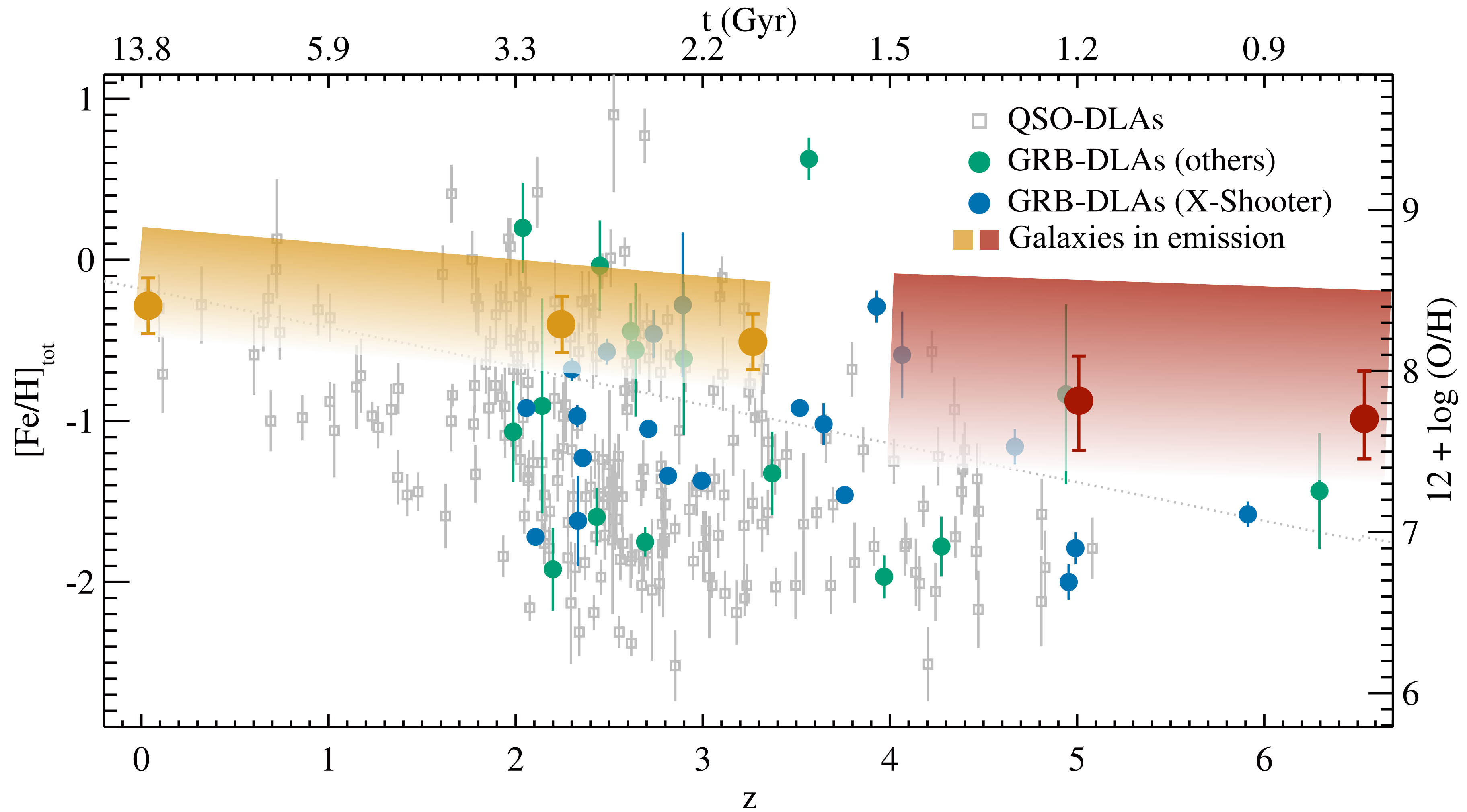


Adapted from De Cia+18a



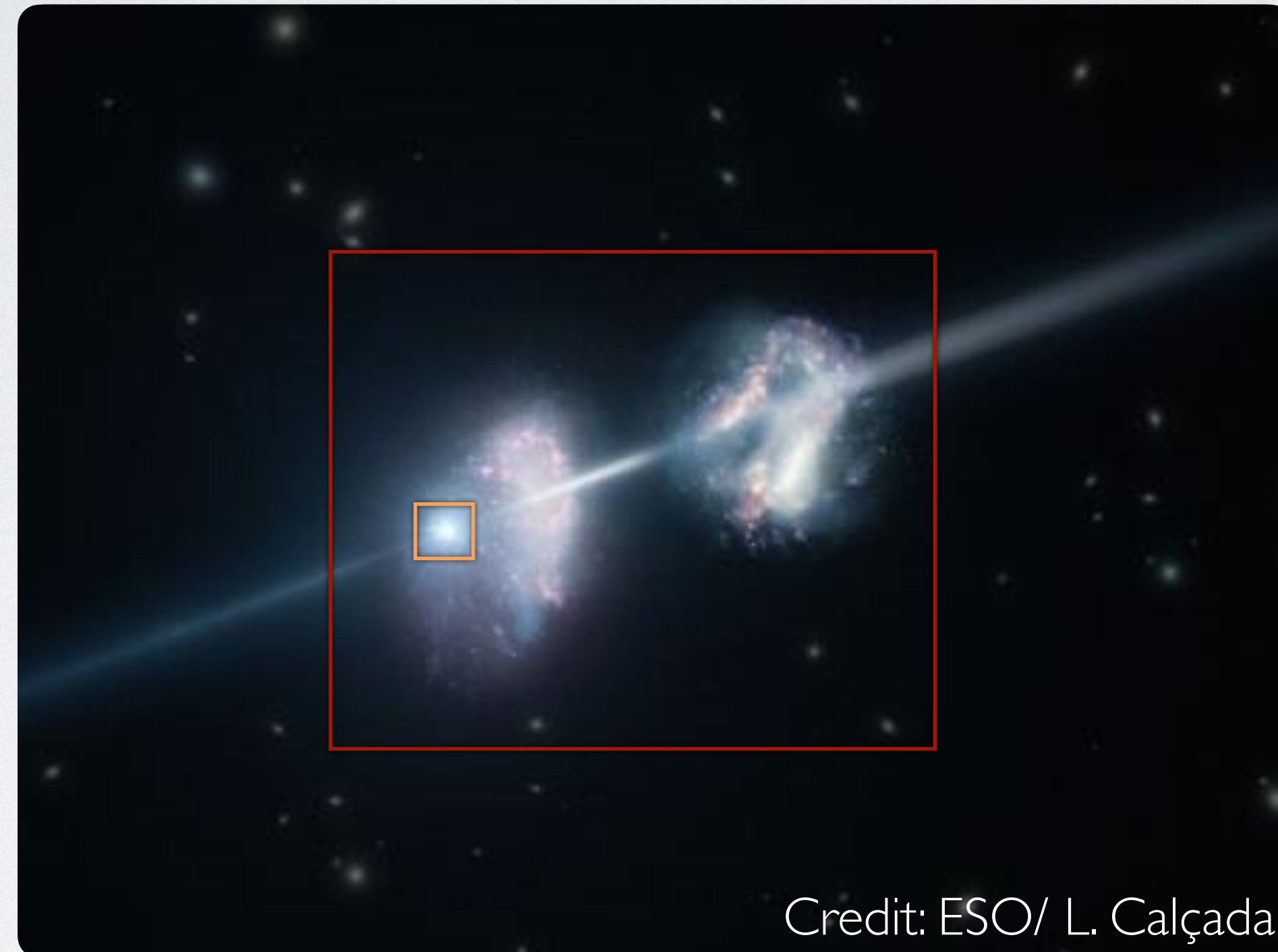


# COSMIC METALLICITY EVOLUTION





# ABSORPTION VS. EMISSION PROBES



Credit: ESO/ L. Calçada

## Absorption probes:

- Probe galaxy neutral gas
- More sensitive than emission probes
- Relatively model-independent
- Single sightline through galaxy
- Rare

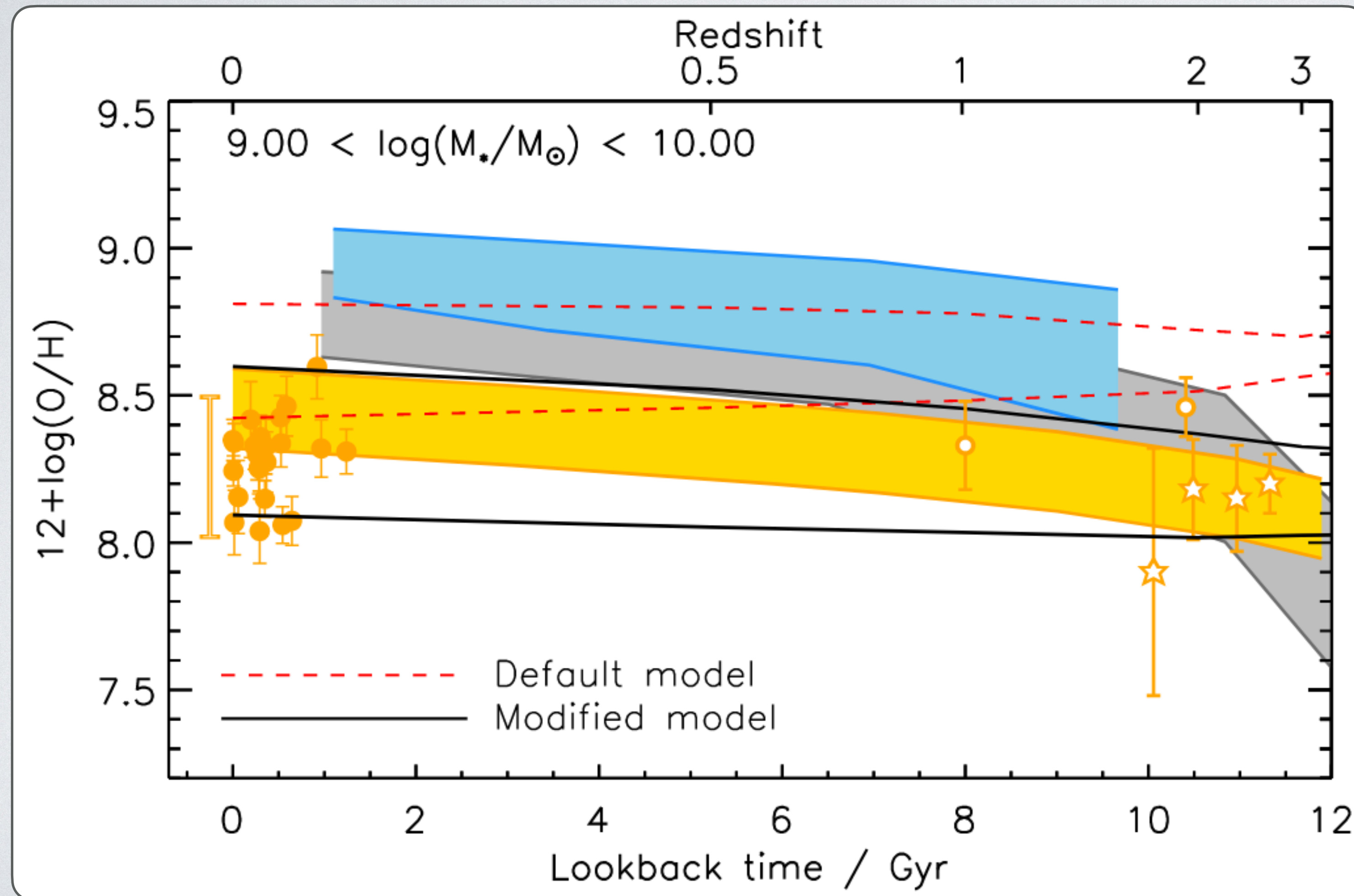
## Emission probes:

- Probe galaxy star forming regions
- Luminosity-dependent probes
- Very model-dependent
- Galaxy-integrated light
- Common





# COMBINING EMISSION AND ABSORPTION LINES



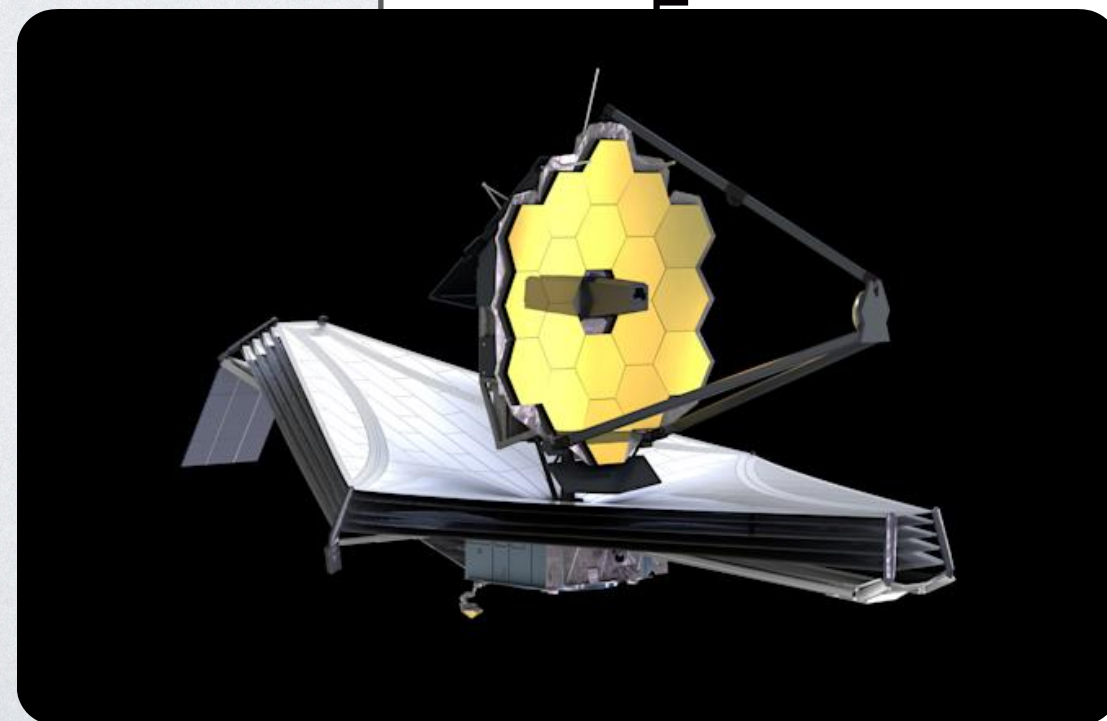
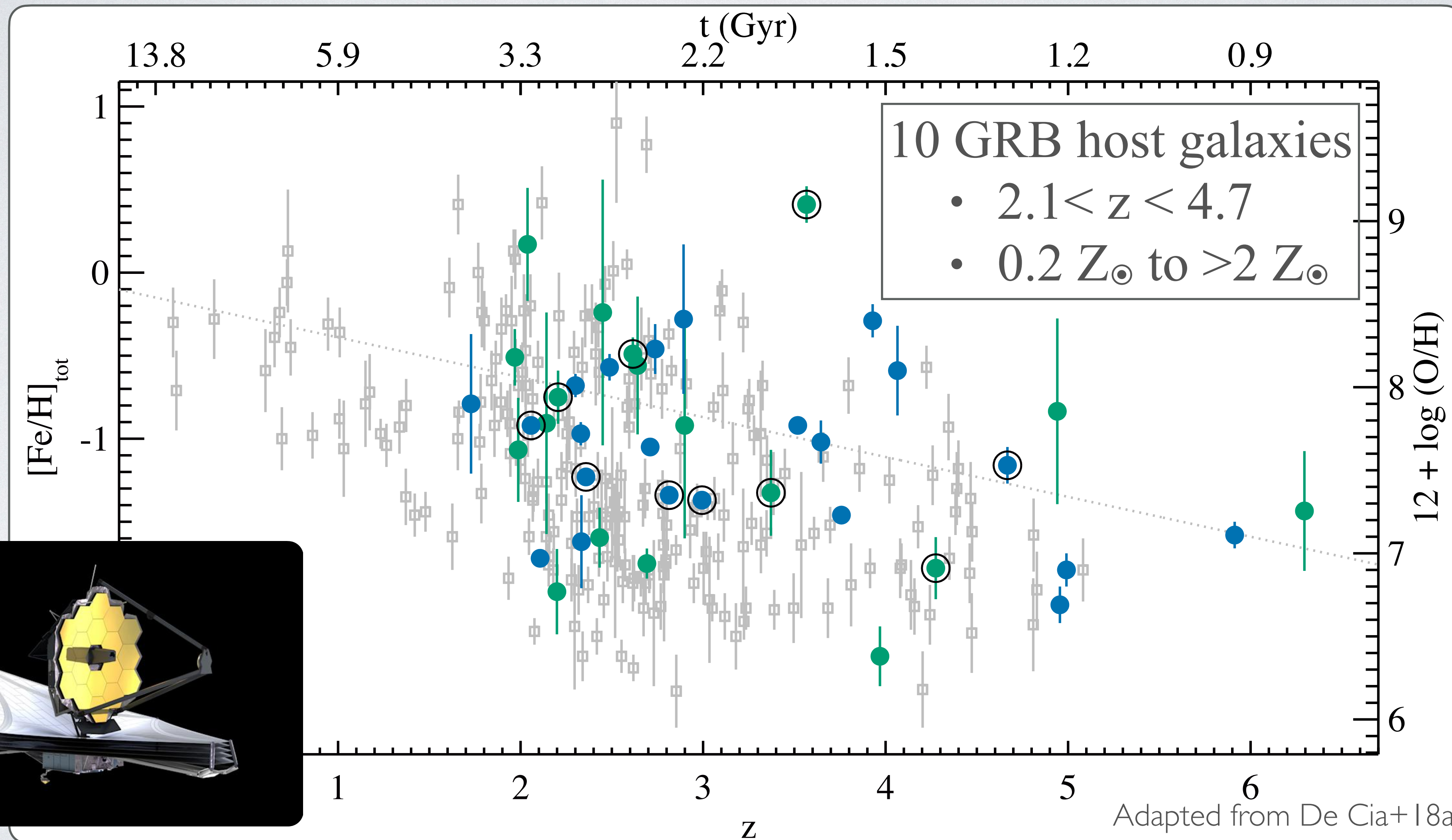
- What are absorber characteristic properties?
- How does metallicity of multi-phase ISM compare?
- What is effect of pencil beam probe?

Yates+21





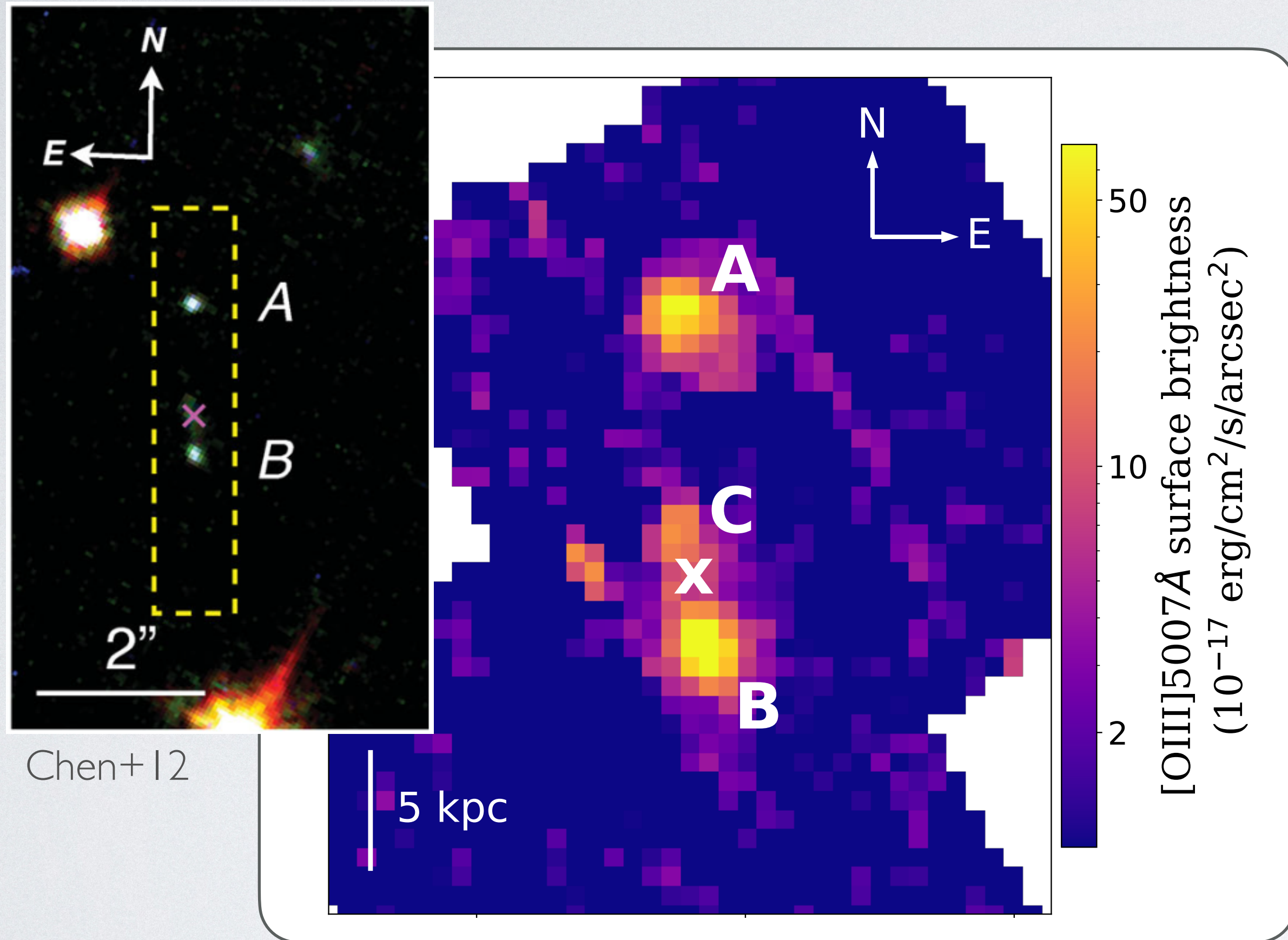
# EMISSION LINE METALLICITIES WITH JWST



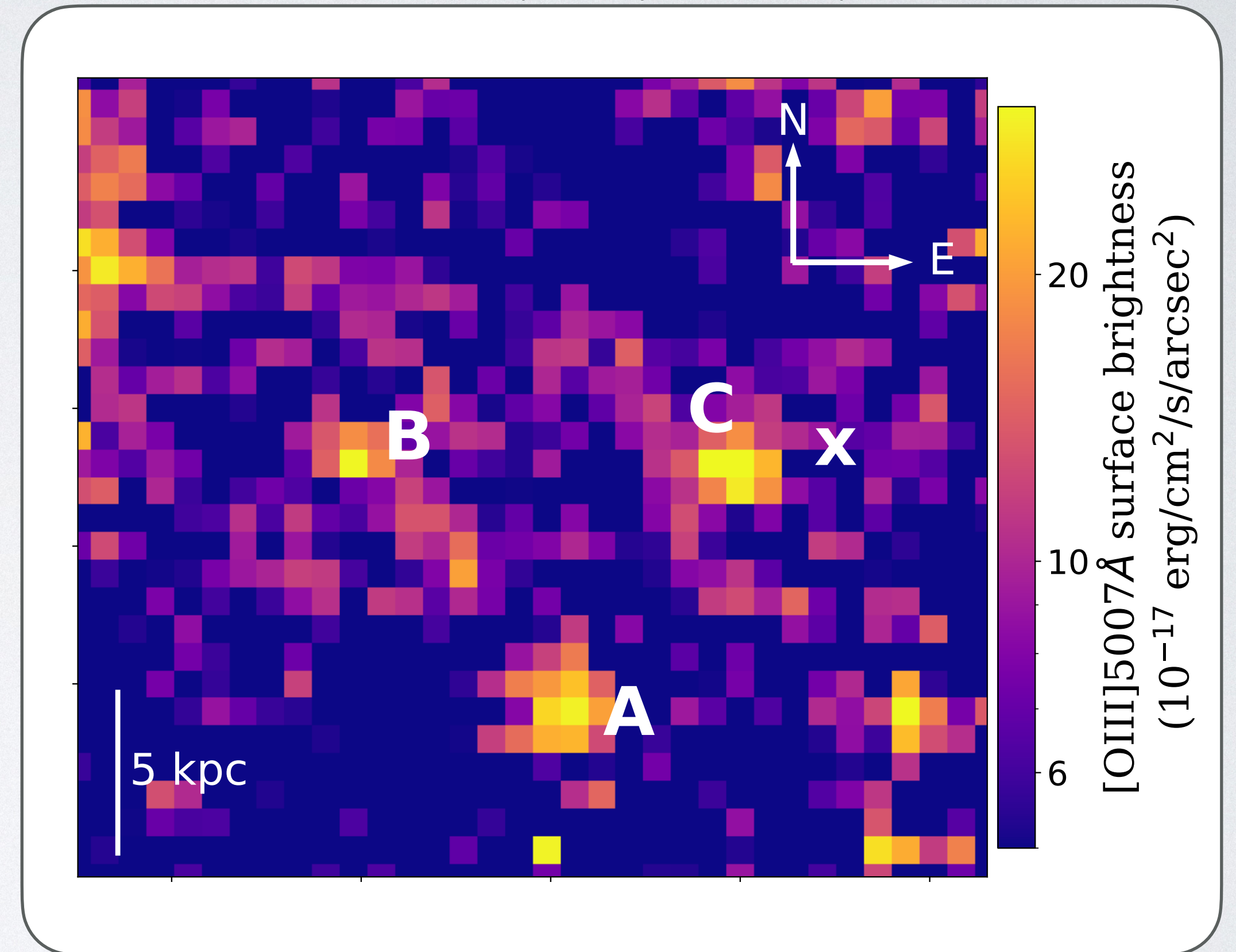


# JWST NIRSPEC IFS OBSERVATIONS

Schady+24 (see also Topçu+25, submitted)



GRB050820A Host Galaxy at  $z=2.613$

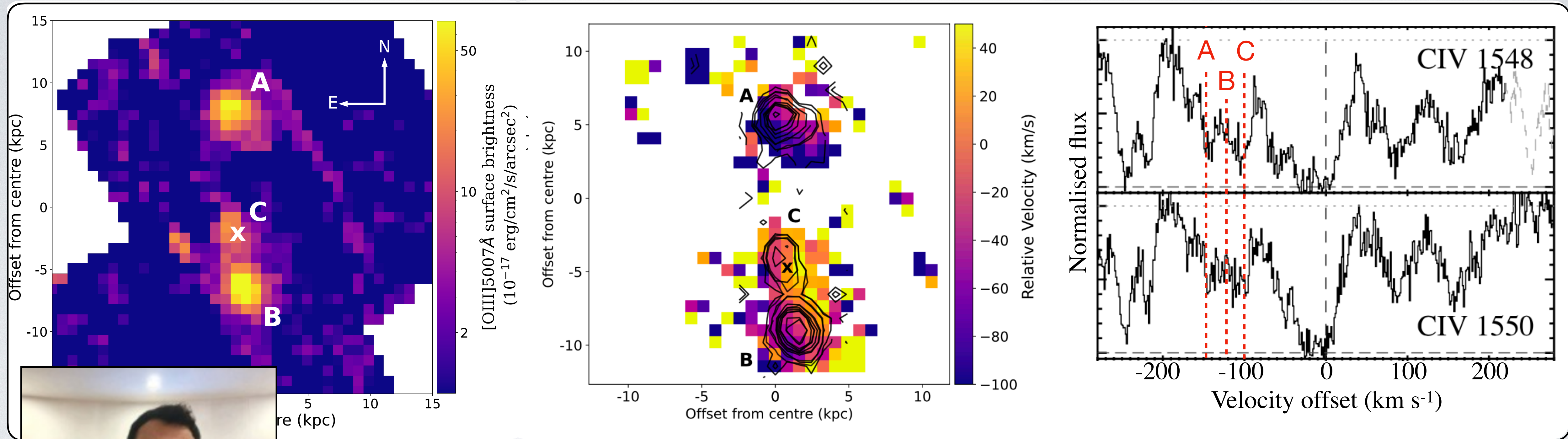


GRB150403A Host Galaxy at  $z=2.057$





# GRB HOSTS: BUILDING A 3D PICTURE



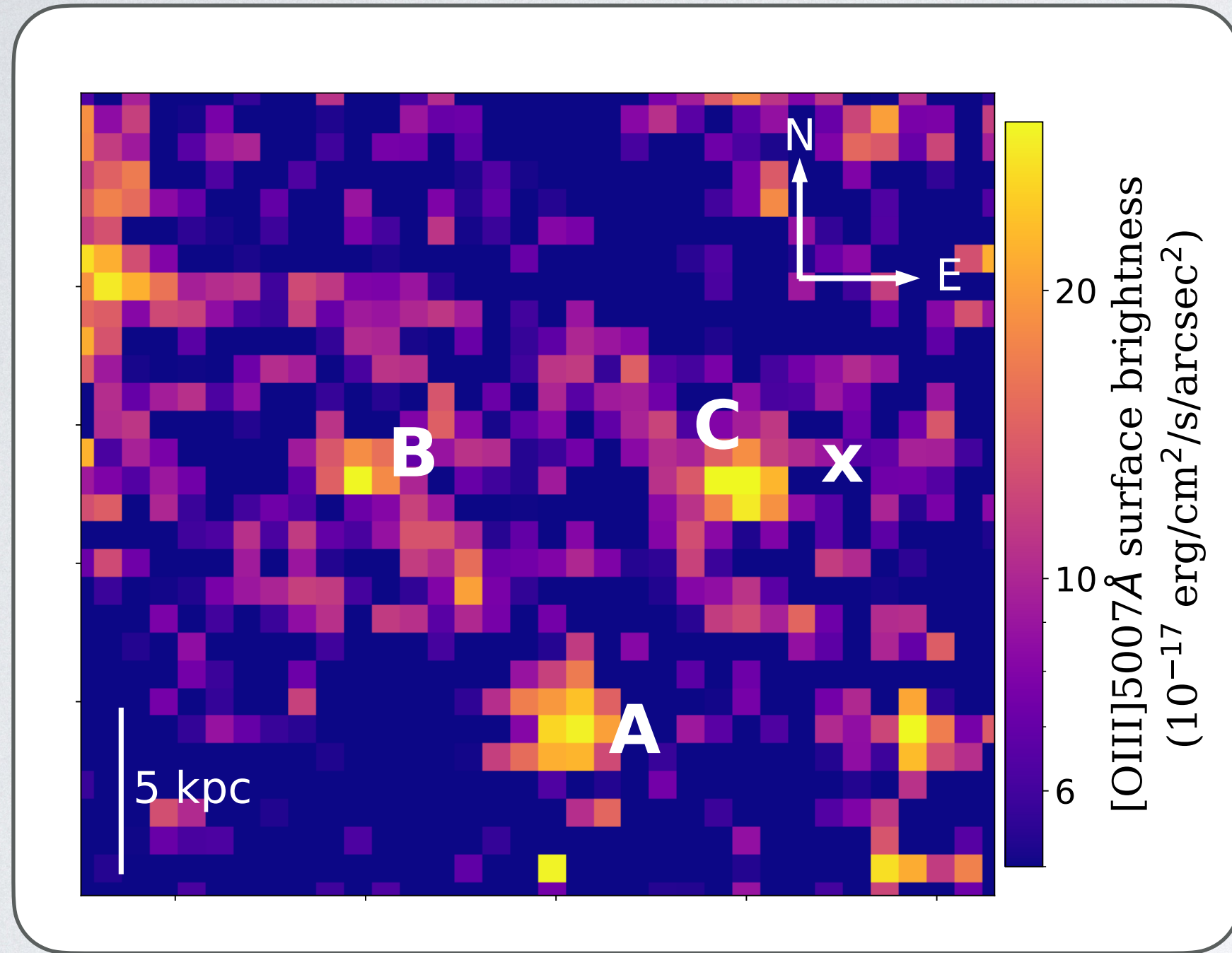
Schady+24, Chen+12, Topçu+submitted





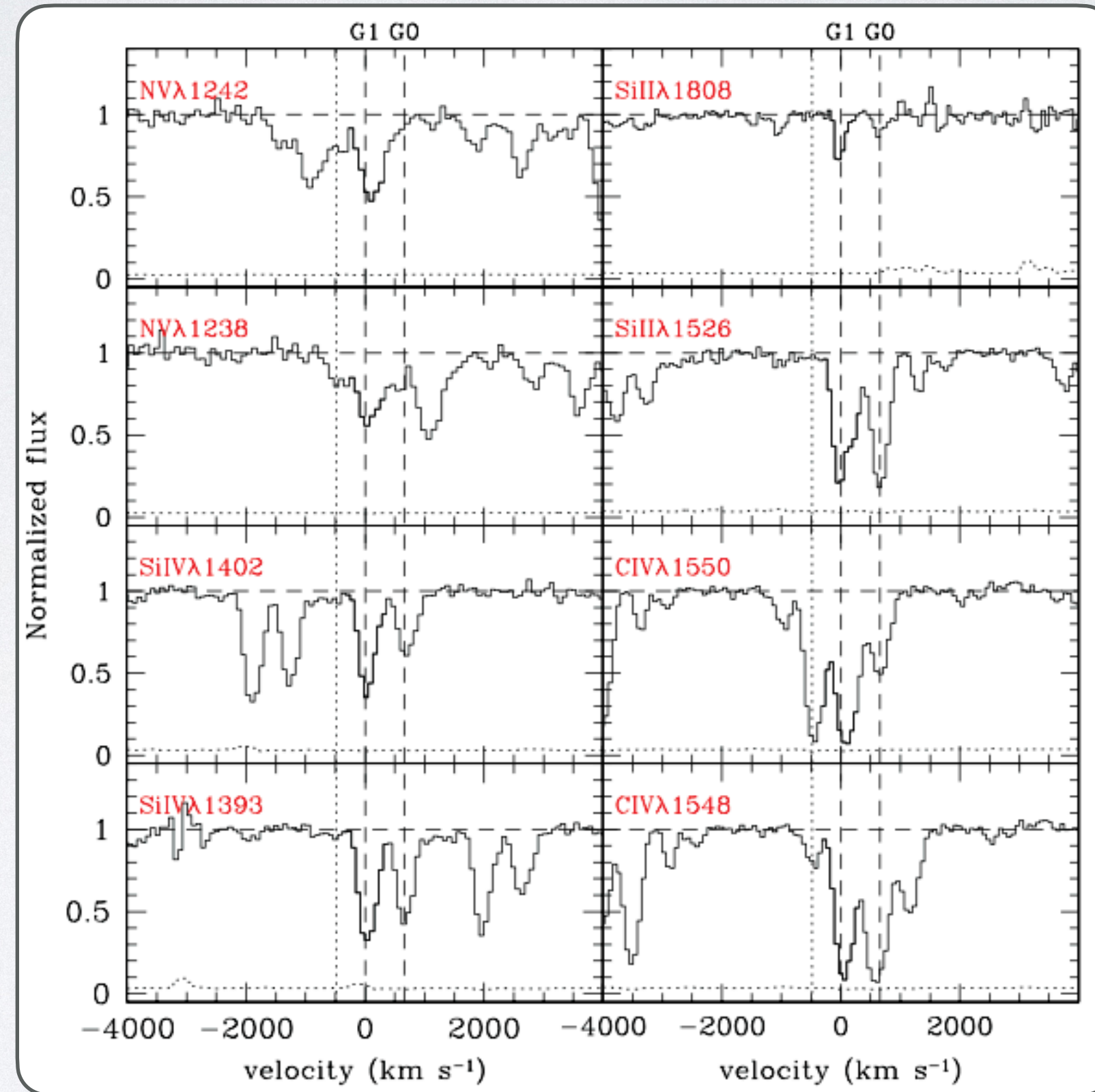
# AN ABUNDANCE OF INTERACTING SYSTEMS?

GRB150403A

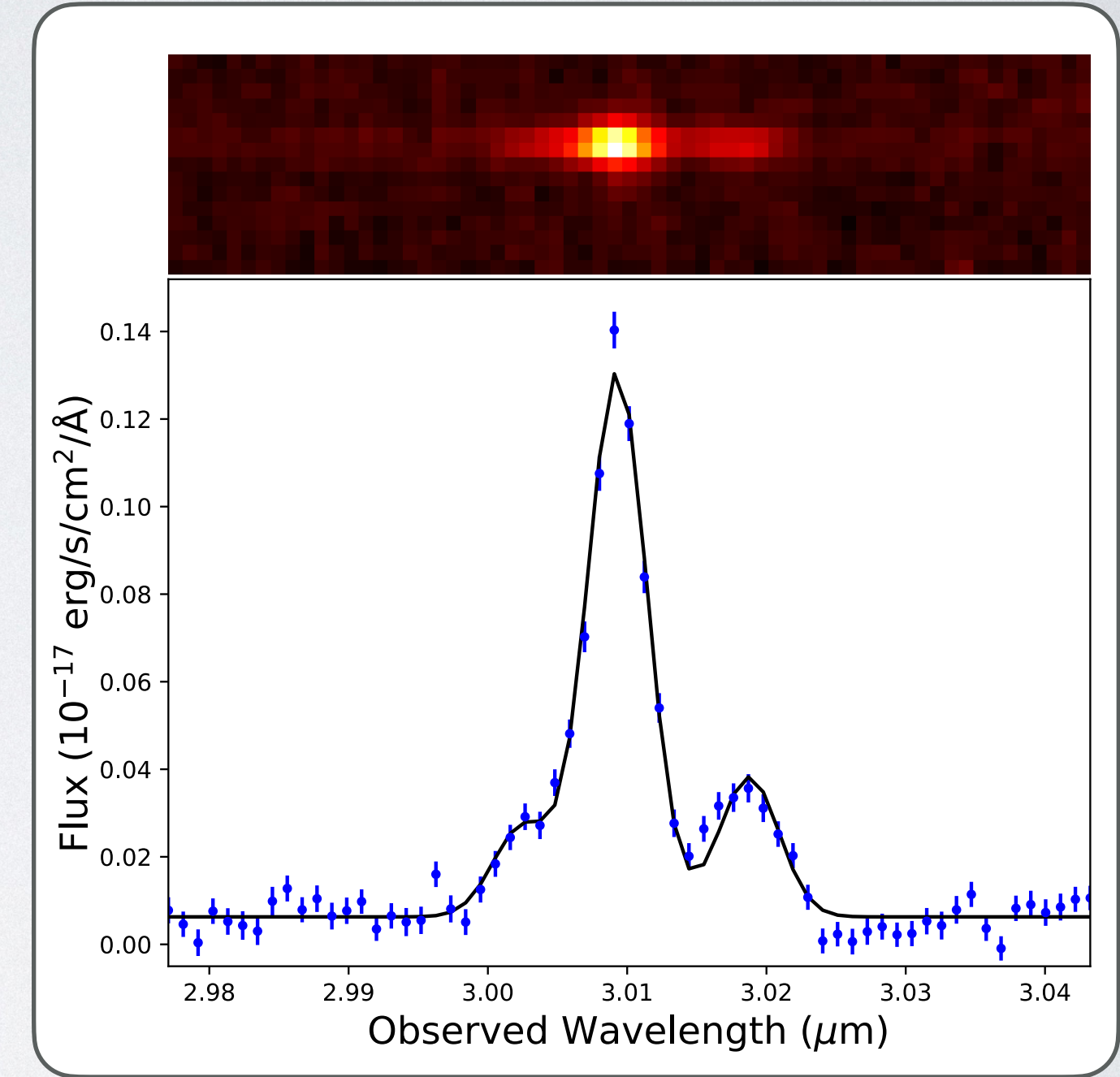


Schady+24, Topçu+submitted

GRB090323



Savaglio+12



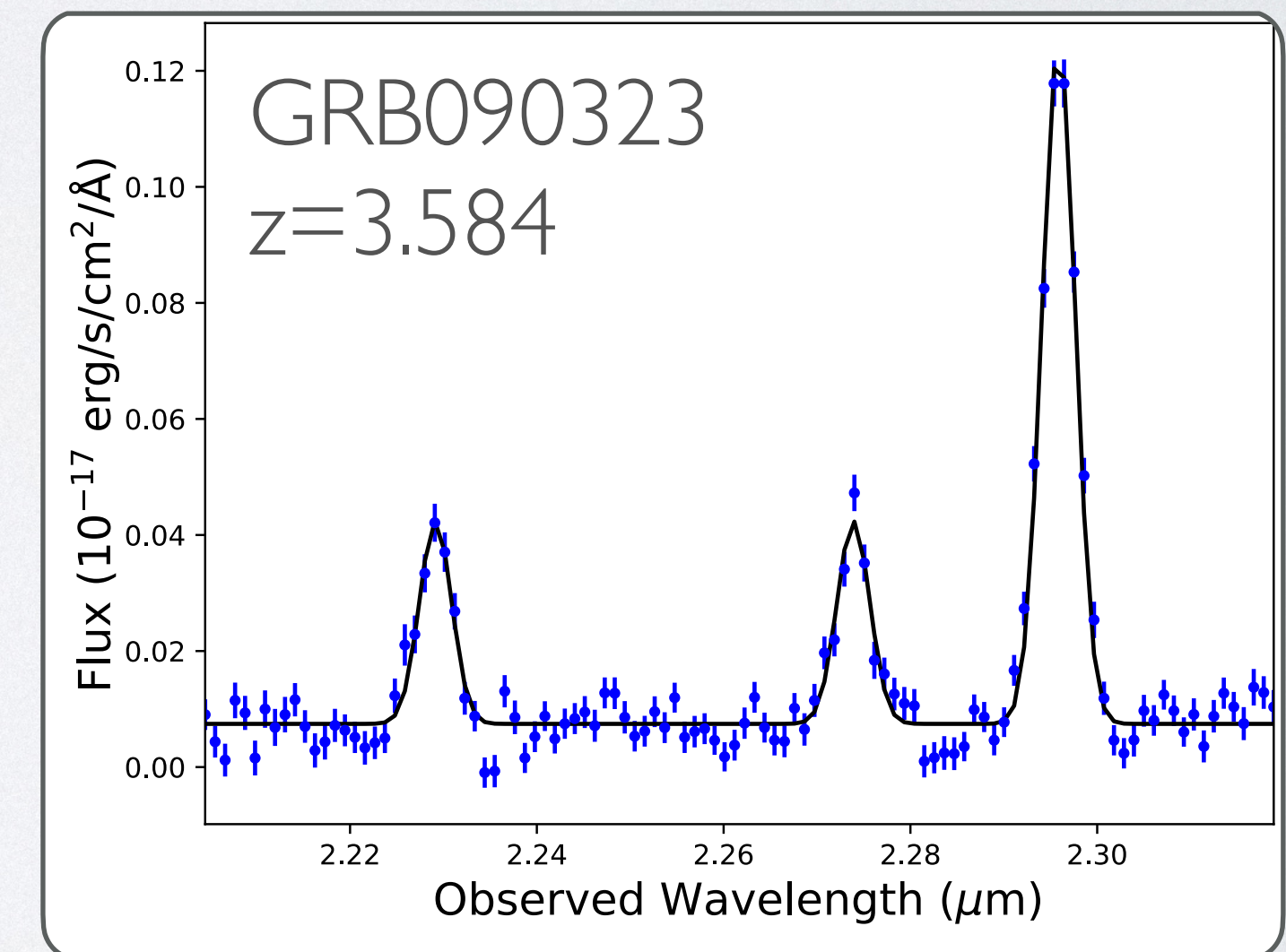
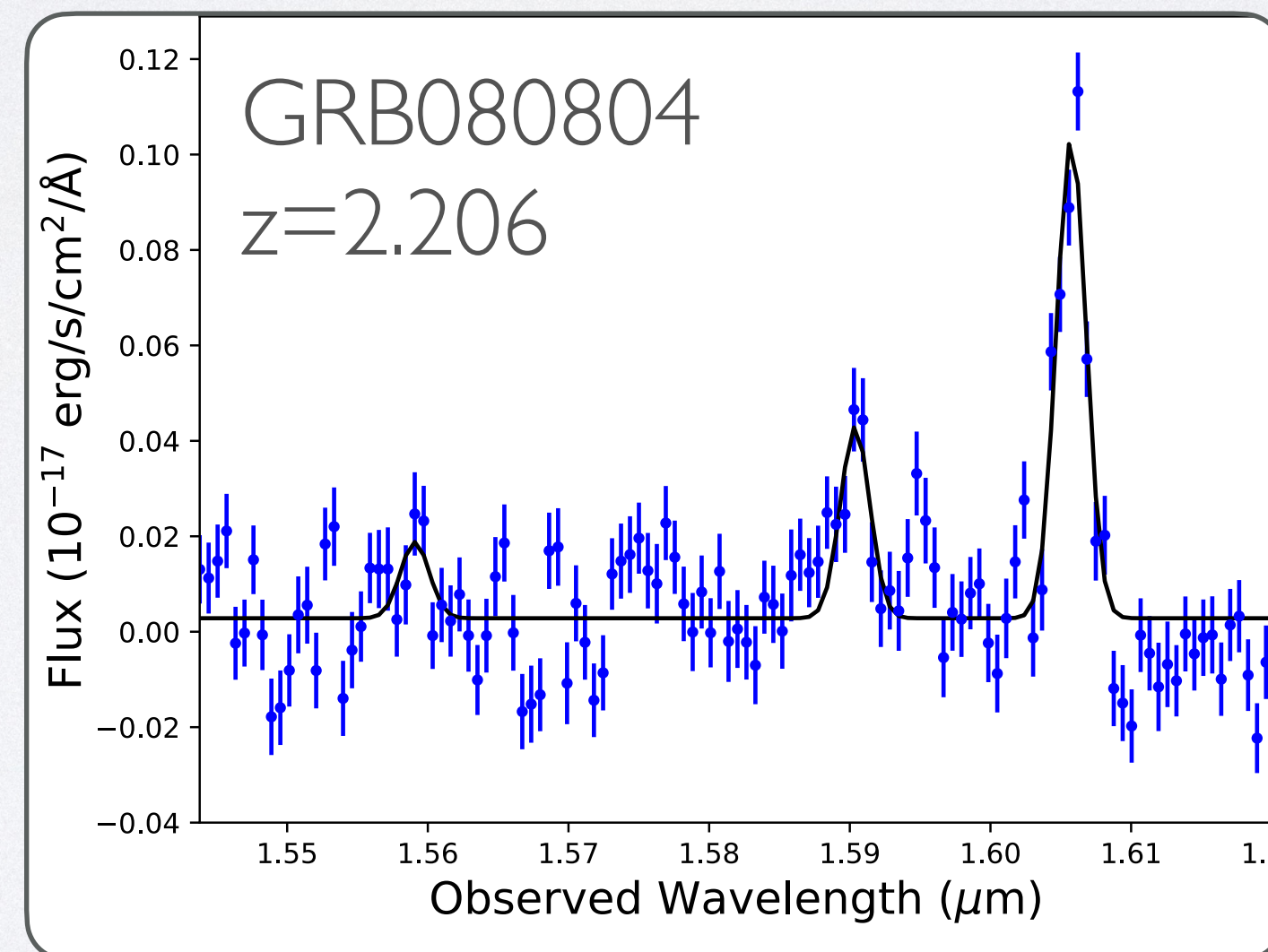
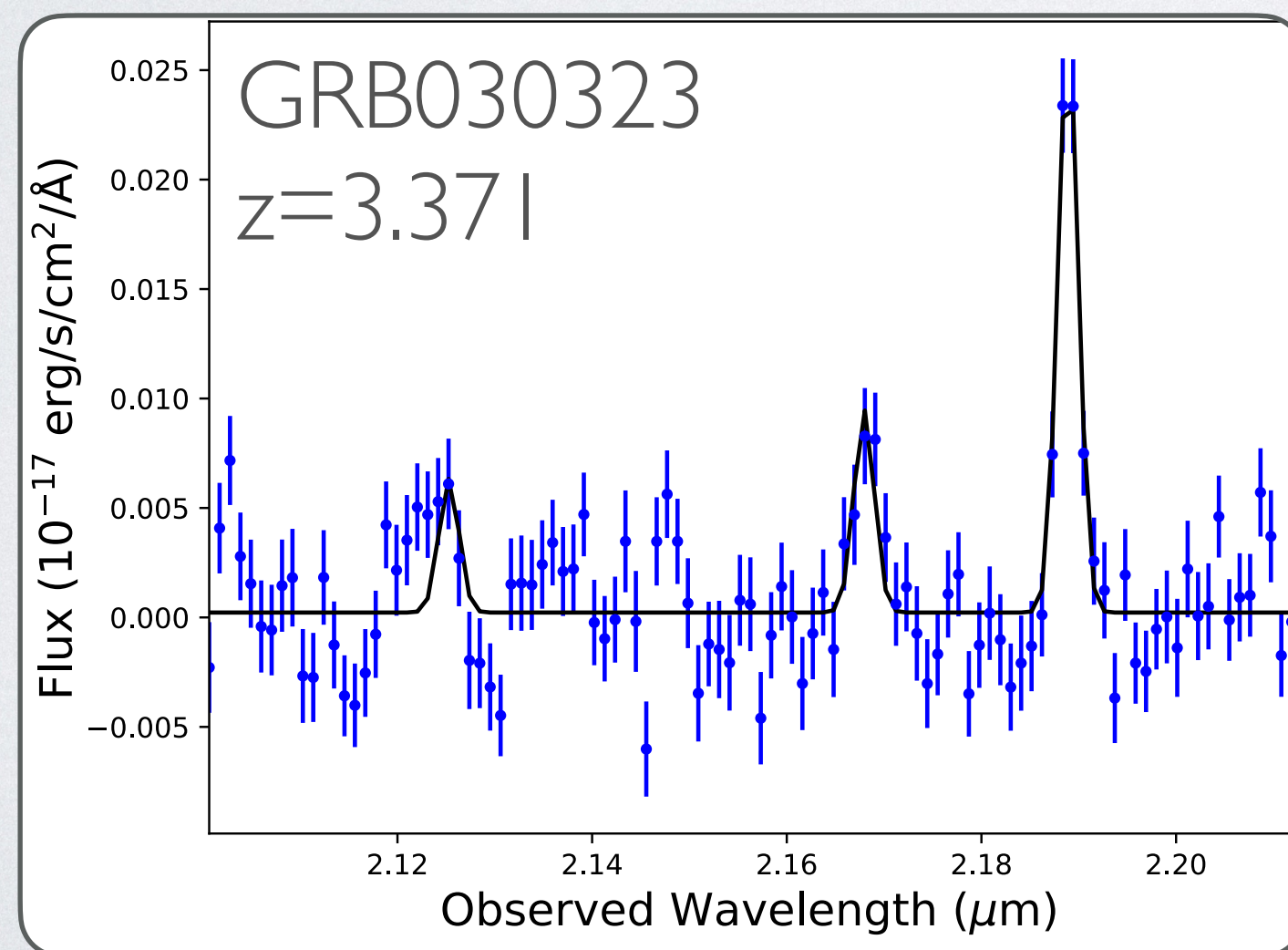
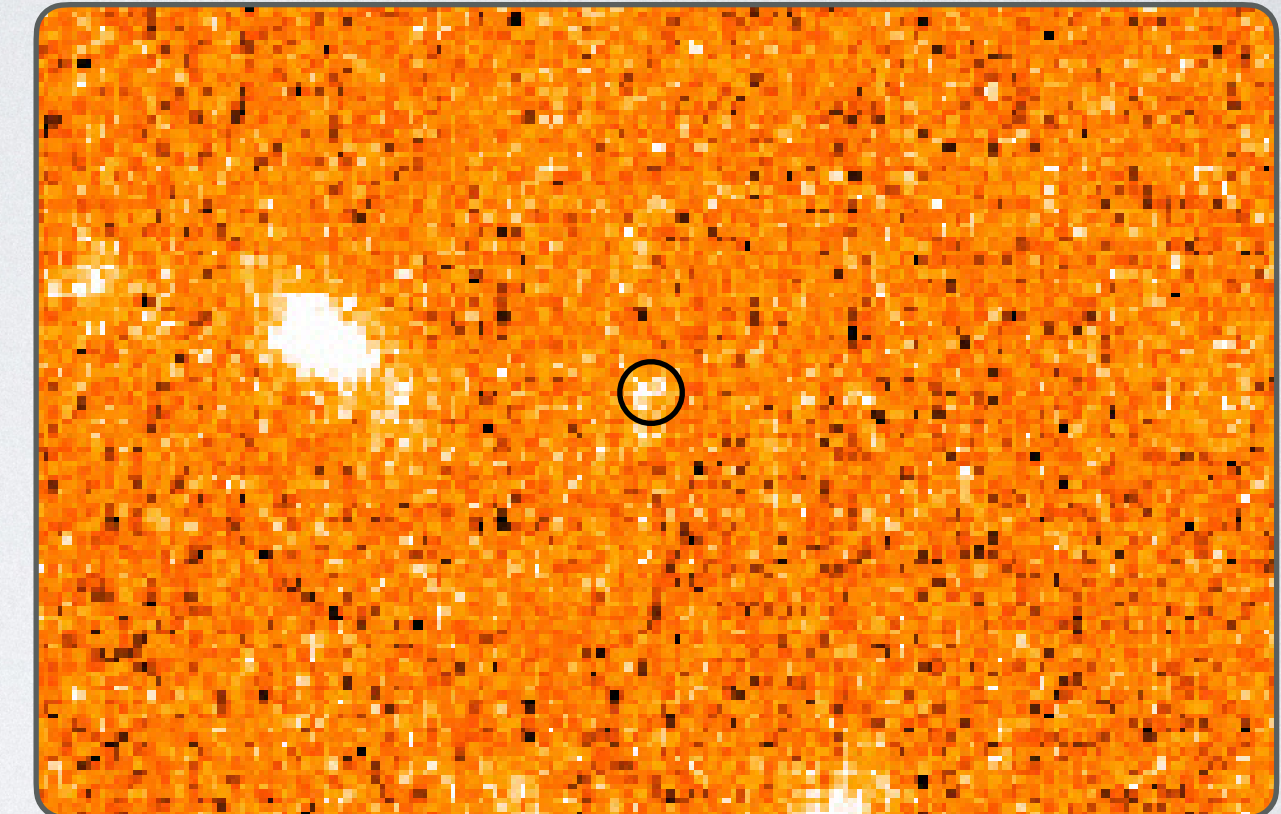
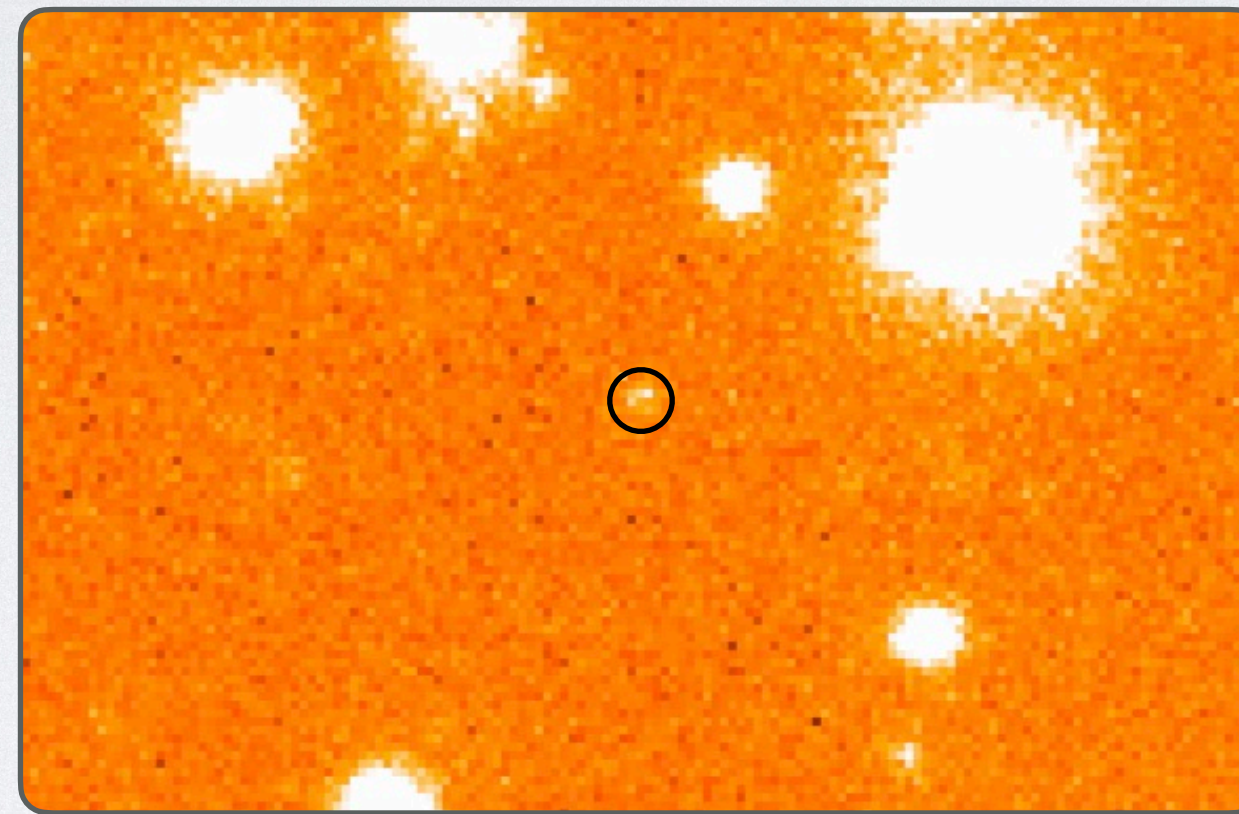
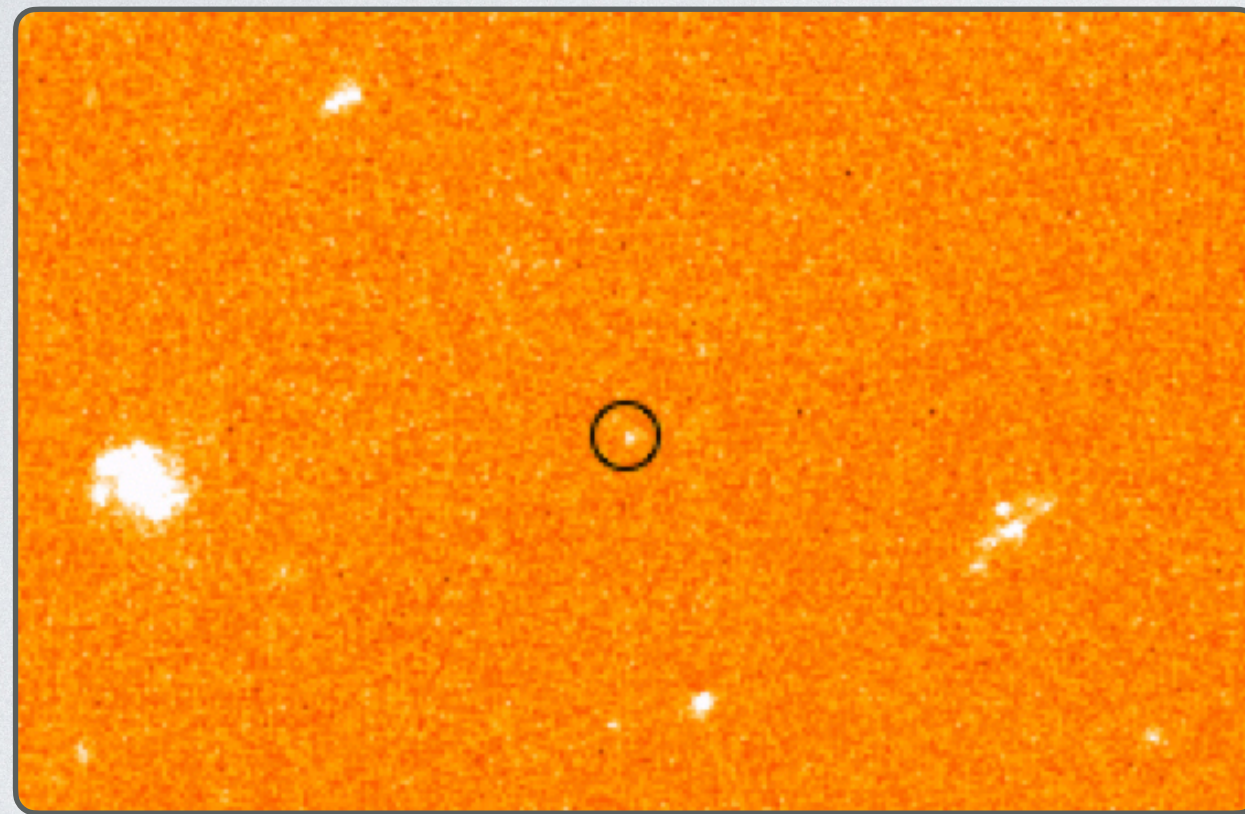
Schady+24,

(See also e.g. Castro-Tirado+07, Rol+07, Perley+13, Thöne+13, Wiseman+17b)



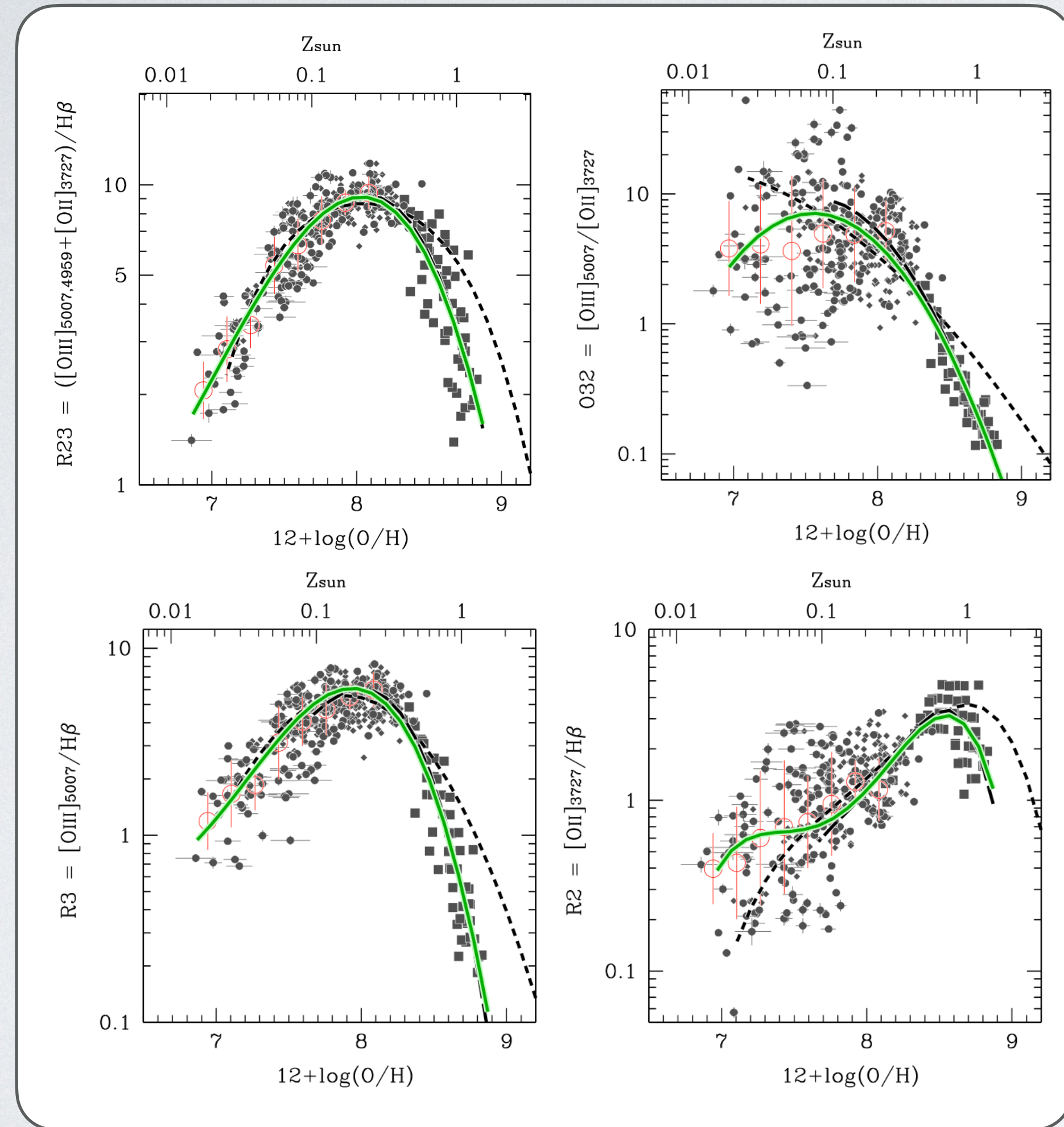


# NIRSPEC FIXED SLIT SPECTRA

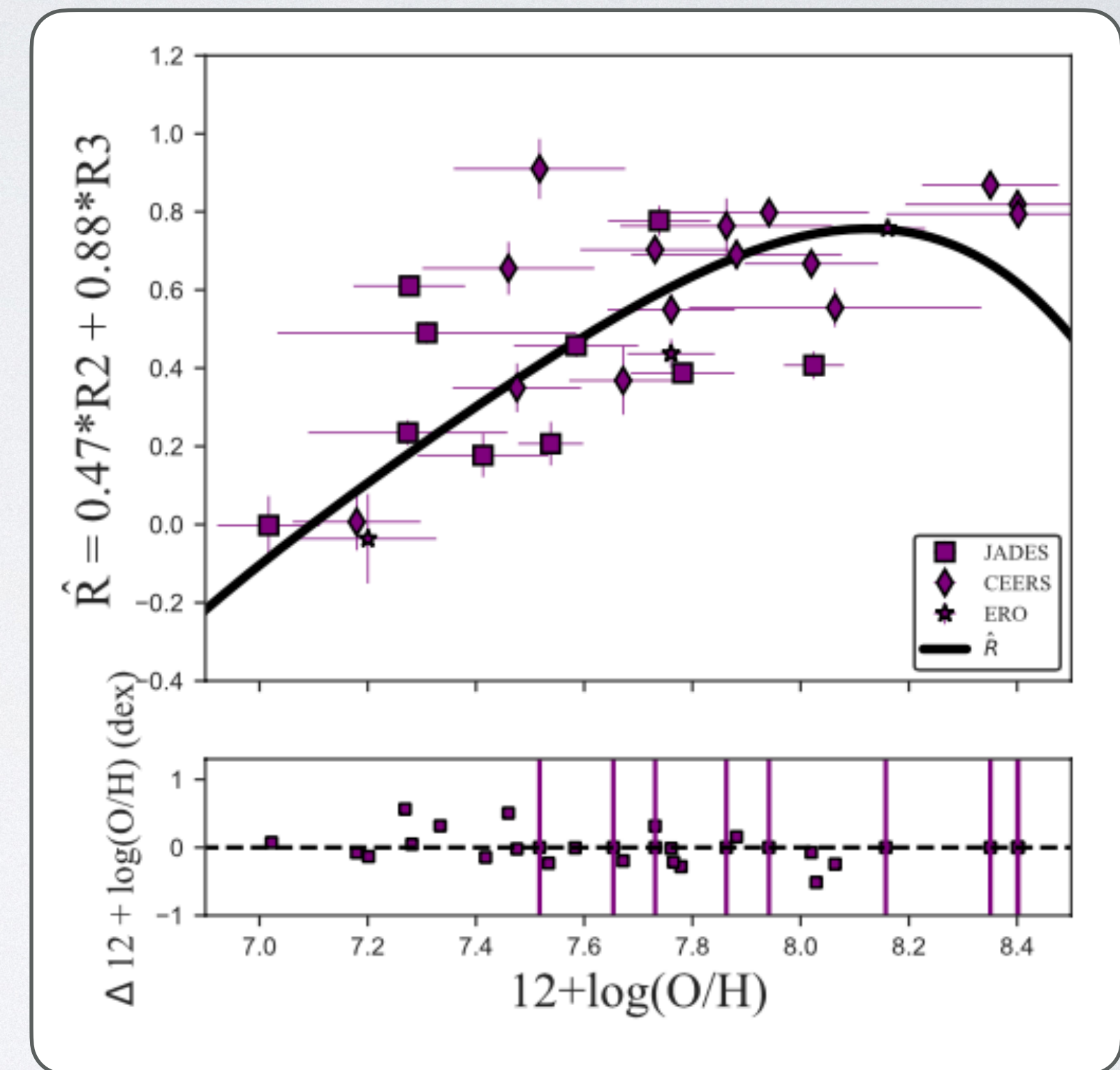




# WHICH METALLICITY DIAGNOSTICS TO USE?



Nakajima+22



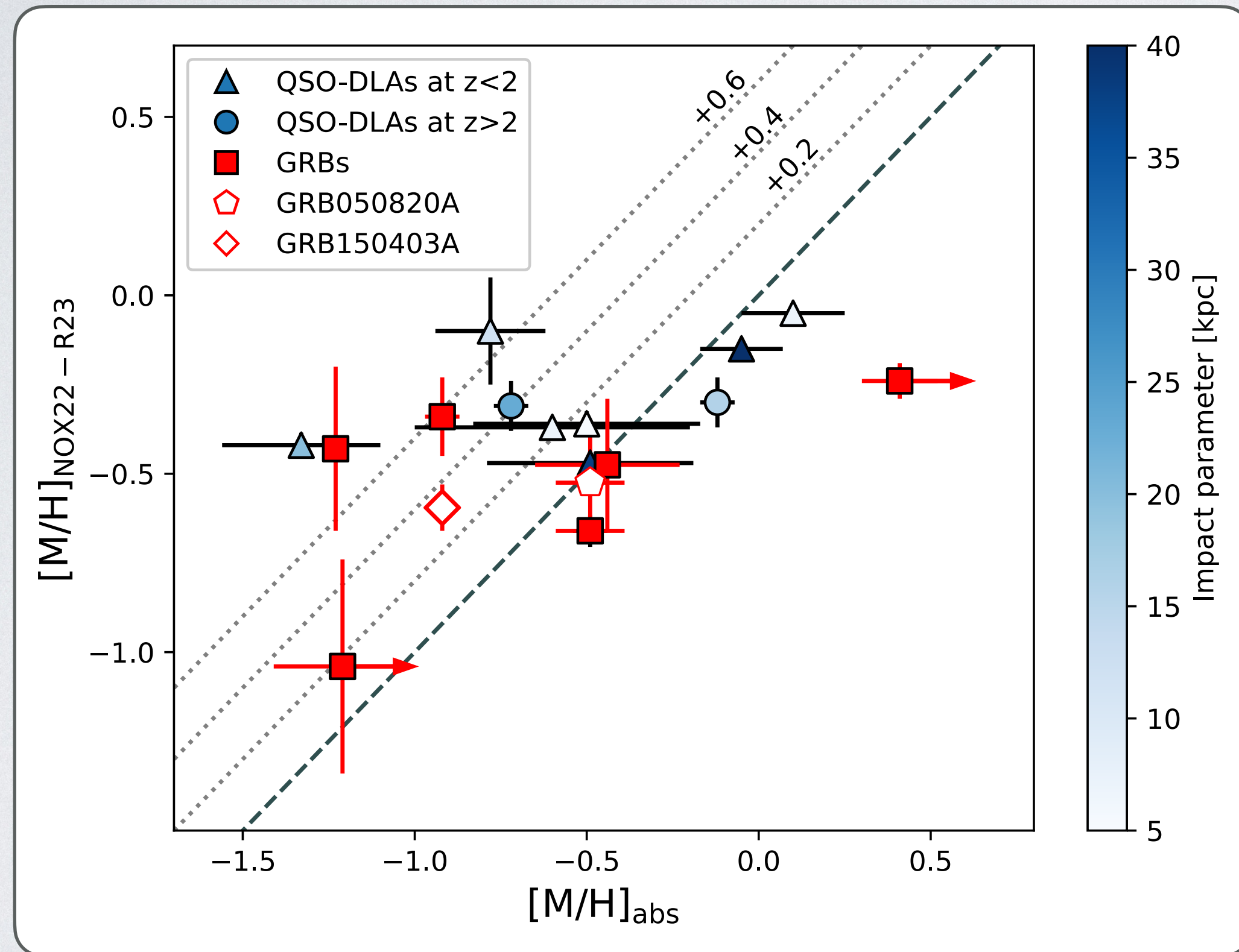
Laseter+23



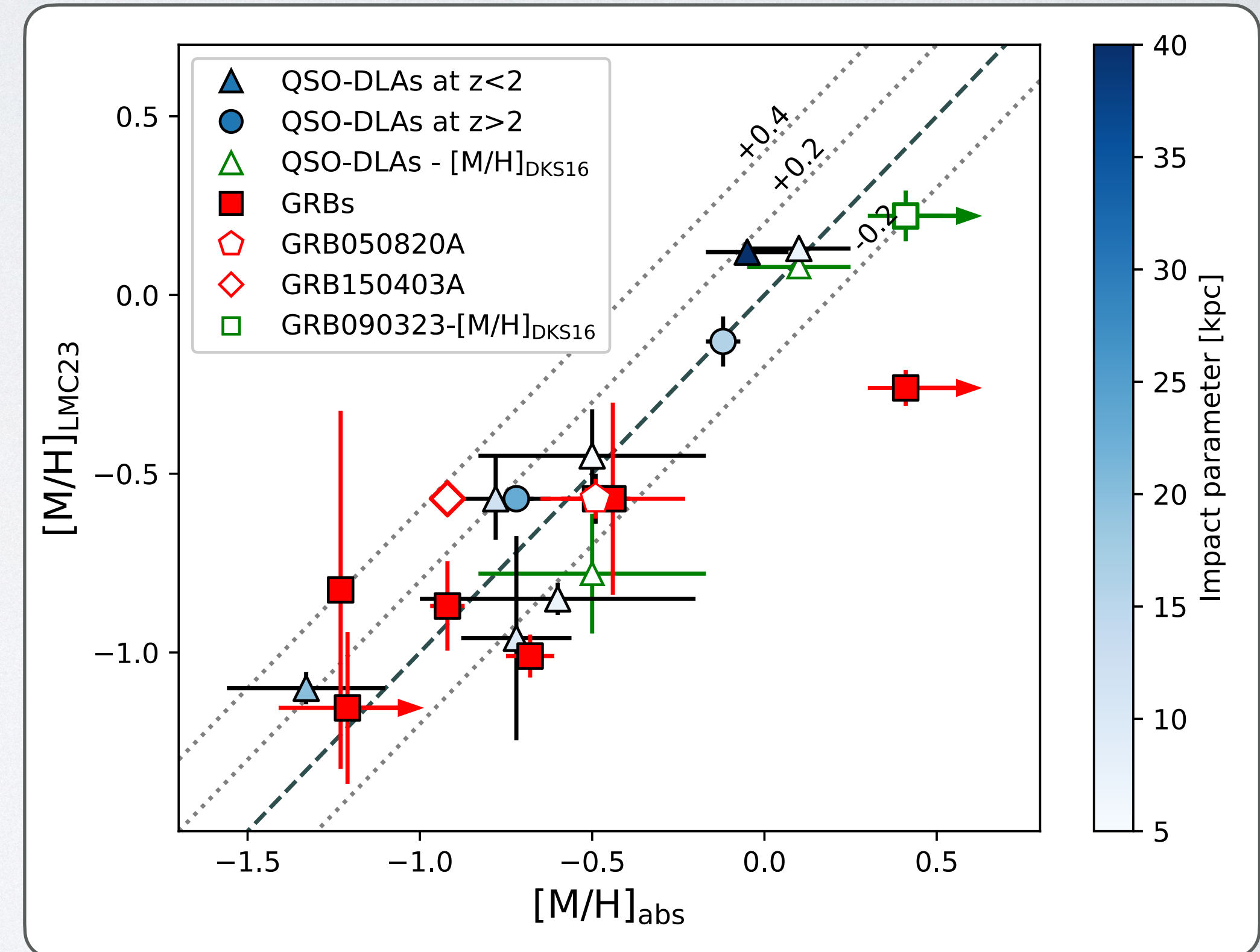


# ABSORPTION VS EMISSION METALLICITY

Nakijima+22  $R_{23}$



Laseter+23  $\hat{R}$  diagnostic



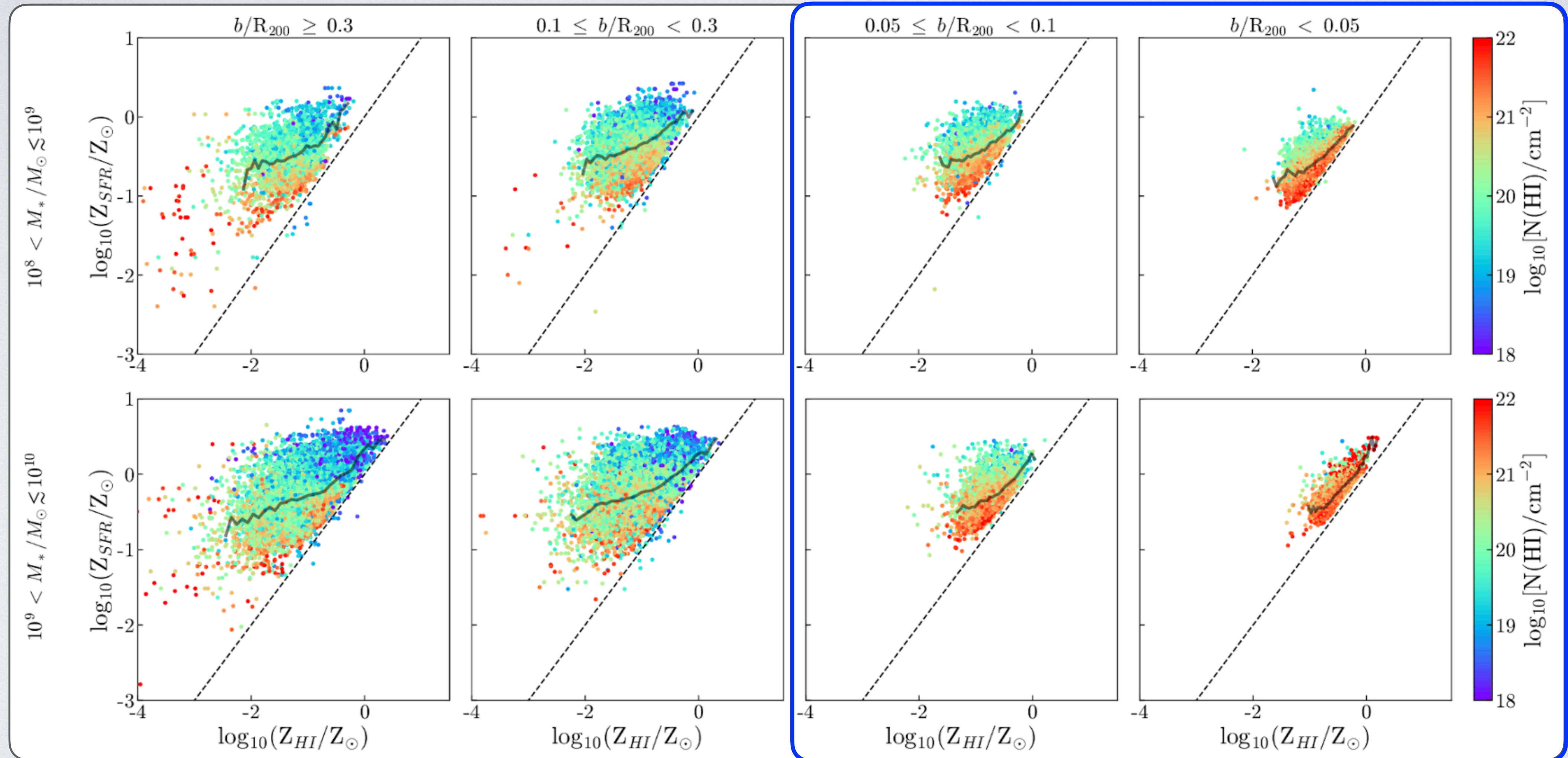
$$[X/H] = \log(X/H) - \log(X/H)_{\odot}$$

PS+24





# ABSORPTION VS EMISSION VS NHI METALLICITY



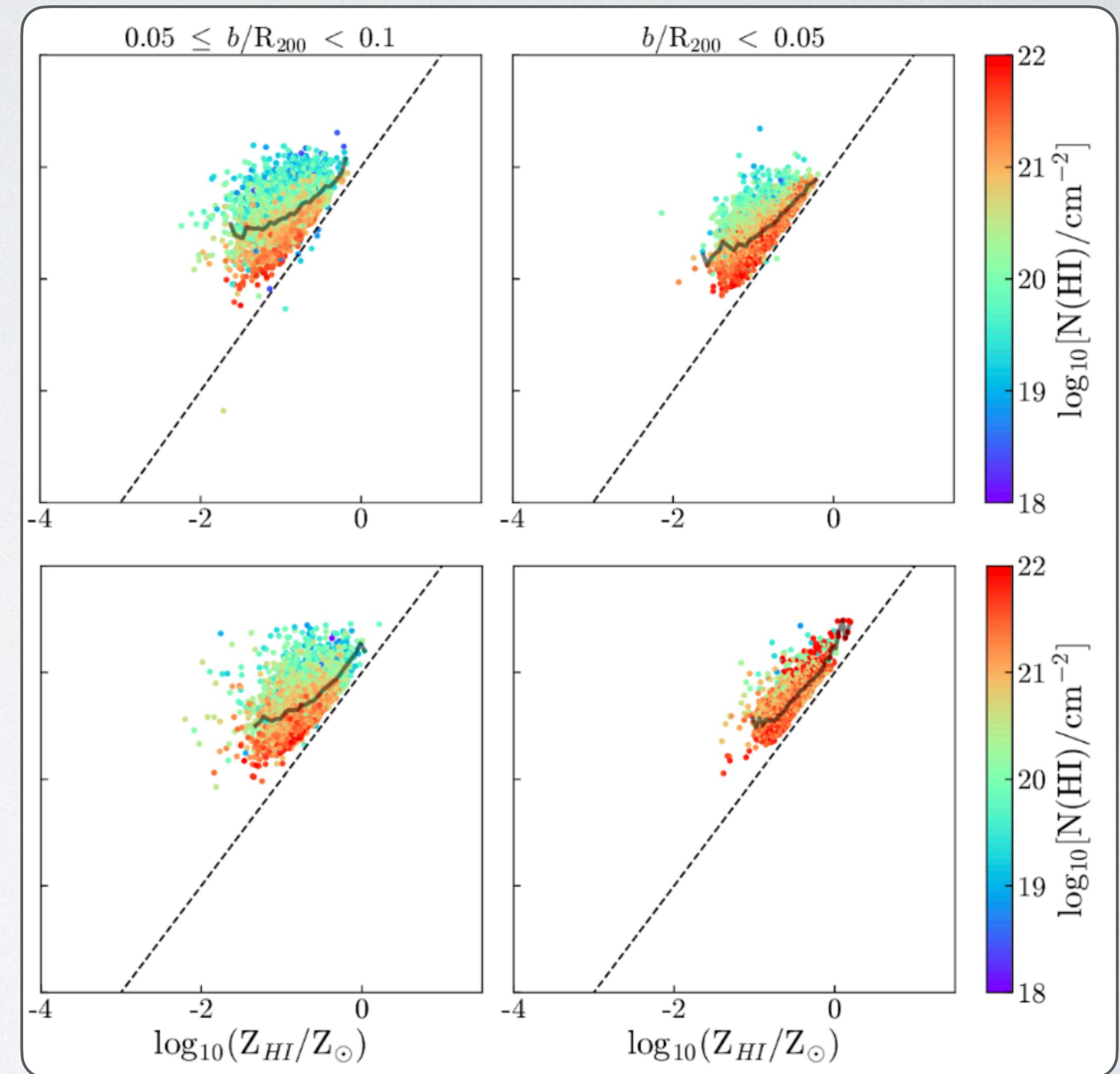
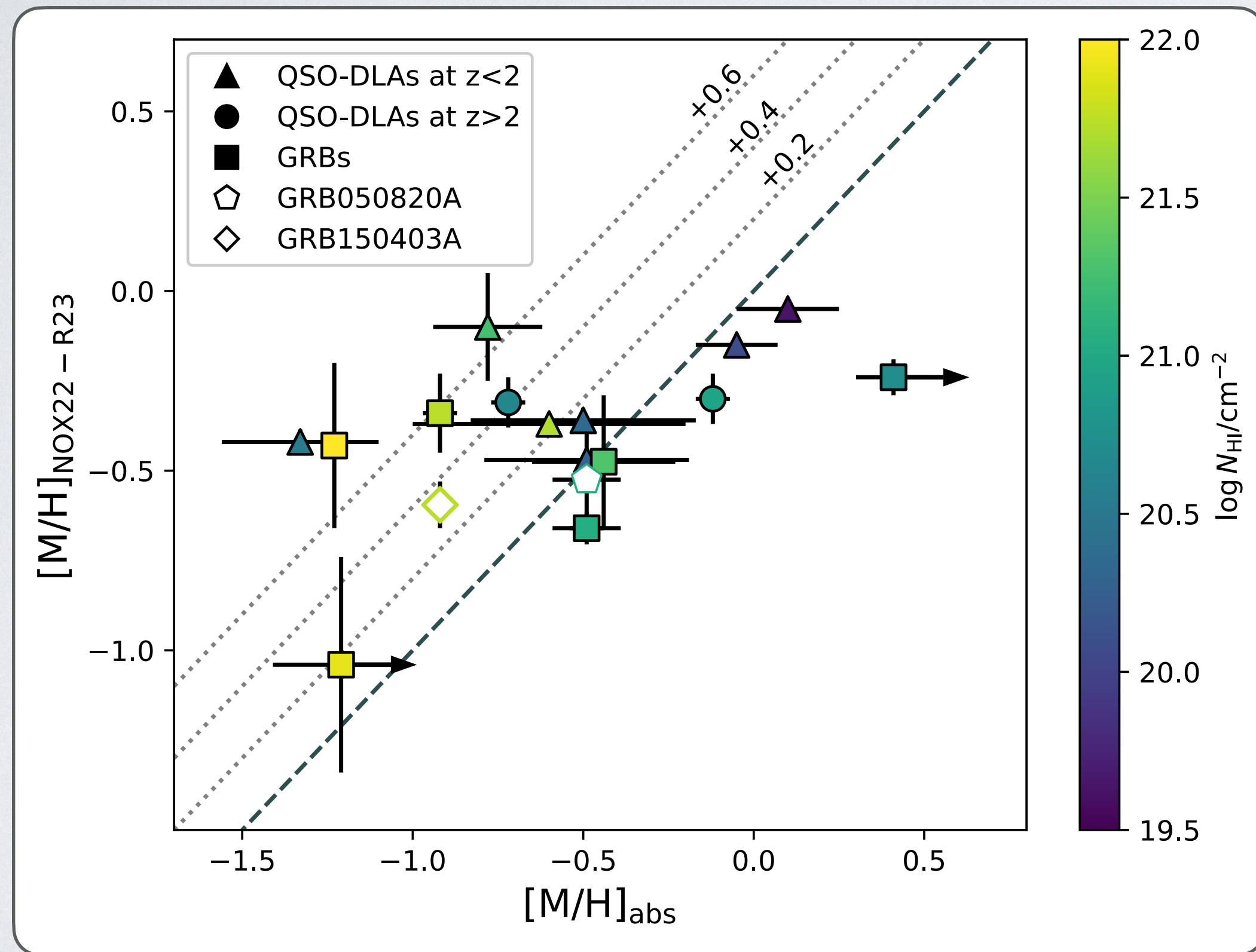
Arabsalmani+23  
(see also Metha+20,+23)





# ABSORPTION VS EMISSION VS NHI METALLICITY

Nakijima+22  $R_{23}$

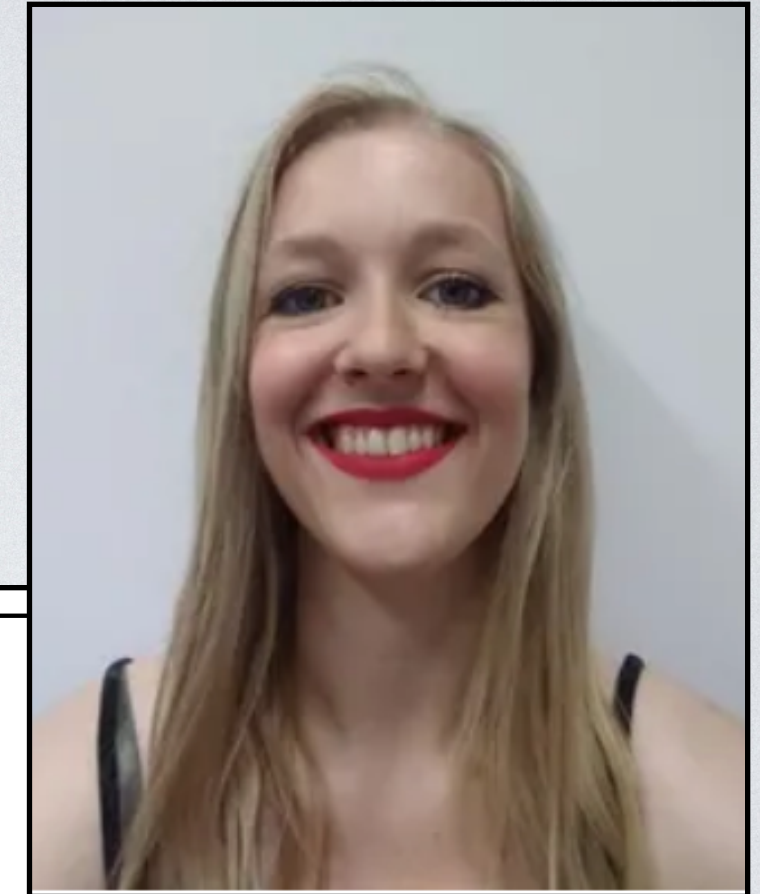


Arabsalmani+23  
(see also Metha+20,+23)

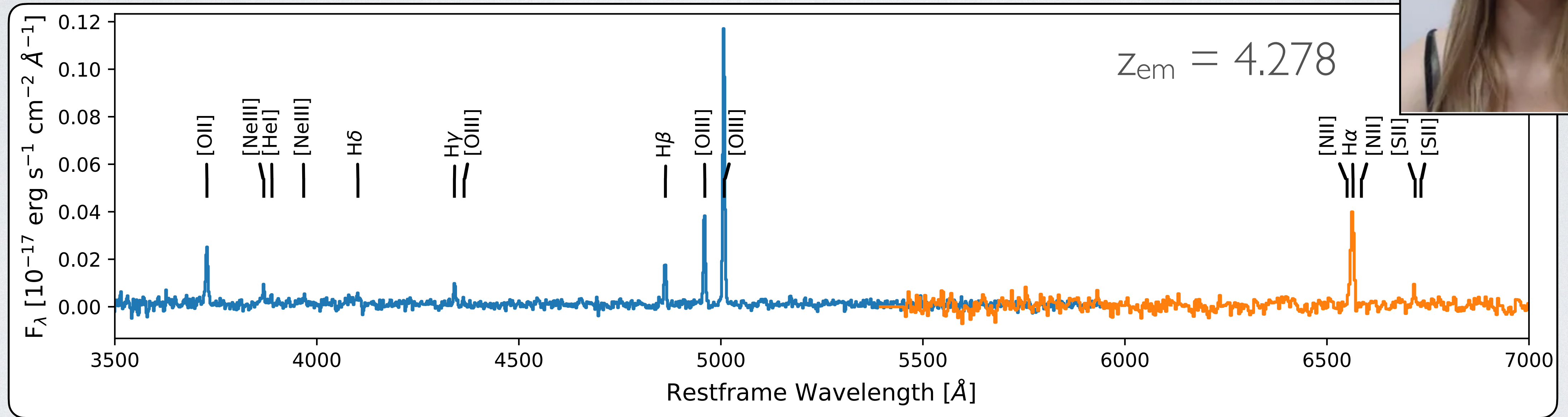




# GRB050505: FINAL JWST HOST SPECTRUM



JWST/NIRSpec G235M/F170LP (blue) and G395M/290LP (orange)

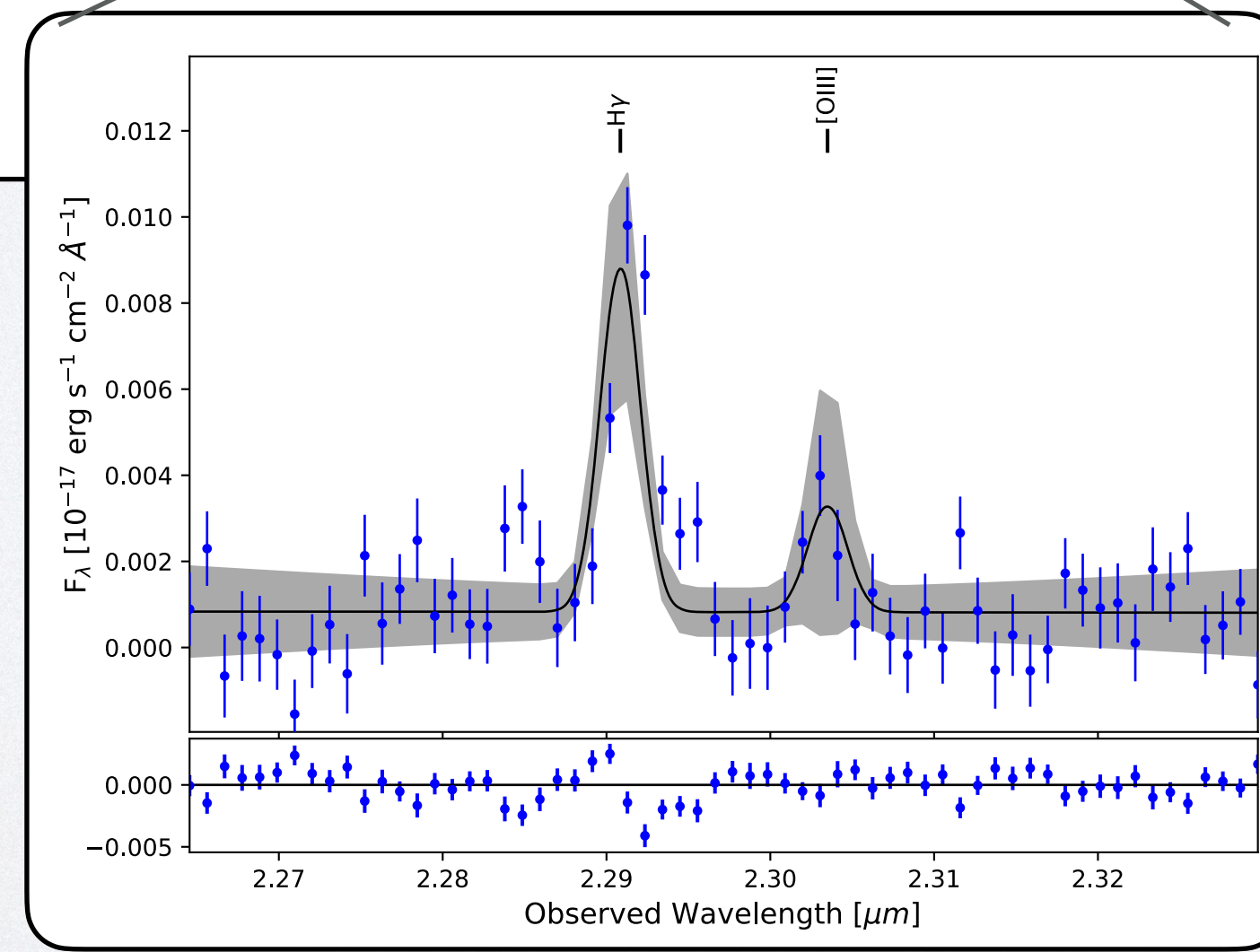
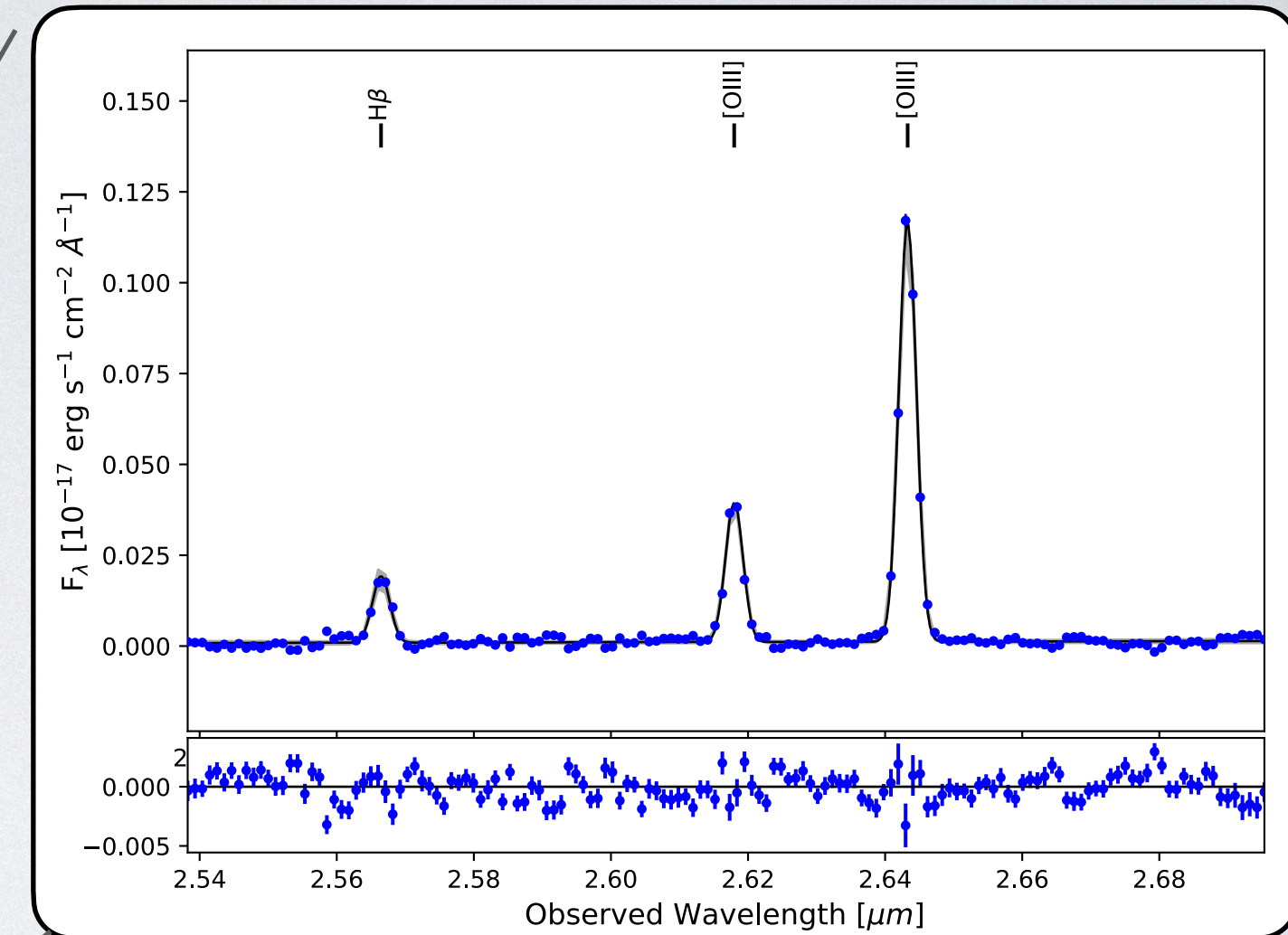
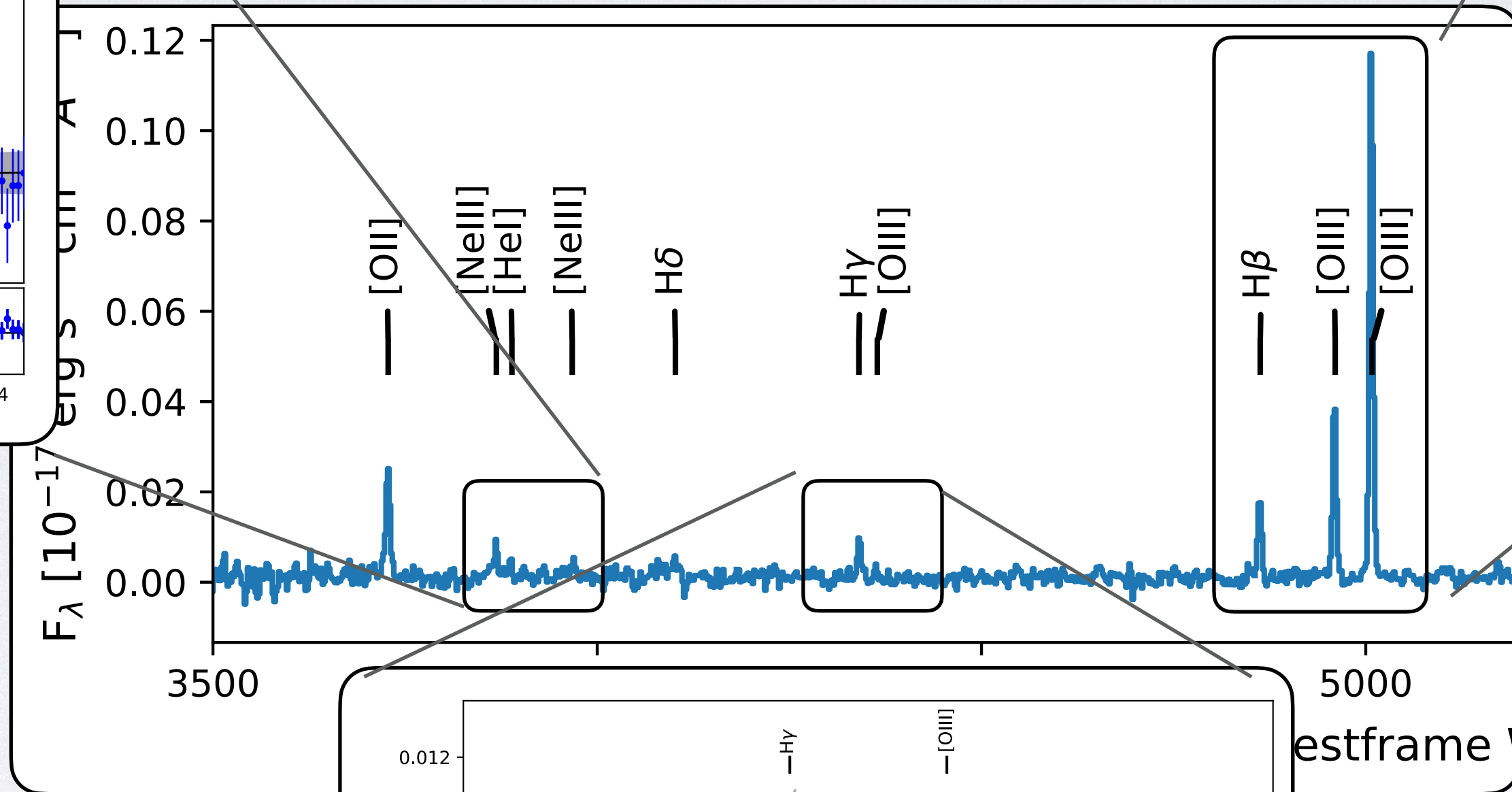
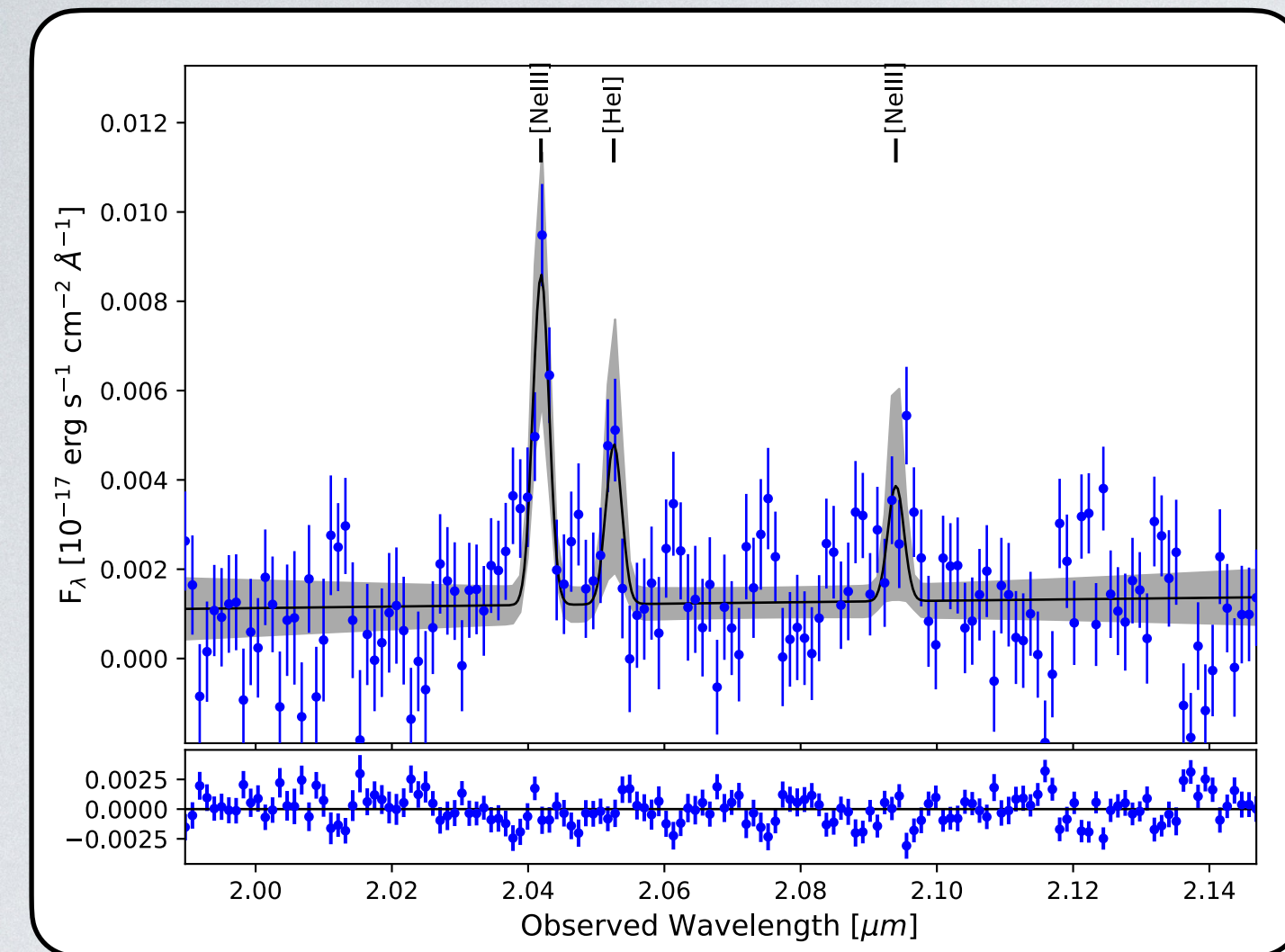


Inkenhaag+25, in prep



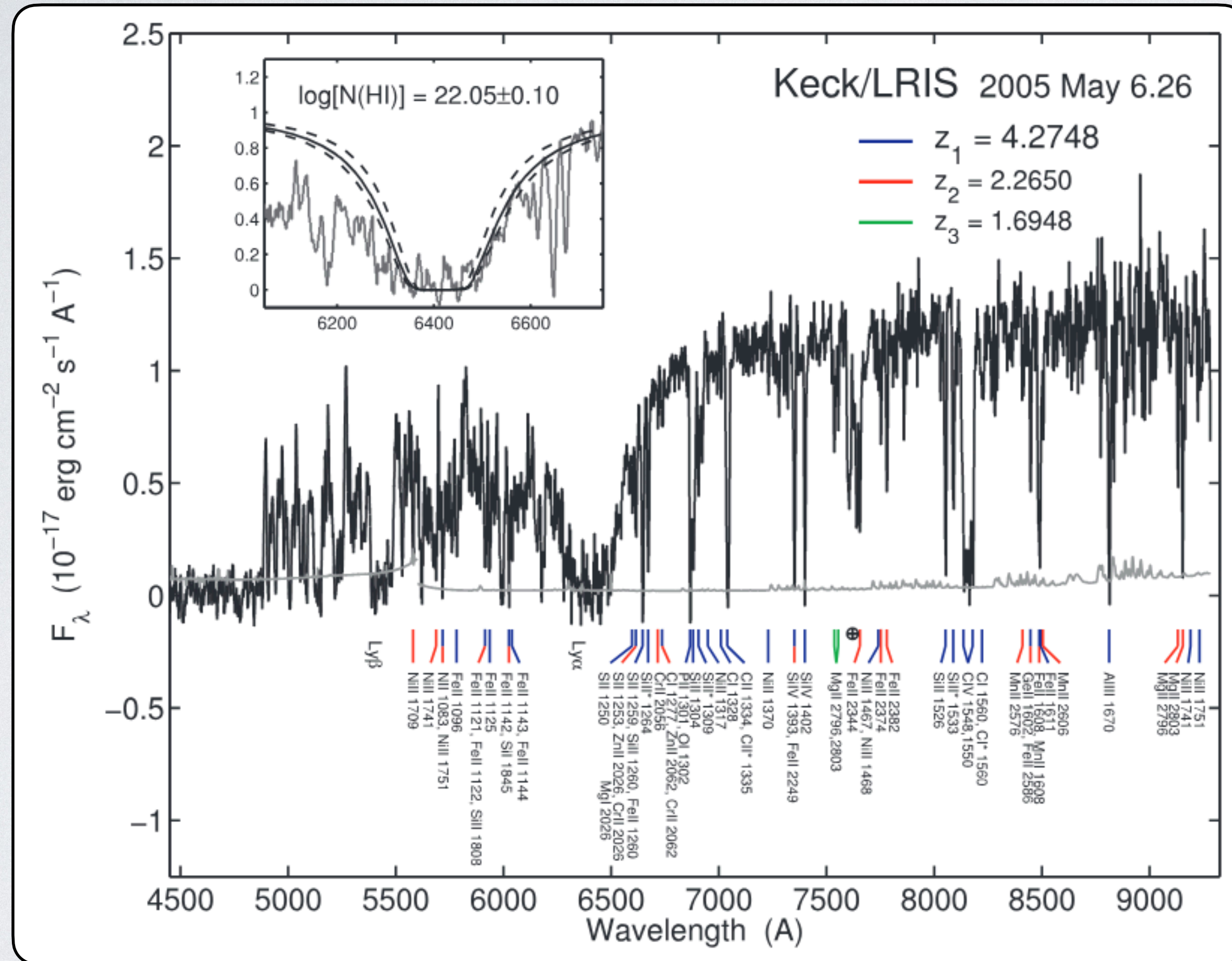


# GRB050505: FINISH WITH A BANG

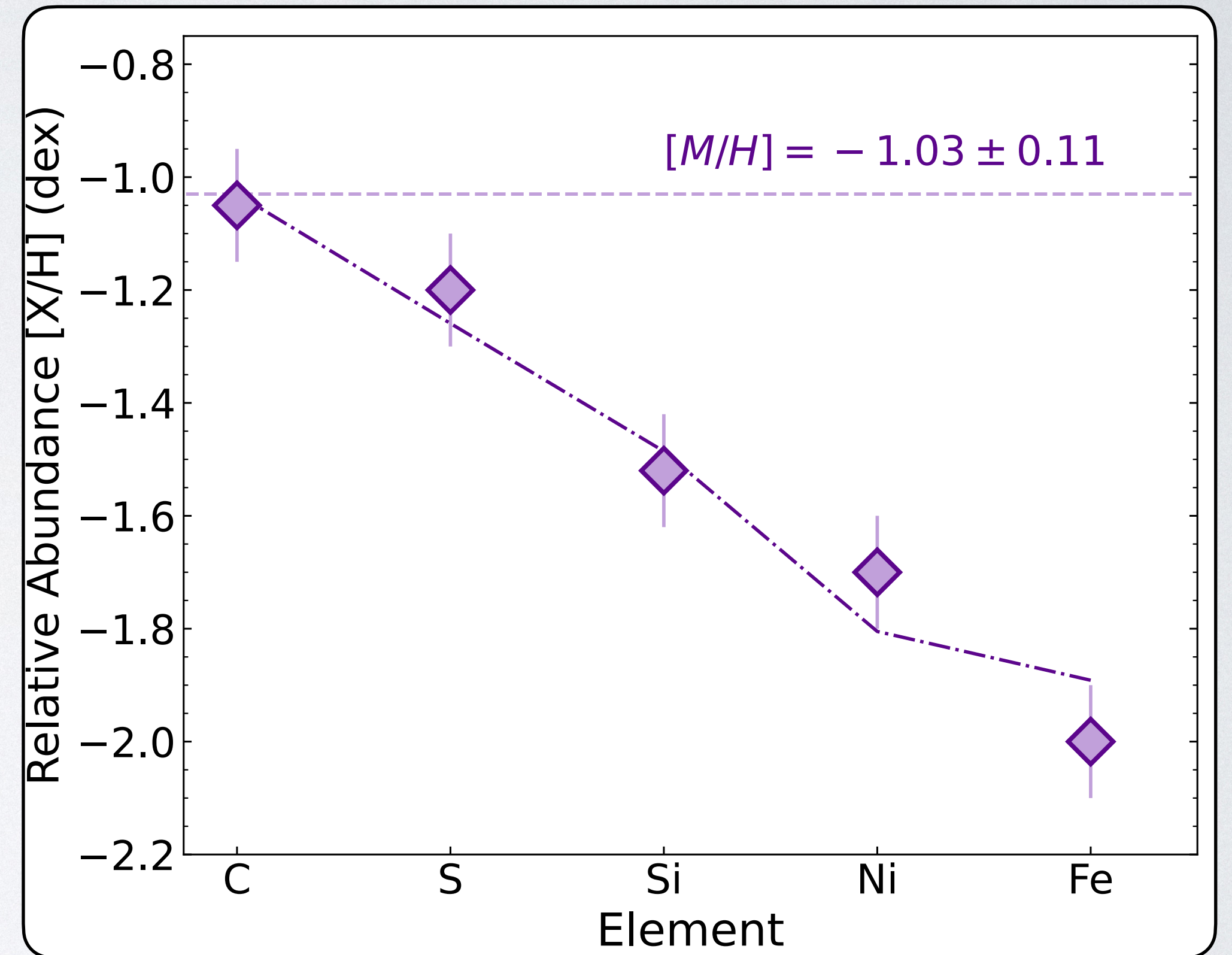




# GRB050505: ABSORPTION METALLICITY



Berger+06

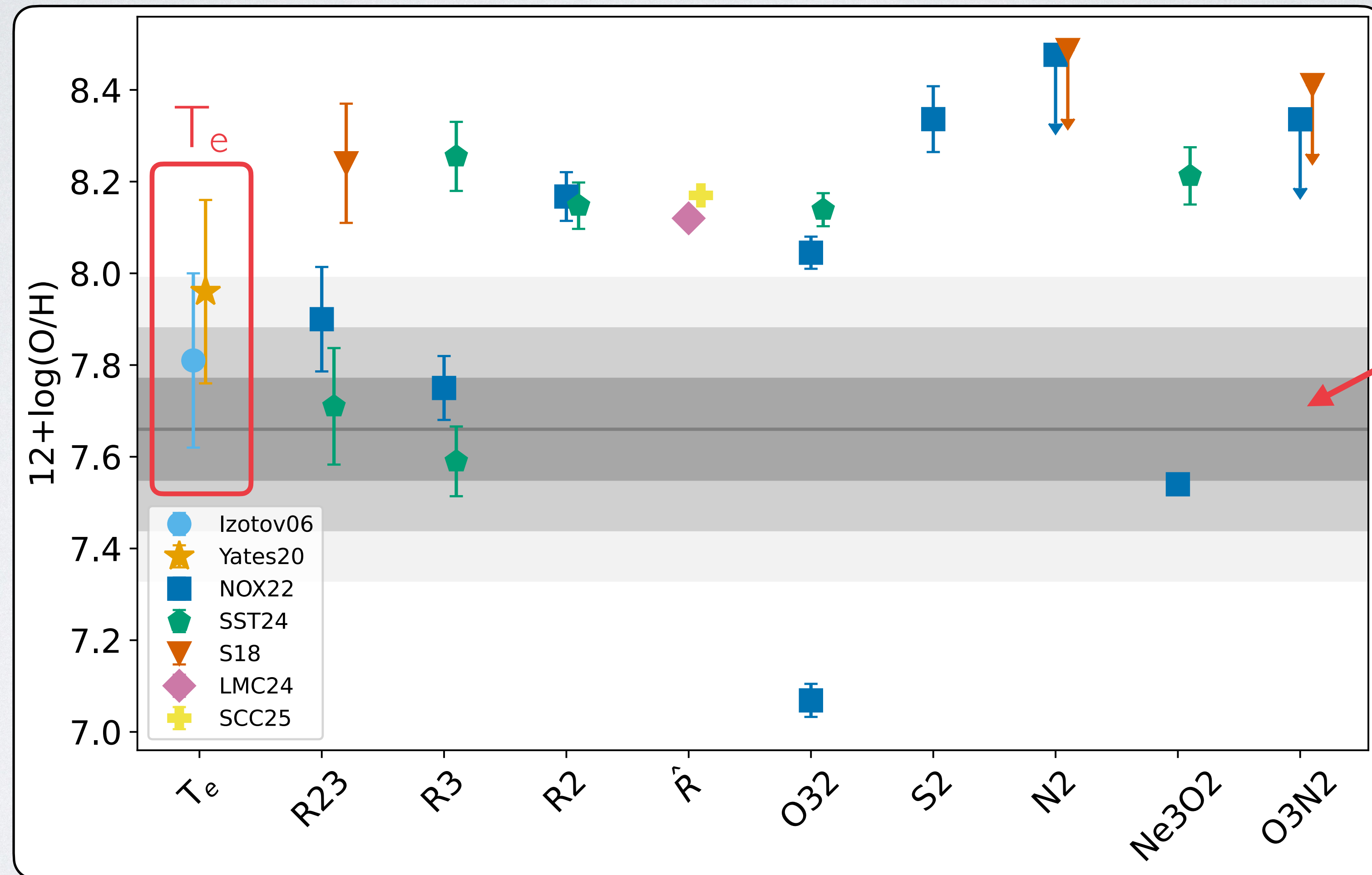


Inkenhaag+25, in prep





# GRB050505: ABSORPTION VS. EMISSION METALLICITY



Inkenhaag+25, in prep





# ABSORPTION VS EMISSION LINE PROPERTIES

- GRB afterglows provide a truly unique probe of conditions of ISM in high- $z$  galaxies
- JWST allowing absorption and emission line metallicities on sample of GRB host galaxies to be compared for the first time
- Are long GRBs more likely to occur within interacting galaxies?
- Good evidence that GRB sight lines can be used to trace chemical composition of high- $z$  galaxies

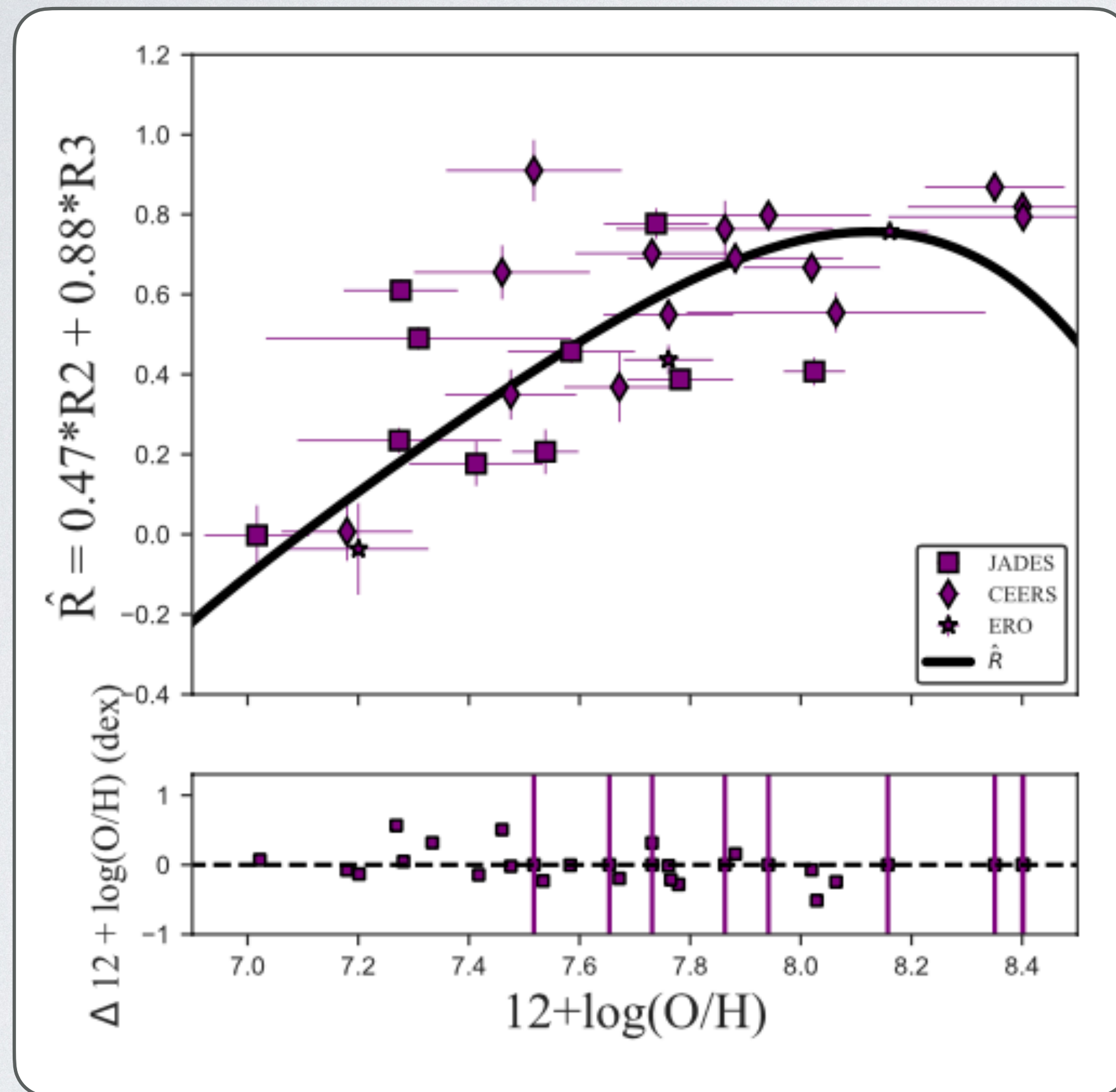
## **But...**

- Need to characterise host galaxies of those GRBs with accurate absorption line metallicities
- Wish to understand relation between GRB and QSO-DLA absorbers
- A reliable high- $z$  emission line metallicity diagnostic is of fundamental importance

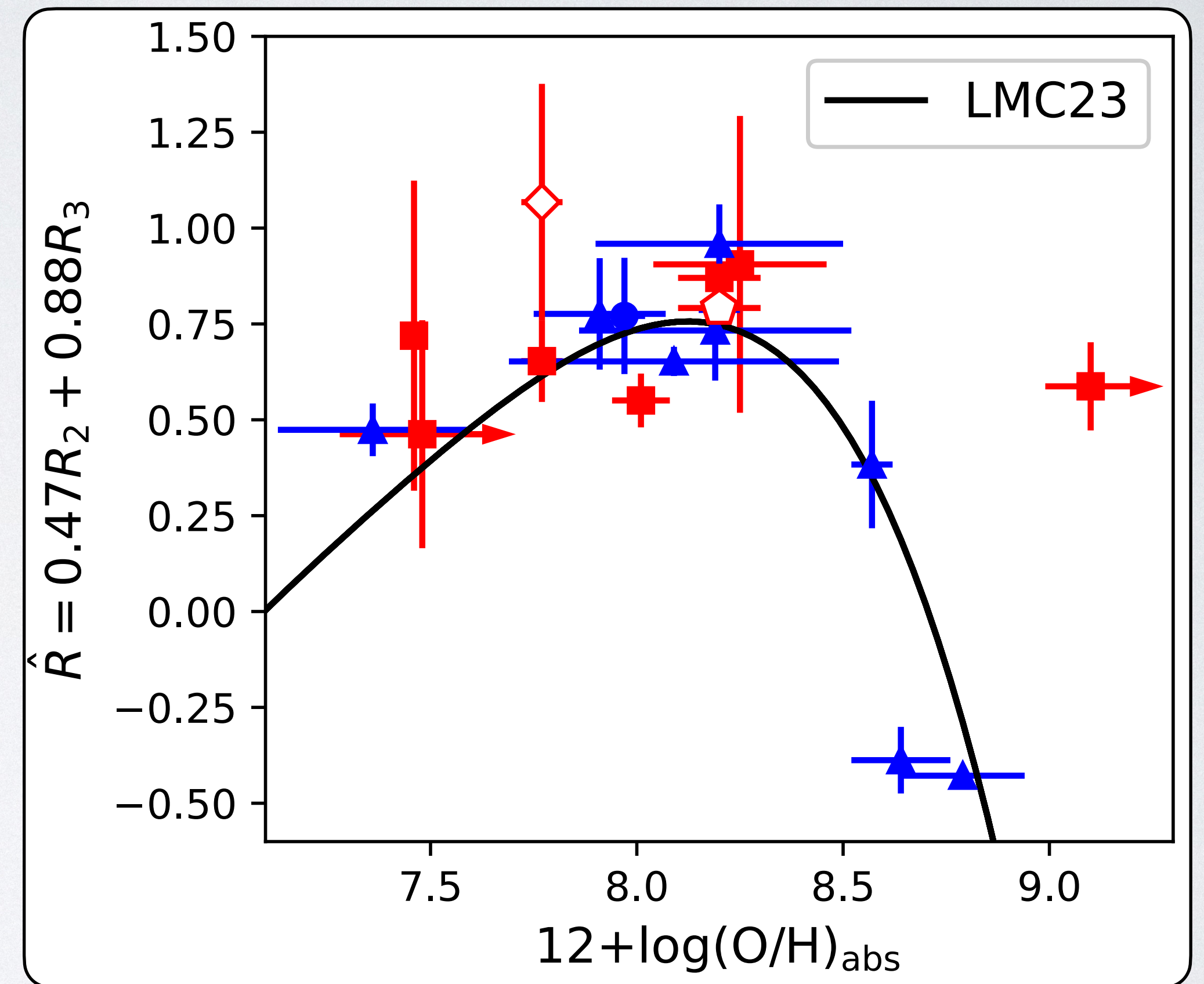




# CALIBRATE HIGH-Z DIAGNOSTICS WITH GRBs?



Laseter+23

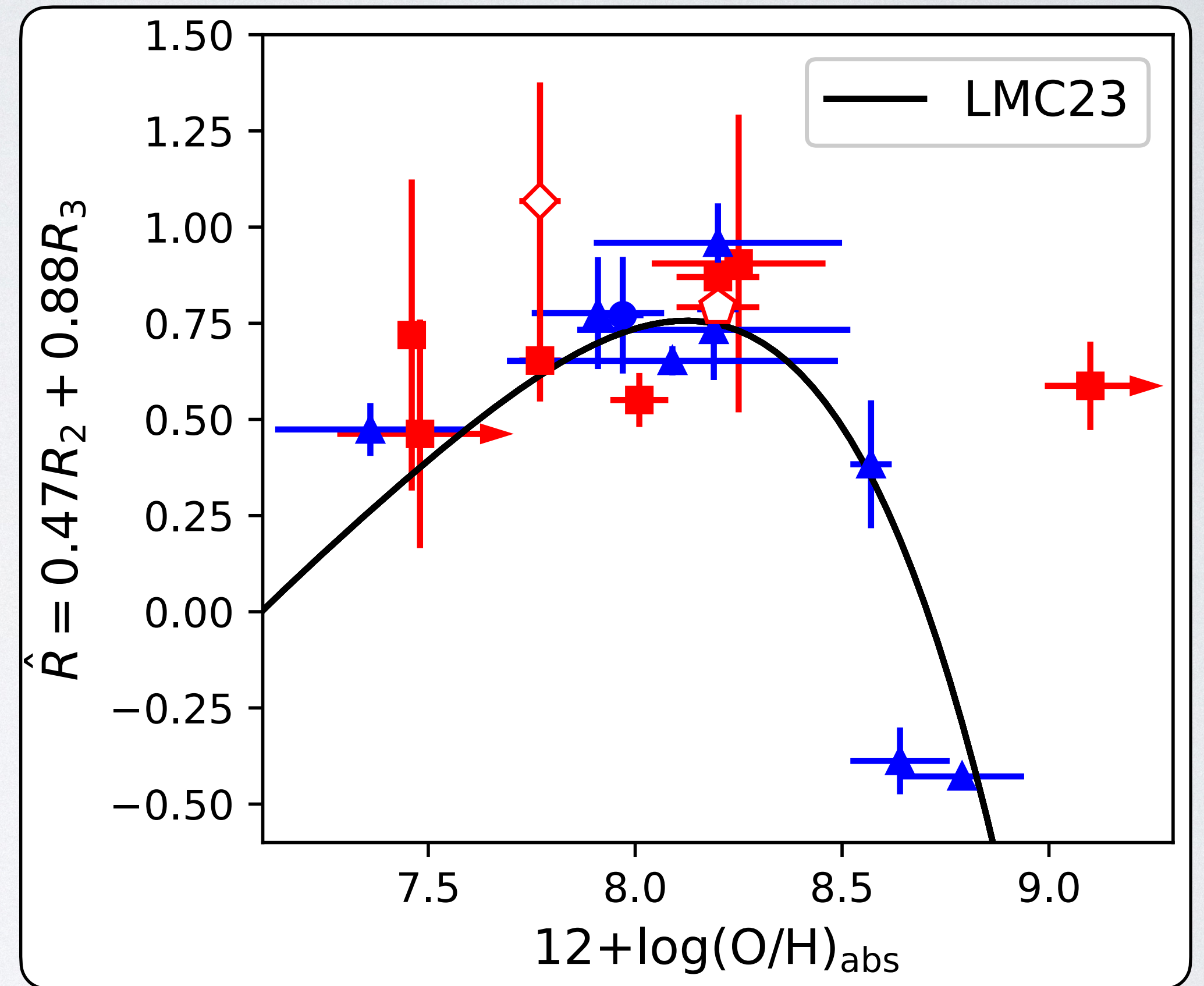
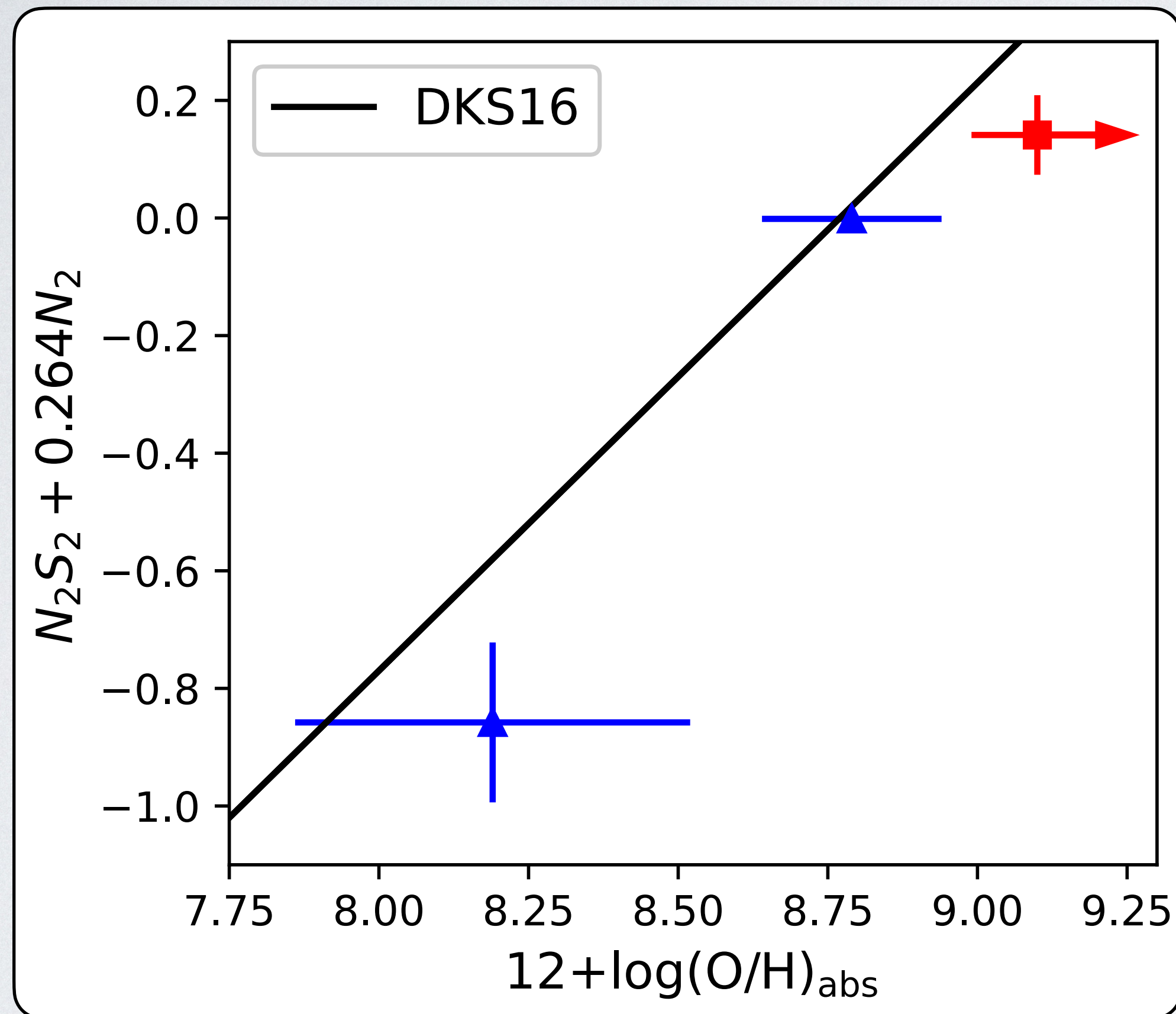


PS+24, submitted





# THE PECULIAR CASE OF GRB090323

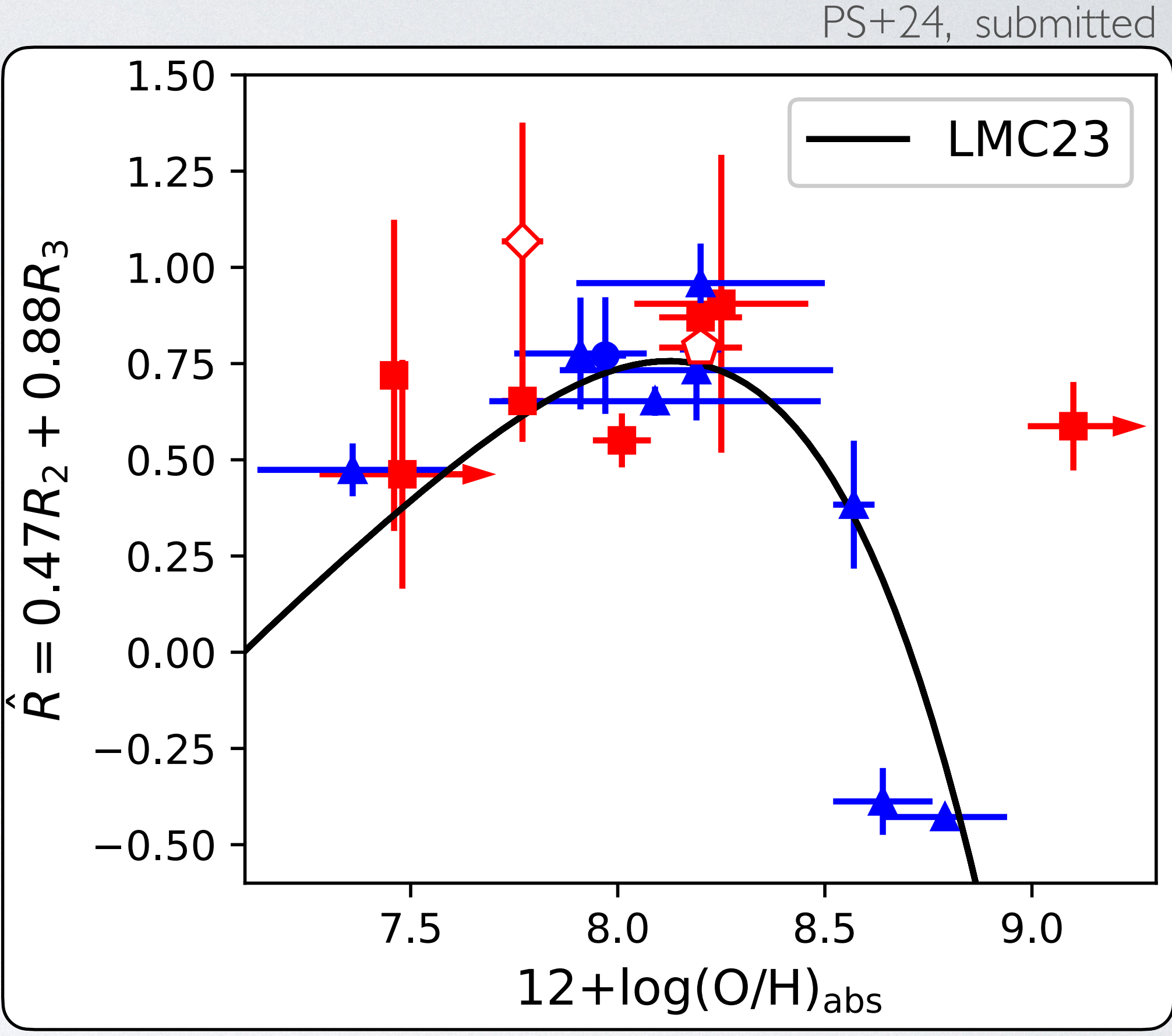
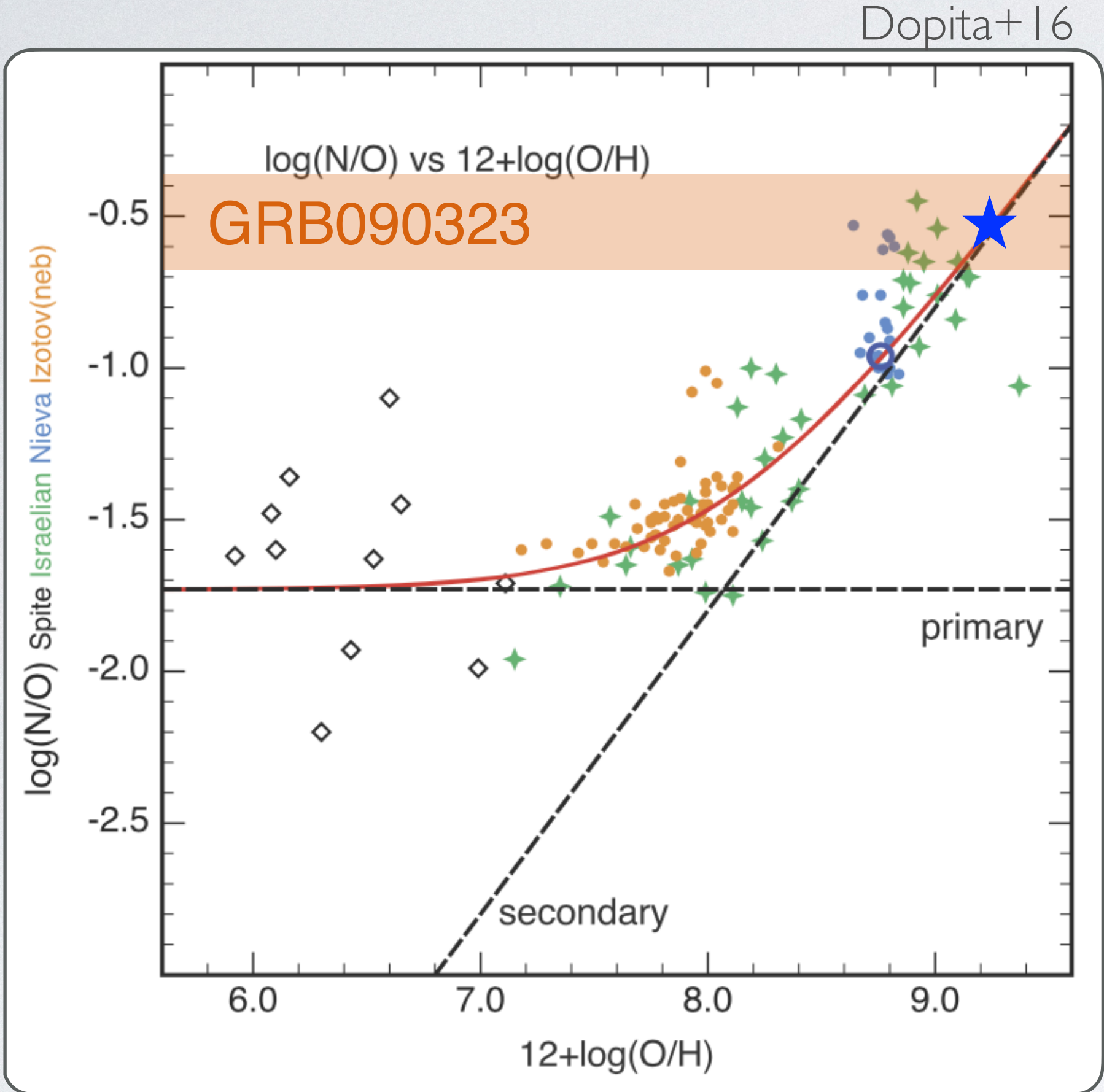


PS+24, submitted





# GRB090323: N/O-O/H RELATION AT HIGH-Z

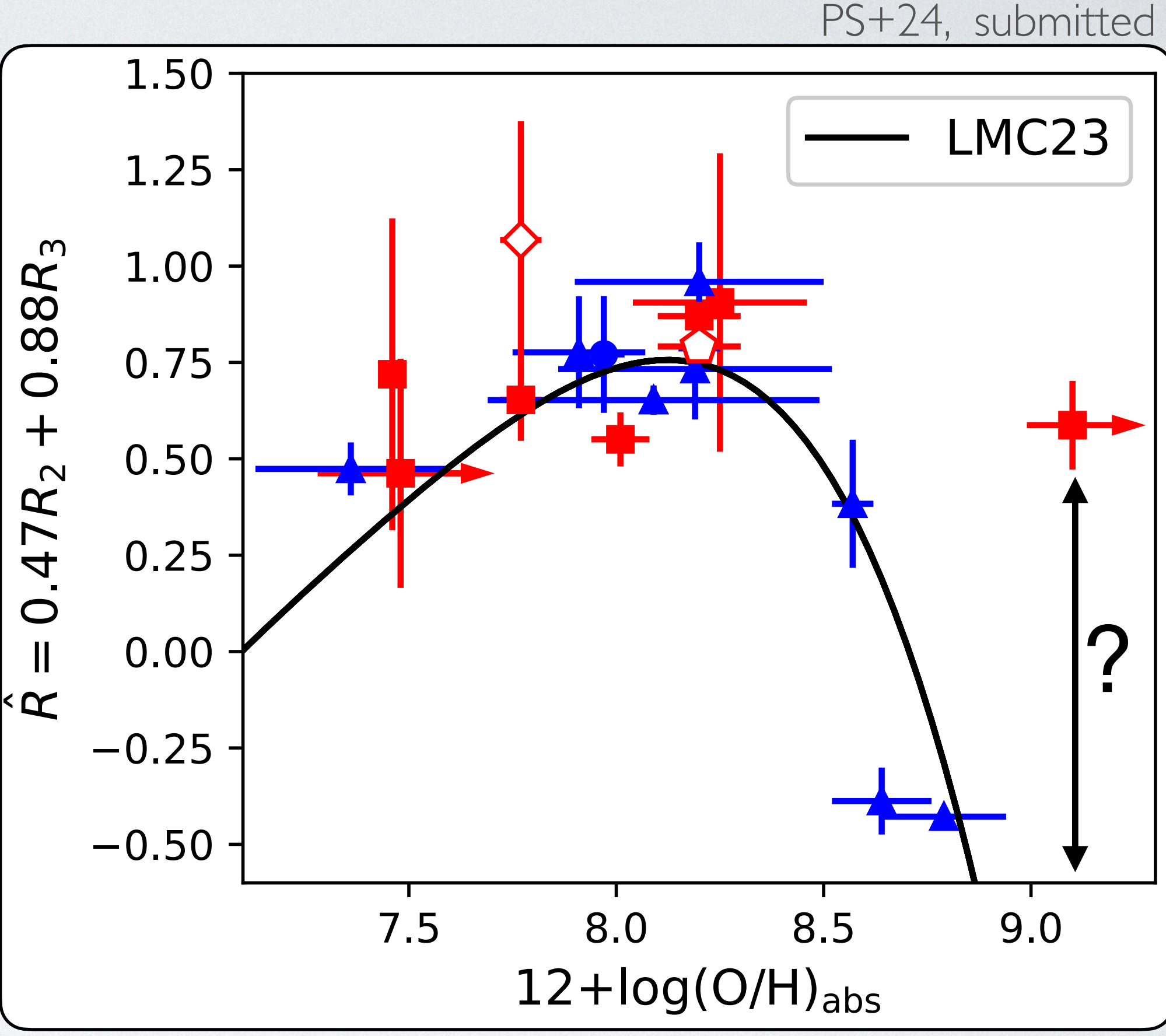
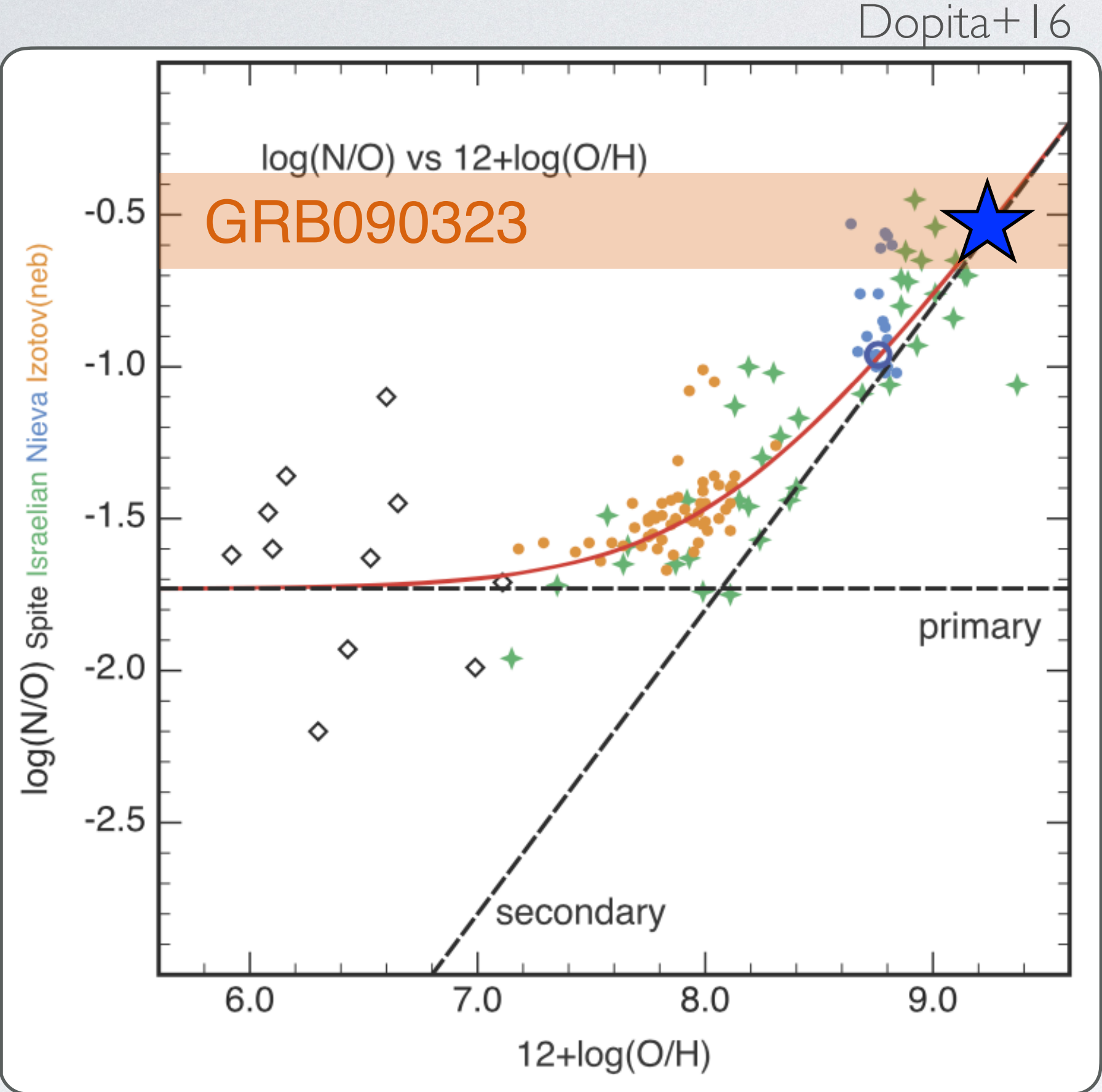


Option 1: Standard N/O-O/H relation, R2&R3 enhanced





# GRB090323: N/O-O/H RELATION AT HIGH-Z



Option 1: Standard N/O-O/H relation, R2&R3 enhanced

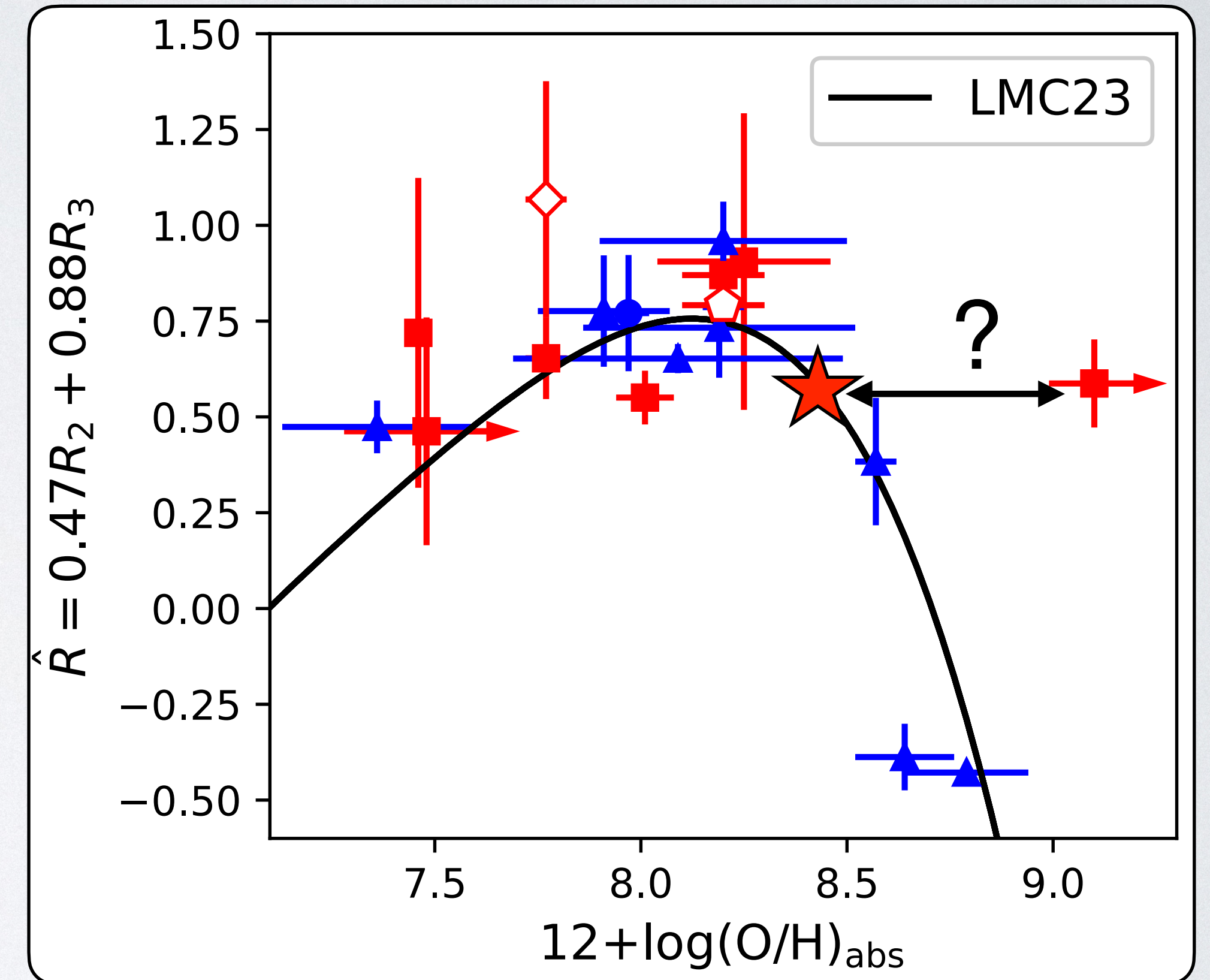
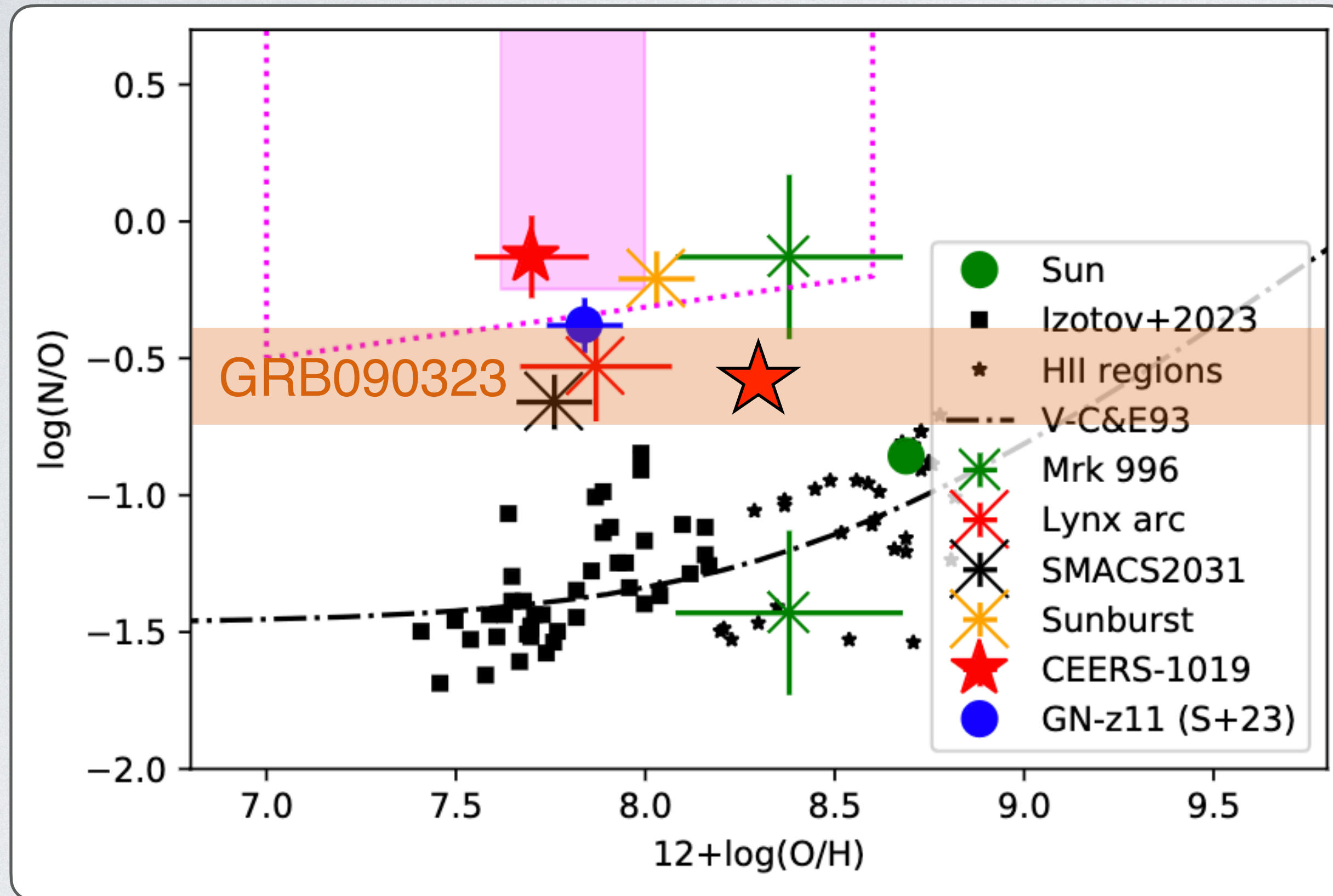




# GRB090323: N/O-O/H RELATION AT HIGH-Z

Marques-Chavez+24

PS+24, submitted



Option 2: R2&R3 standard, N/O is enhanced

