VLT/UVES survey of GRB afterglows

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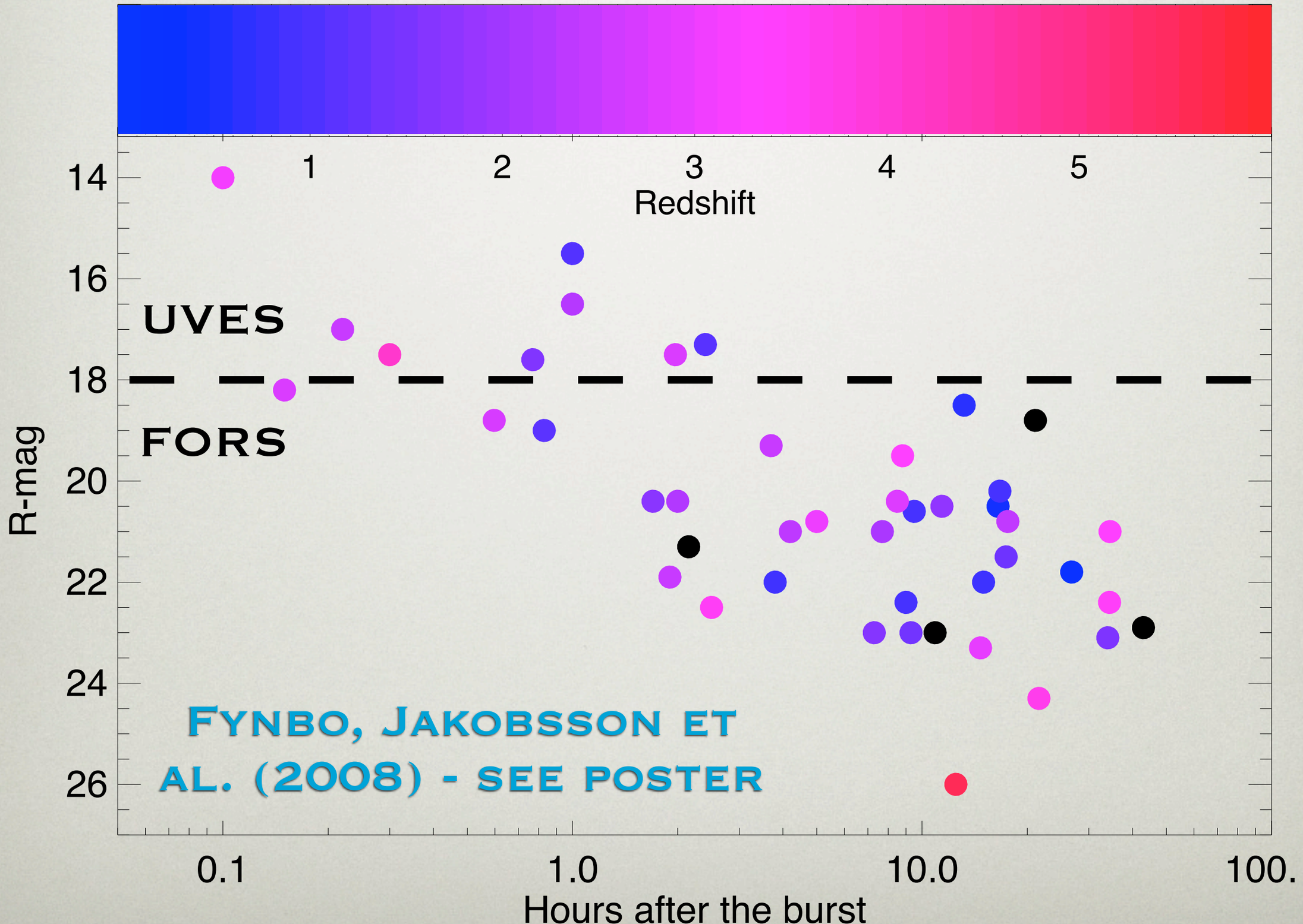
Johan Fynbo (DARK)

Very few GRB afterglows bright enough for UVES



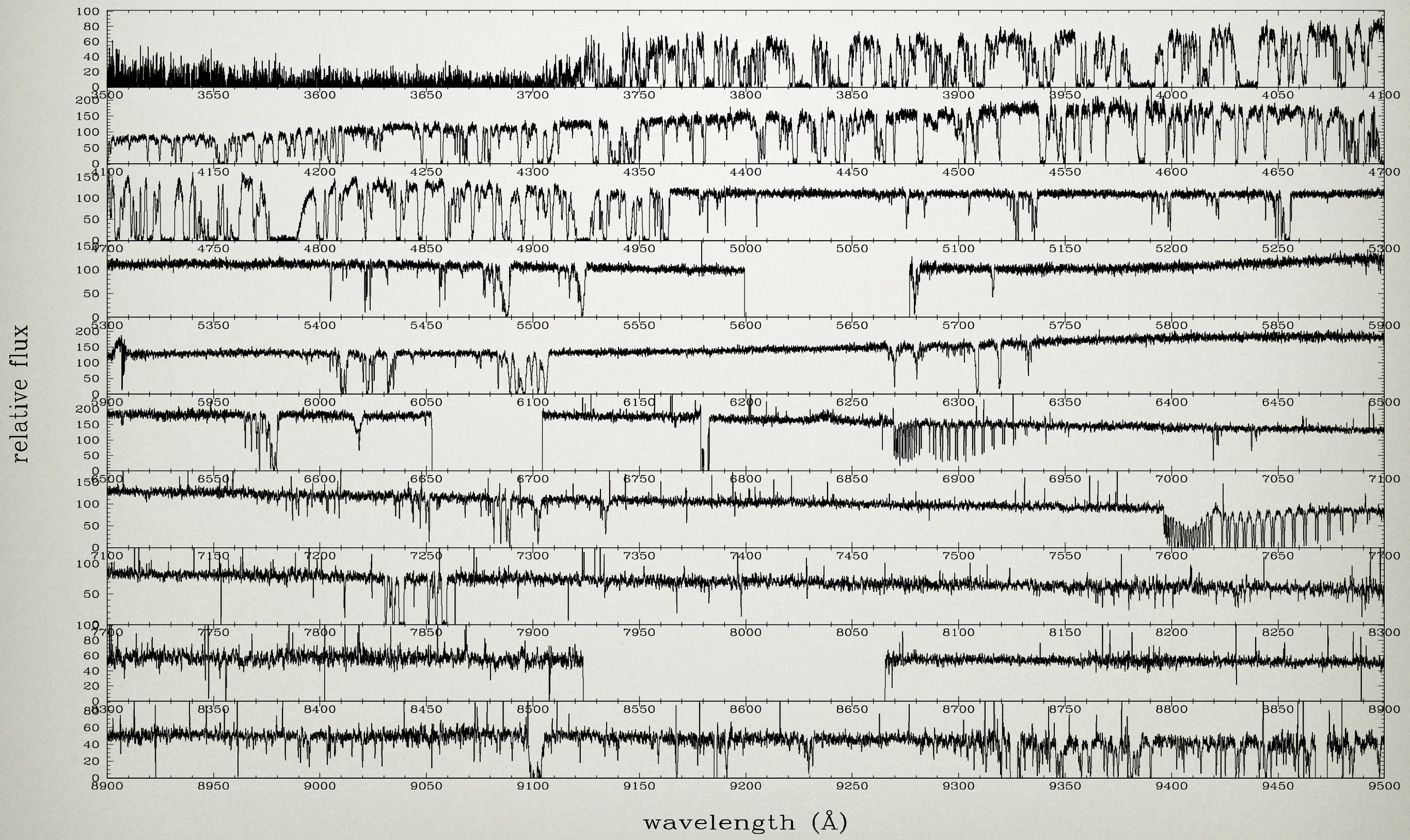
VLT Rapid-Response Mode

- allows automatic observations at the Very Large Telescope
- approved program defines observations (OBs)
- activation through upload of ftp file
  - name: description of observation
  - content: RA and DEC
- if various conditions met (observability, instrument mounted, etc.), then current observation read-out, and slew to new position
- delay activation-observation: 5-10 minutes for UVES
- visiting astronomer loss of time is compensated in service mode

UVES GRB sample

GRB	ΔT (HH:MM)	z	EXPTIME (HOURS)	LOG N_{HI}	[X/H]	PROGRAM
021004	13:31	2.329	2.0	19.0		Fiore/van den Heuvel
050730	04:09	3.969	1.7	22.10	-2.18	Fiore
050820	00:22	2.615	1.7	21.05	-0.39	Vreeswijk
050922C	03:33	2.199	1.7	21.55	-1.82	Fiore
060418	00:10	1.490	2.6			Vreeswijk
060607	00:08	3.075	3.3	17.20		Vreeswijk
071031	00:09	2.692	2.6	22.15	-1.73	Vreeswijk
080310	00:13	2.427	1.3	18.80	-1.39	Vreeswijk
080319B	00:09	0.937	2.1			Fiore/ Vreeswijk
080413	03:42	2.435	2.3	21.85	-1.60	Vreeswijk

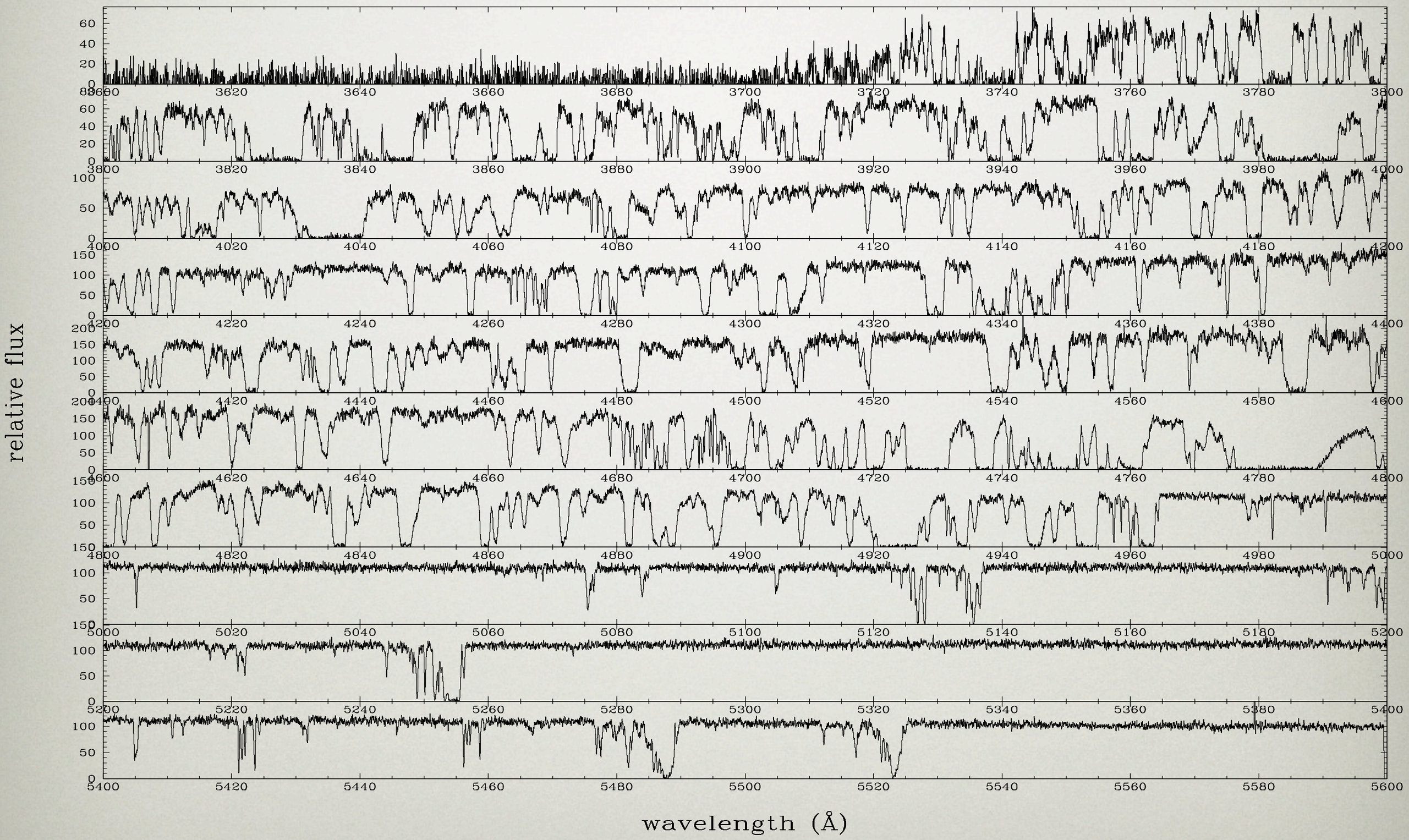
EXAMPLE: GRB 060607



Smette, Savaglio, Ledoux et al. (2008)

EXAMPLE: GRB 060607

z=3.07476 z=3.05002 z=2.93719 z=2.88957 z=2.27842 z=2.21801 z=1.80334 z=1.51026



Smette, Savaglio, Ledoux et al. (2008)

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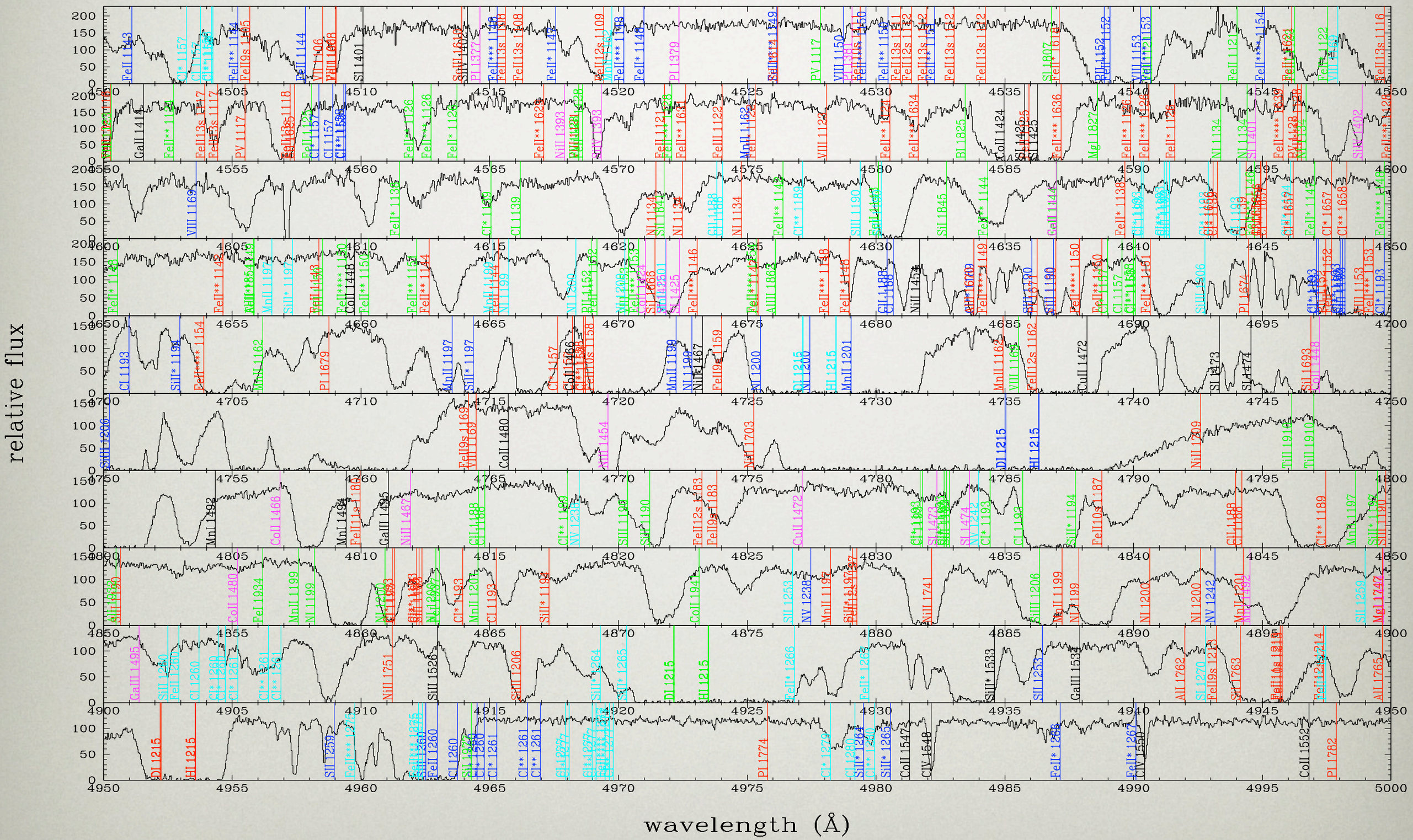
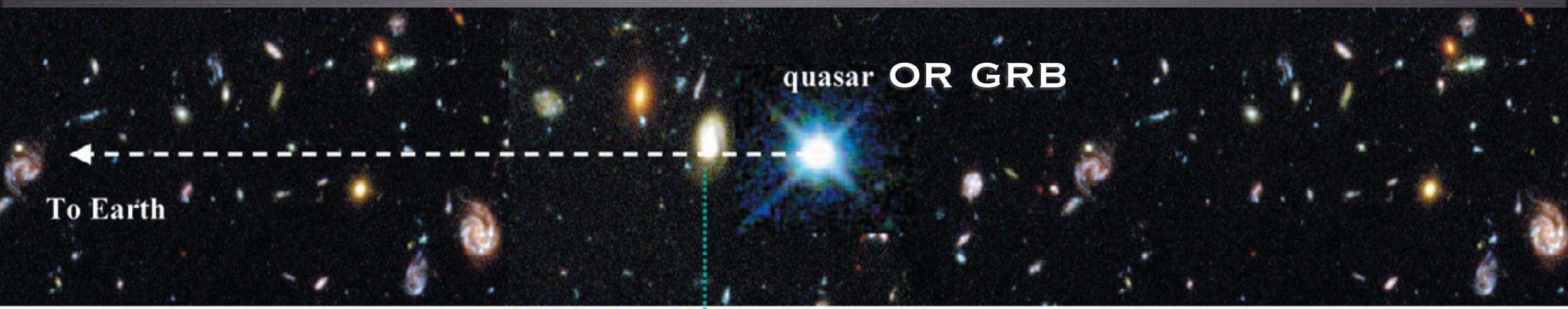
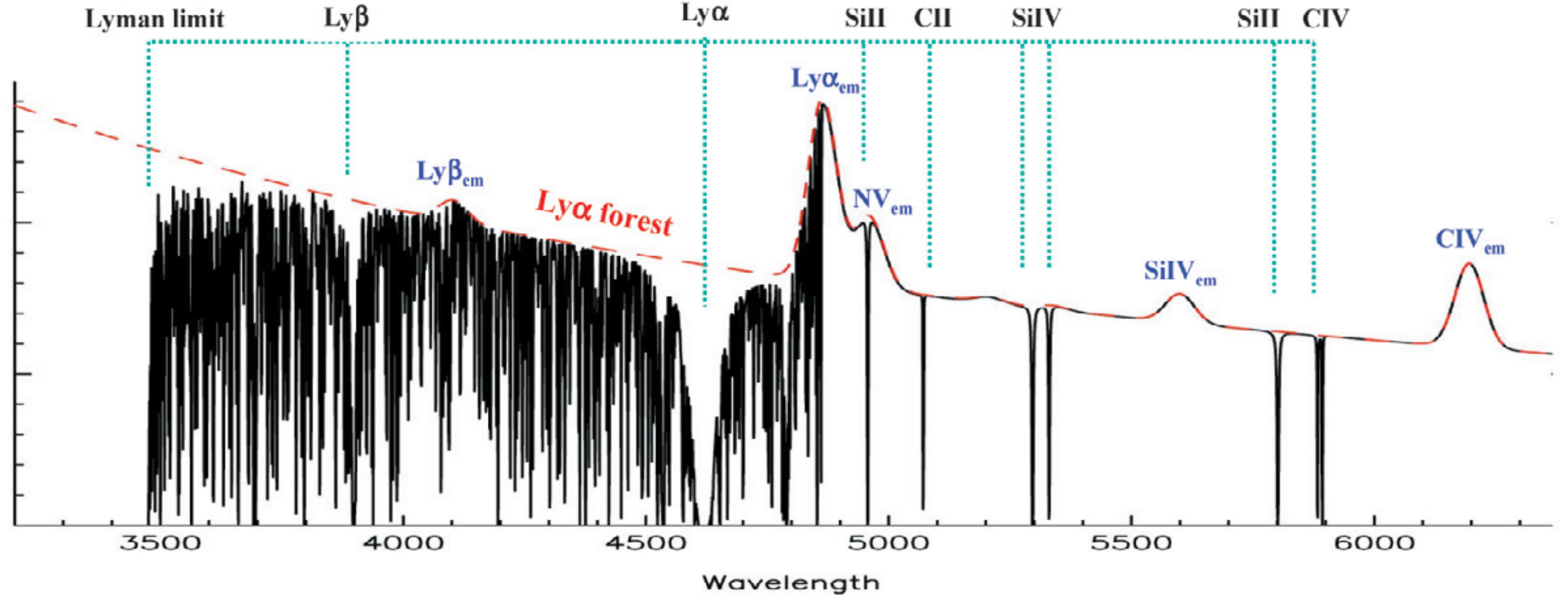


Smette, Savaglio, Ledoux et al. (2008)

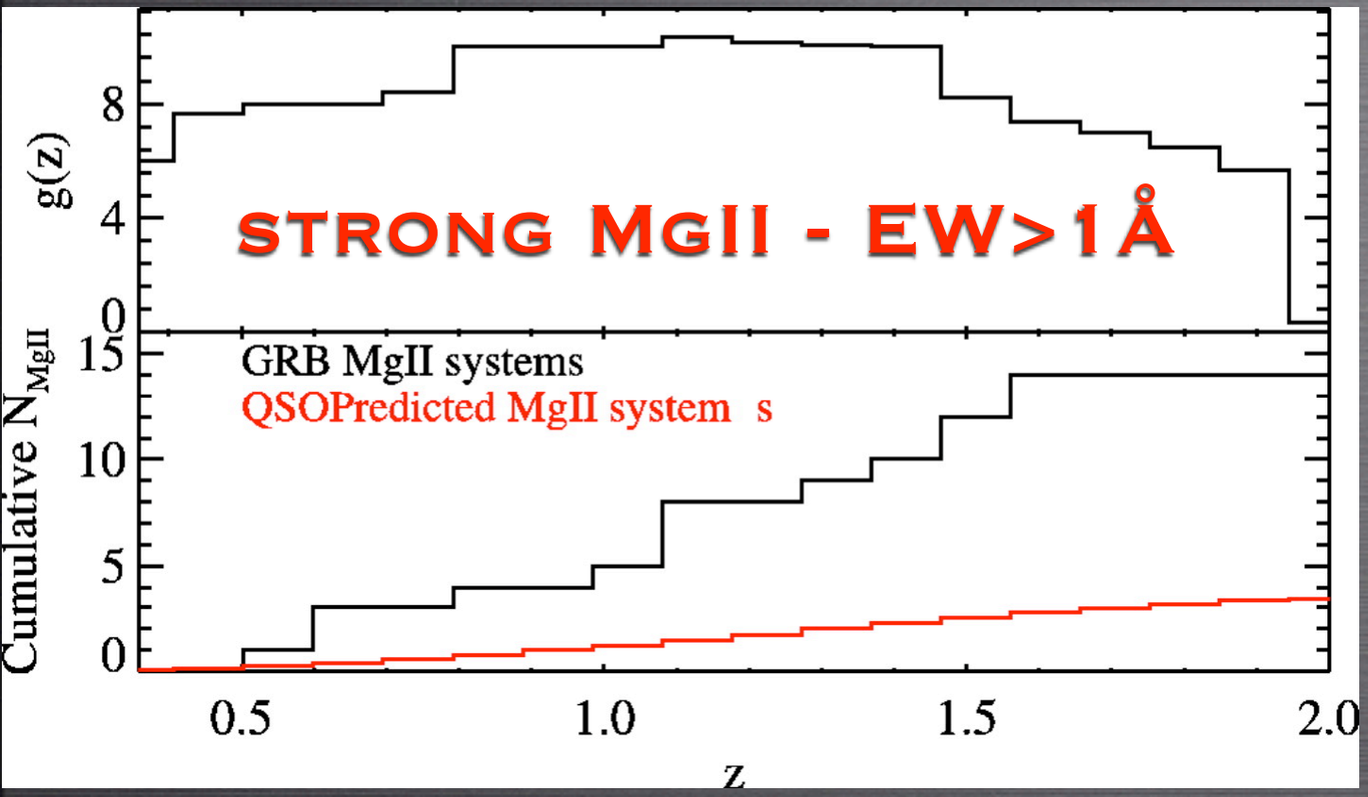
INTERVENING ABSORPTION SYSTEMS



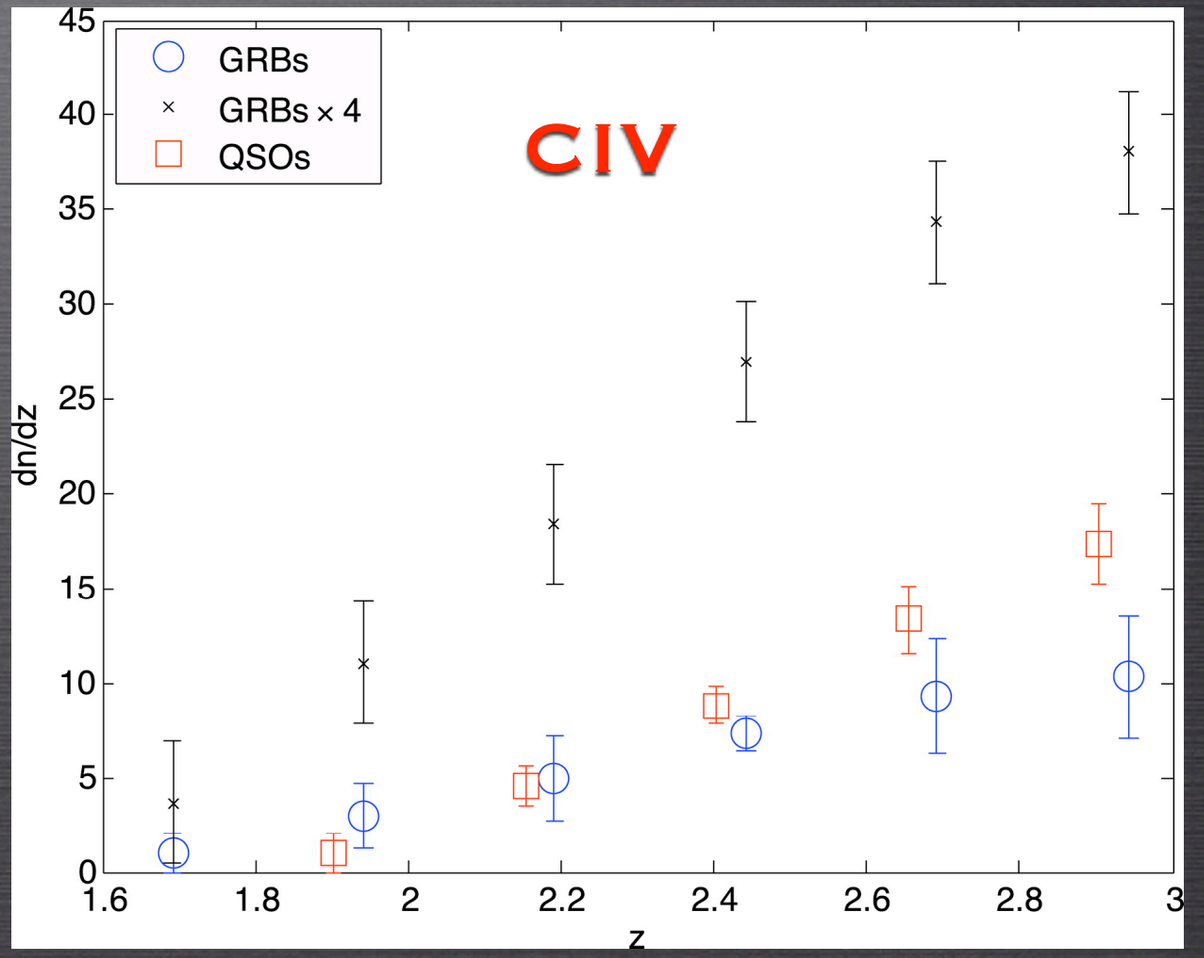
FROM JOHN WEBB



INTERVENING ABSORPTION SYSTEMS

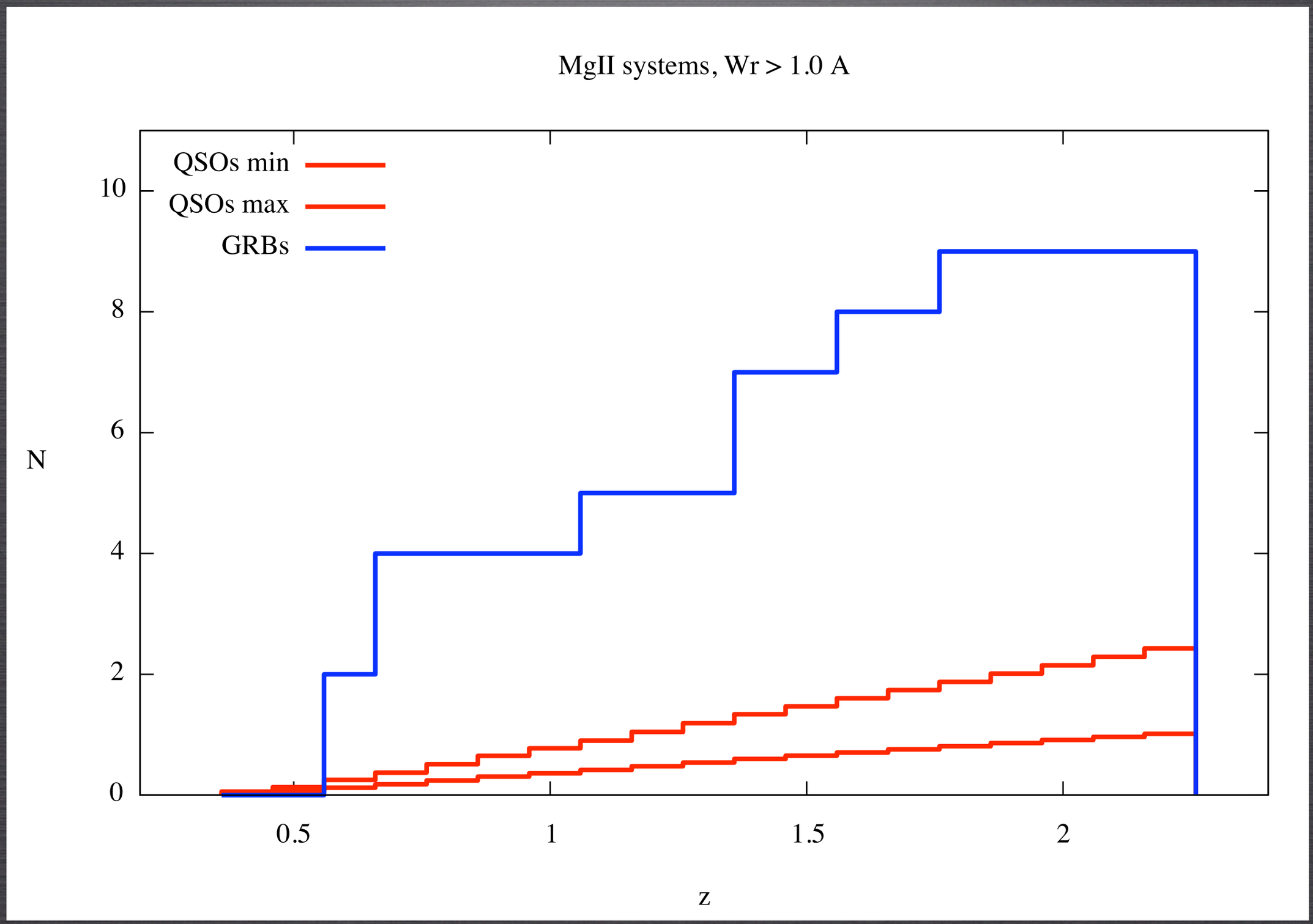


Prochter, prochaska, chen et al. (2006)



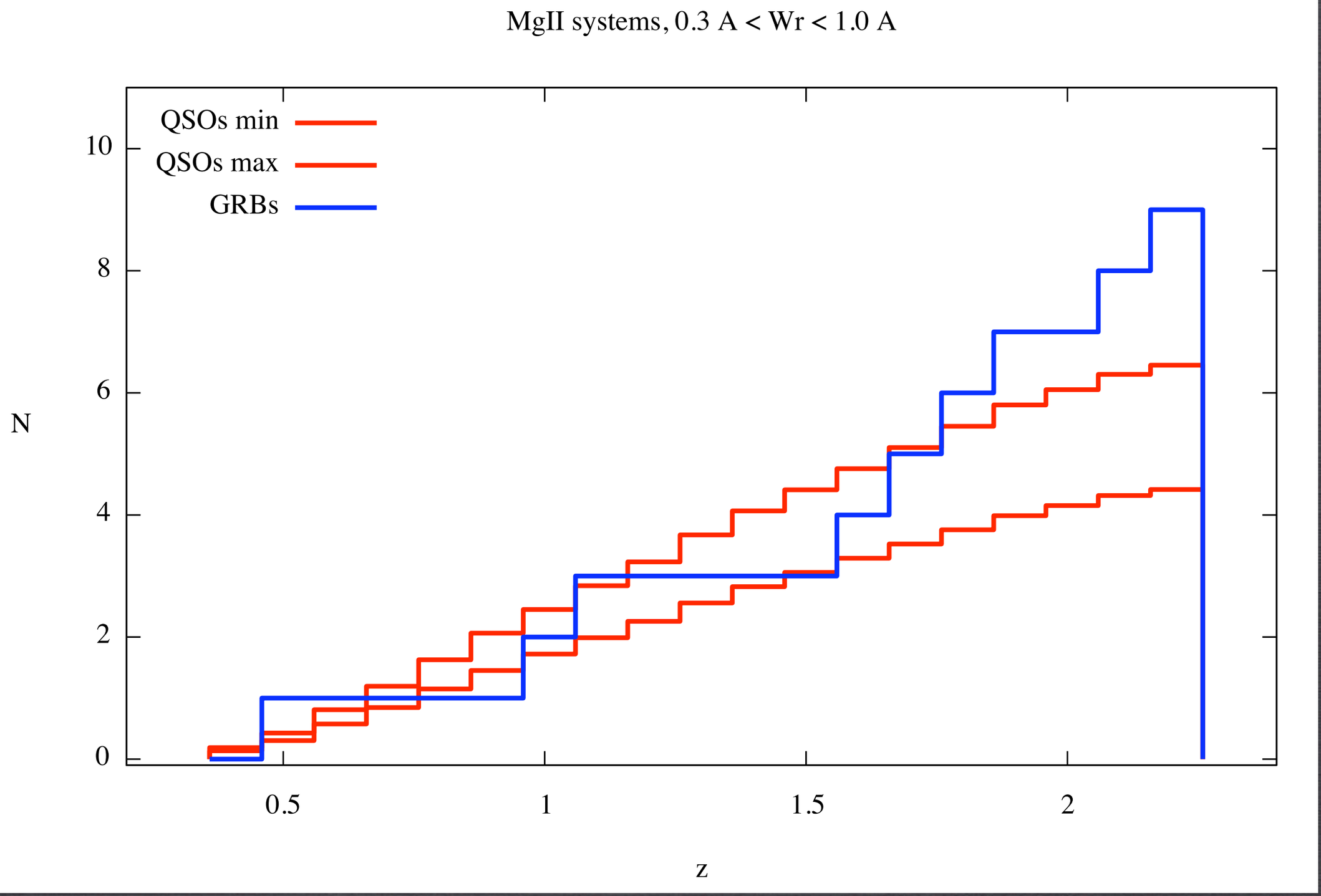
Sudilovsky, savaglio et al. (2007)

INTERVENING STRONG MgII



VERGANI, PETITJEAN, LEDOUX ET AL. (2008) - SEE POSTER

INTERVENING WEAKER MgII

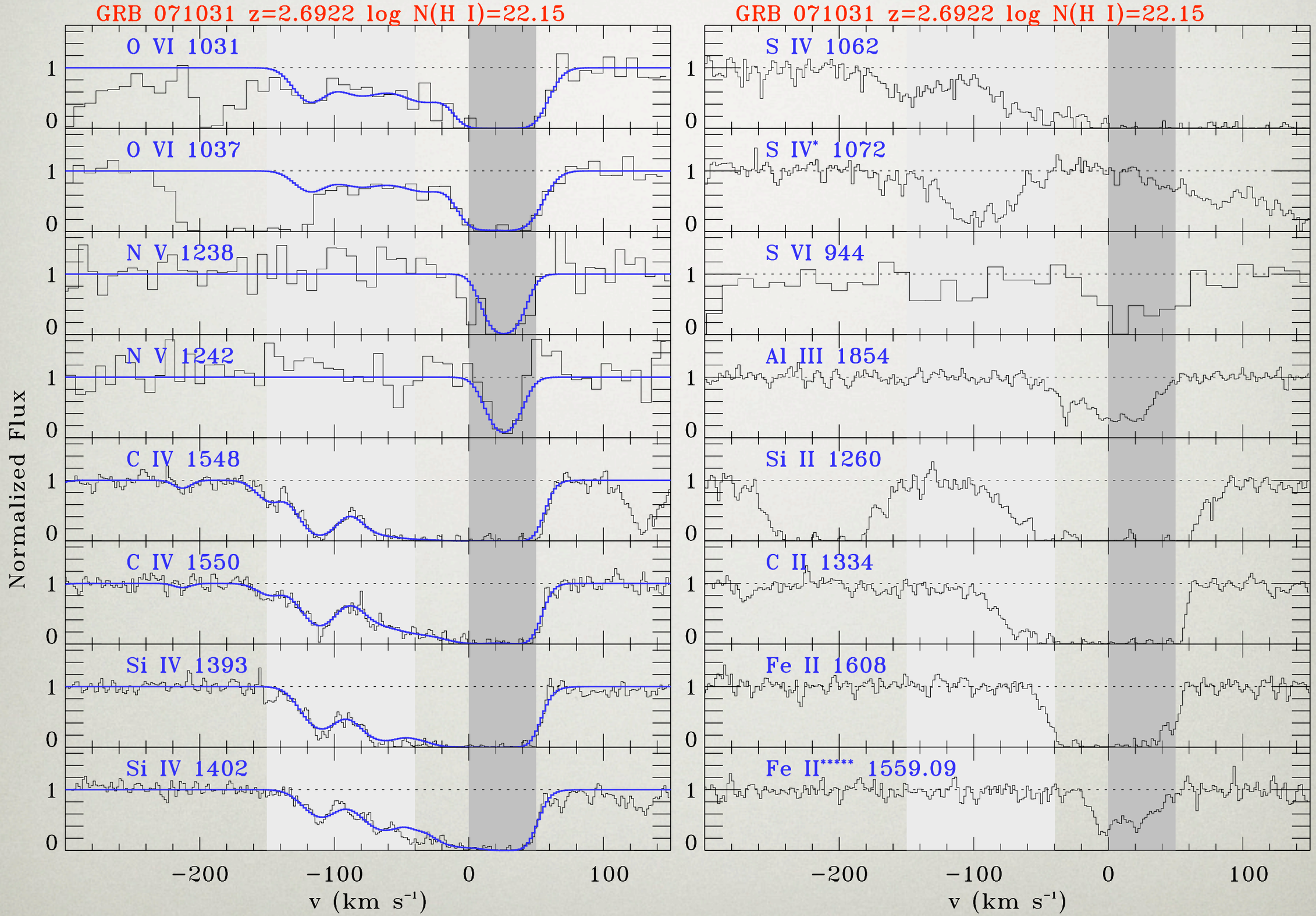


VERGANI, PETITJEAN, LEDOUX ET AL. (2008) - SEE POSTER

INTERVENING ABSORBERS

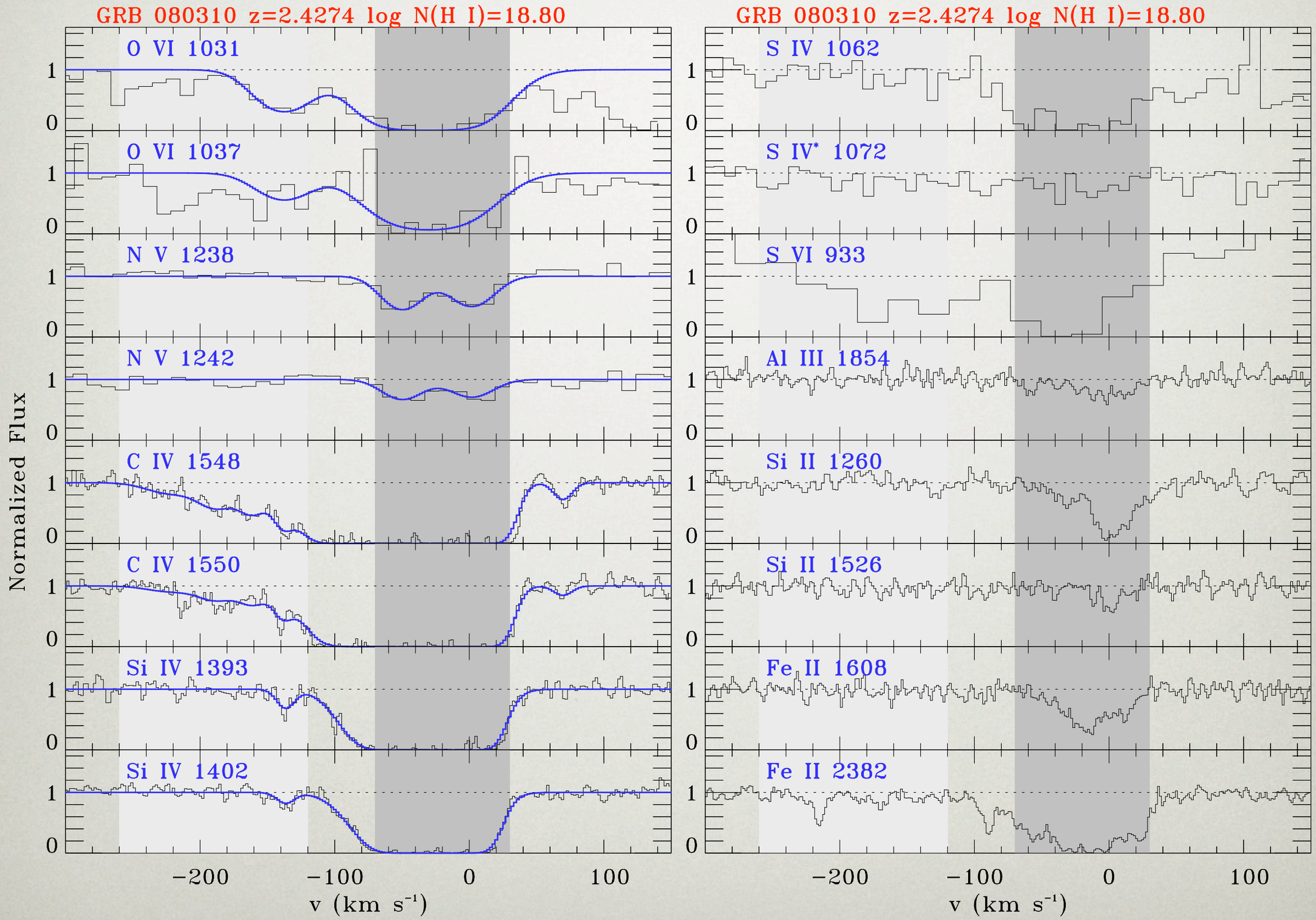
- strong MgII system overdensity confirmed by UVES data
- however: CIV and weaker MgII systems not different from QSO sightlines
- discrepancy has not yet been successfully explained (see Porciani, Viel & Lilly 2007)
  - dust obscuration bias
  - difference in GRB and QSO beam sizes
  - magnification bias
  - ejected systems in GRB sightlines

HIGH-IONIZATION LINES IN 071031



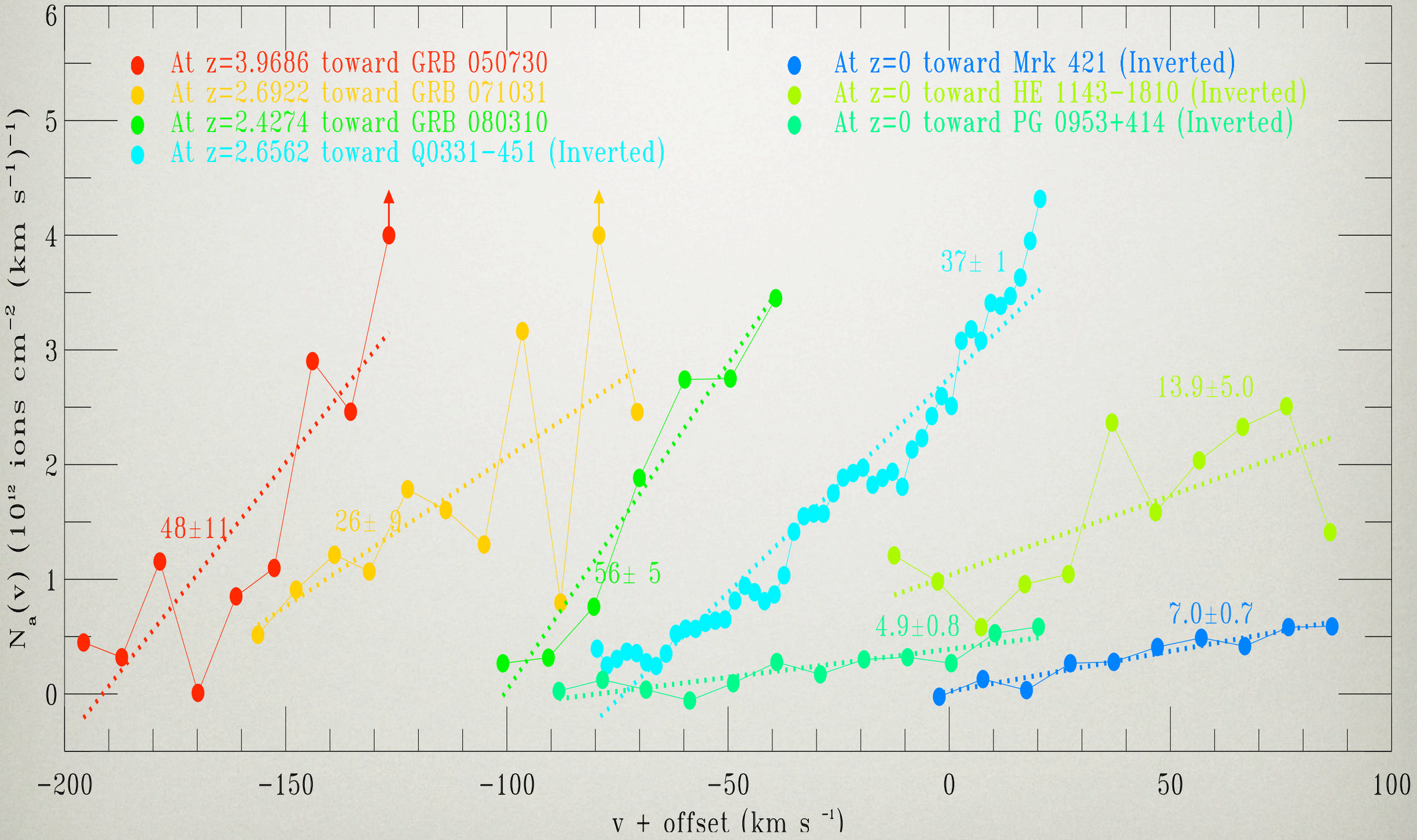
Fox, Ledoux, Vreeswijk et al. (2008)

HIGH-IONIZATION LINES IN 080310



Fox, Ledoux, Vreeswijk et al. (2008)

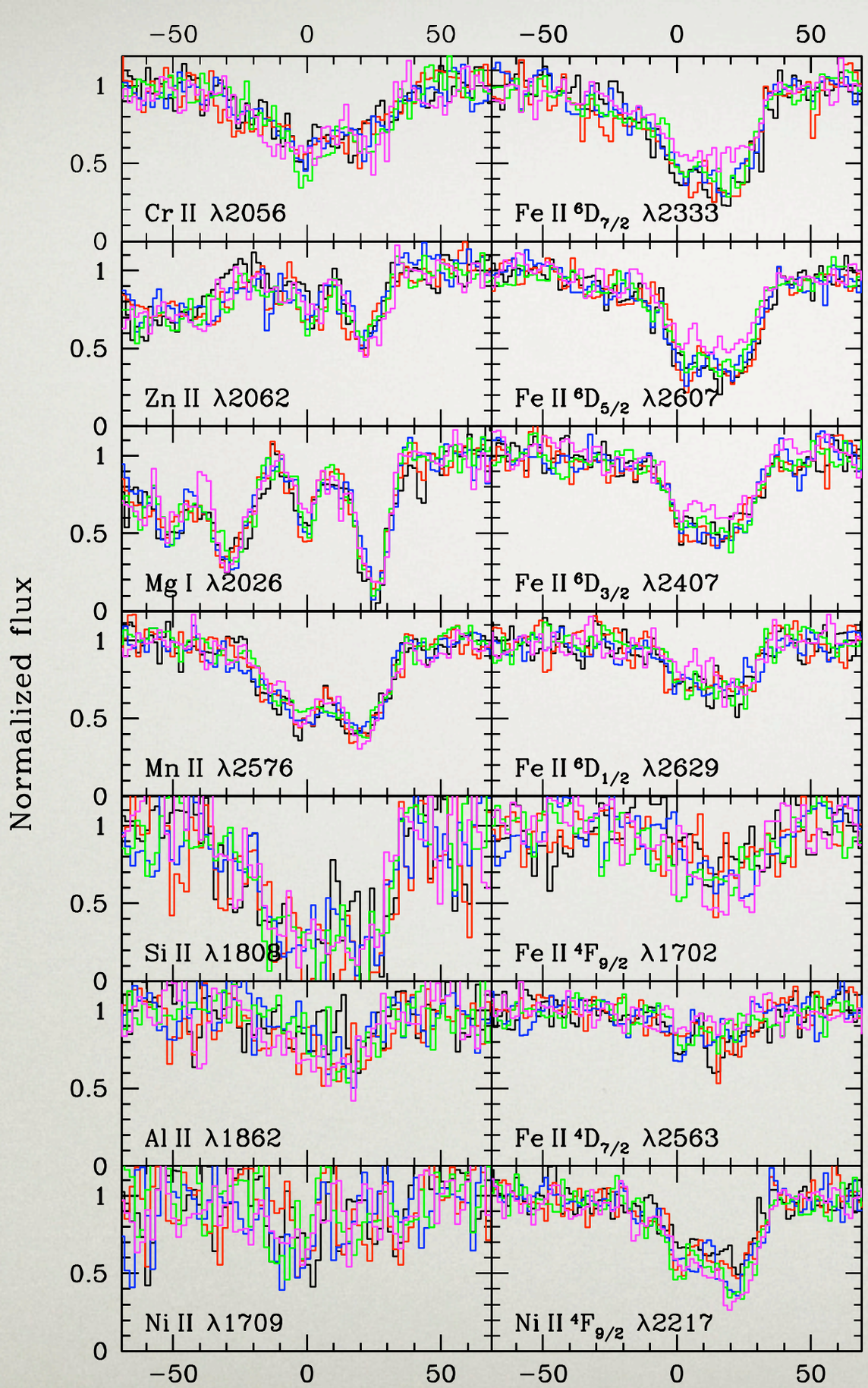
OVI WINGS IN MW, SUB-DLA AND GRBS



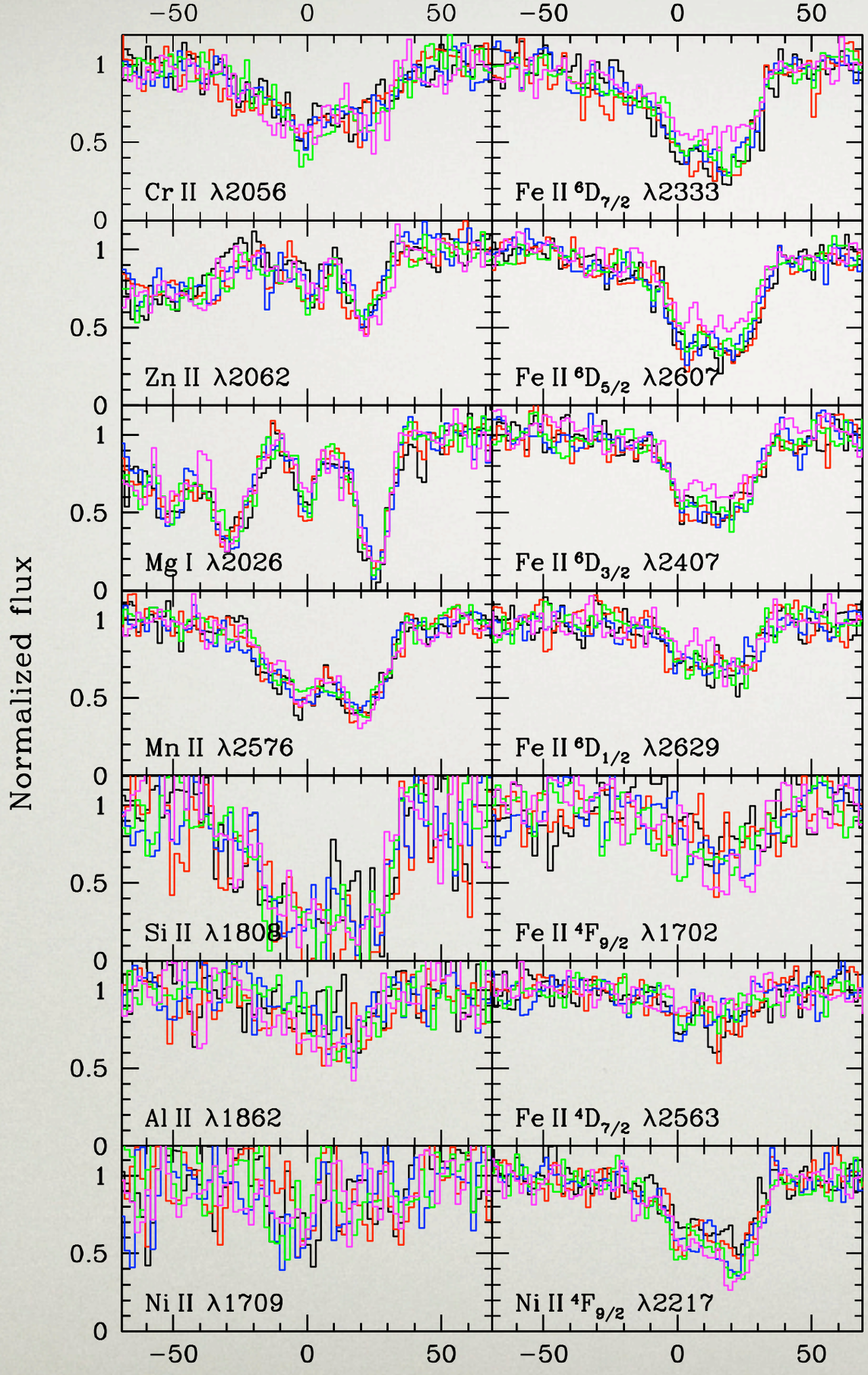
Fox, Ledoux, Vreeswijk et al. (2008)

VLT/UVES on GRB 060418

- GRB 060418 rapidly localized by Swift (Falcone et al. 2006)
- desktop computer triggered the VLT Rapid-Response Mode automatically thanks to Swift's prompt XRT position and Scott Barthelmy's GCN system
- start first Ultra-violet and Visual Echelle Spectrograph (UVES) exposure 10 min after burst trigger
- time series 3, 5, 10, 20, 40 min and 80 min different setting
- resolution 7 km/s, coverage 330-670nm and up to 950nm
- signal-to-noise ratios: 10-20 per pixel per spectrum


−50
0
50
Cr II λ2056
Fe II $^6D_{7/2}$ λ2333
Zn II λ2062
Fe II $^6D_{5/2}$ λ2607
Mg I λ2026
Fe II $^6D_{3/2}$ λ2407
Mn II λ2576
Fe II $^6D_{1/2}$ λ2629
Si II λ1808
Fe II $^4F_{9/2}$ λ1702
Al II λ1862
Fe II $^4D_{7/2}$ λ2563
Ni II λ1709
Ni II $^4F_{9/2}$ λ2217
Normalized flux
Relative velocity (km s^{-1})

GRB 060418


Cr II λ2056
Fe II $^6D_{7/2}$ λ2333
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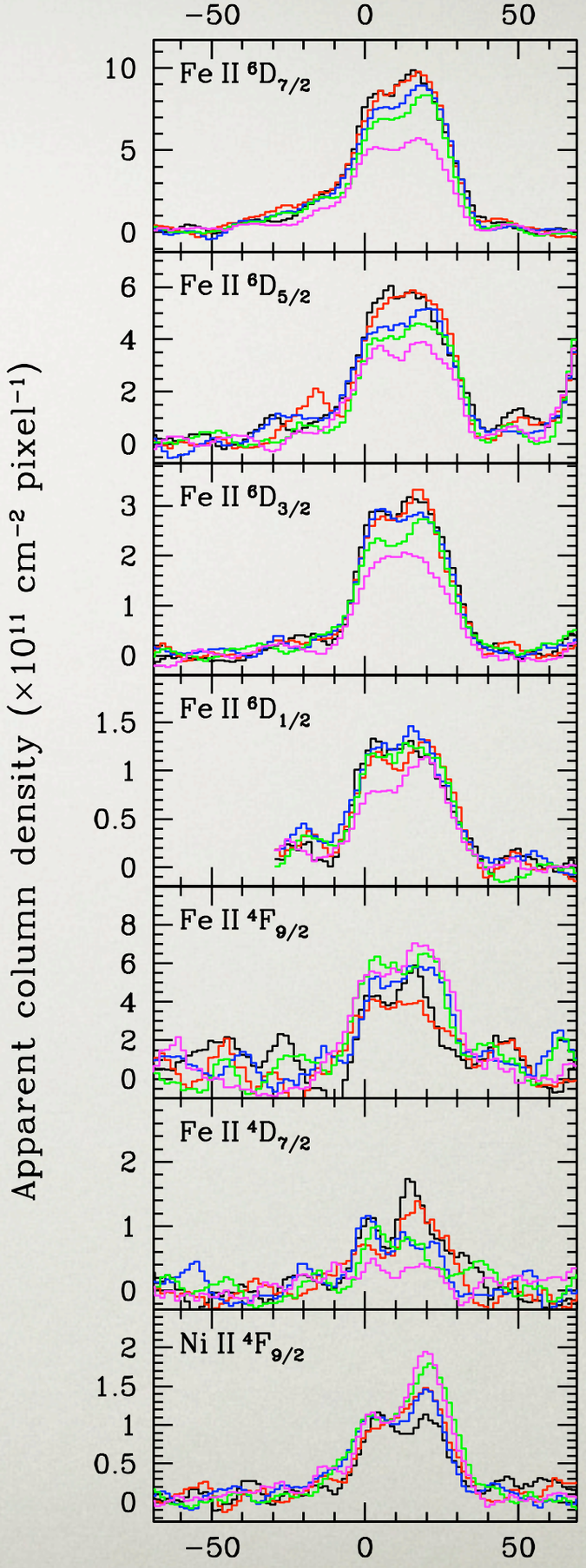
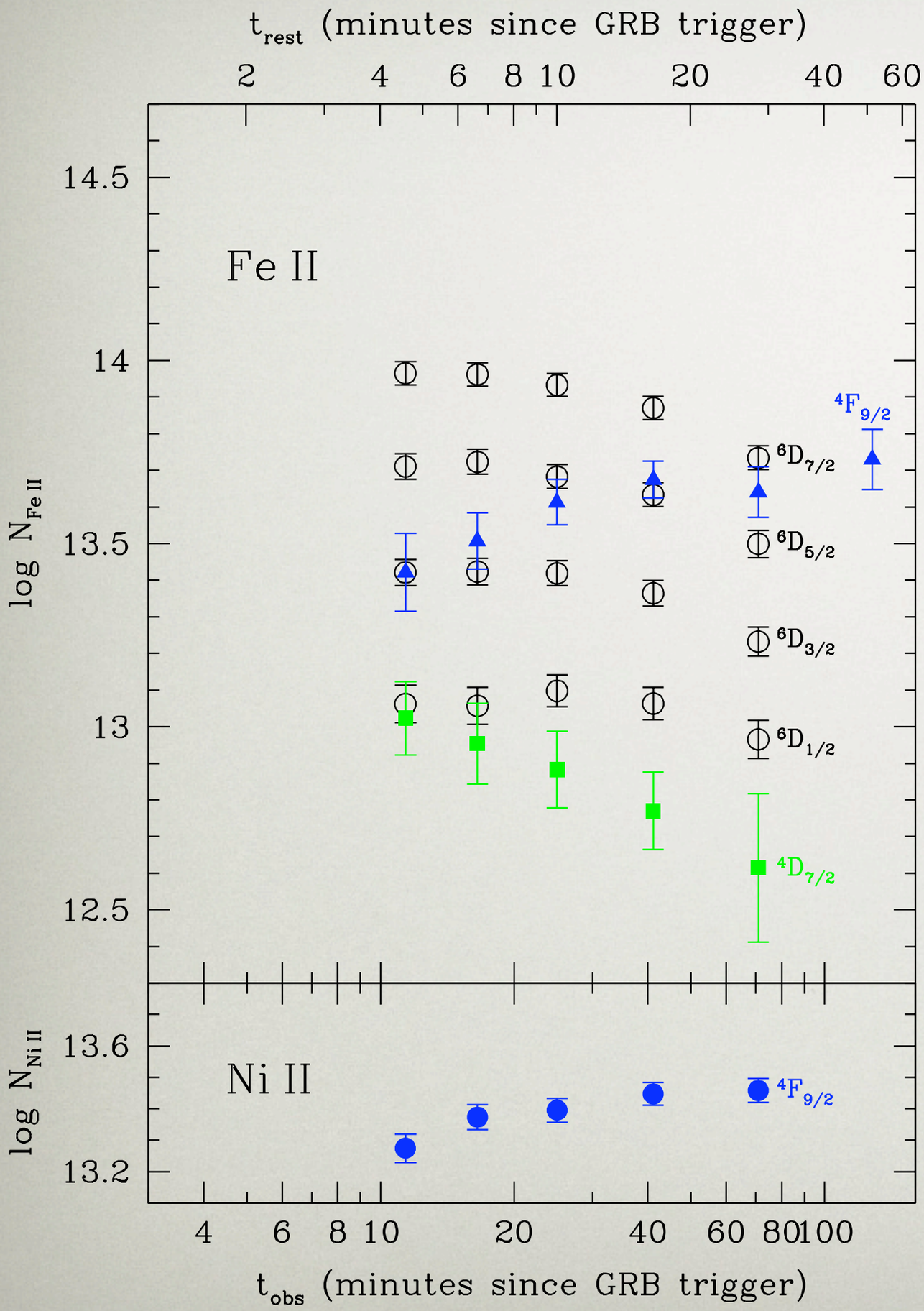
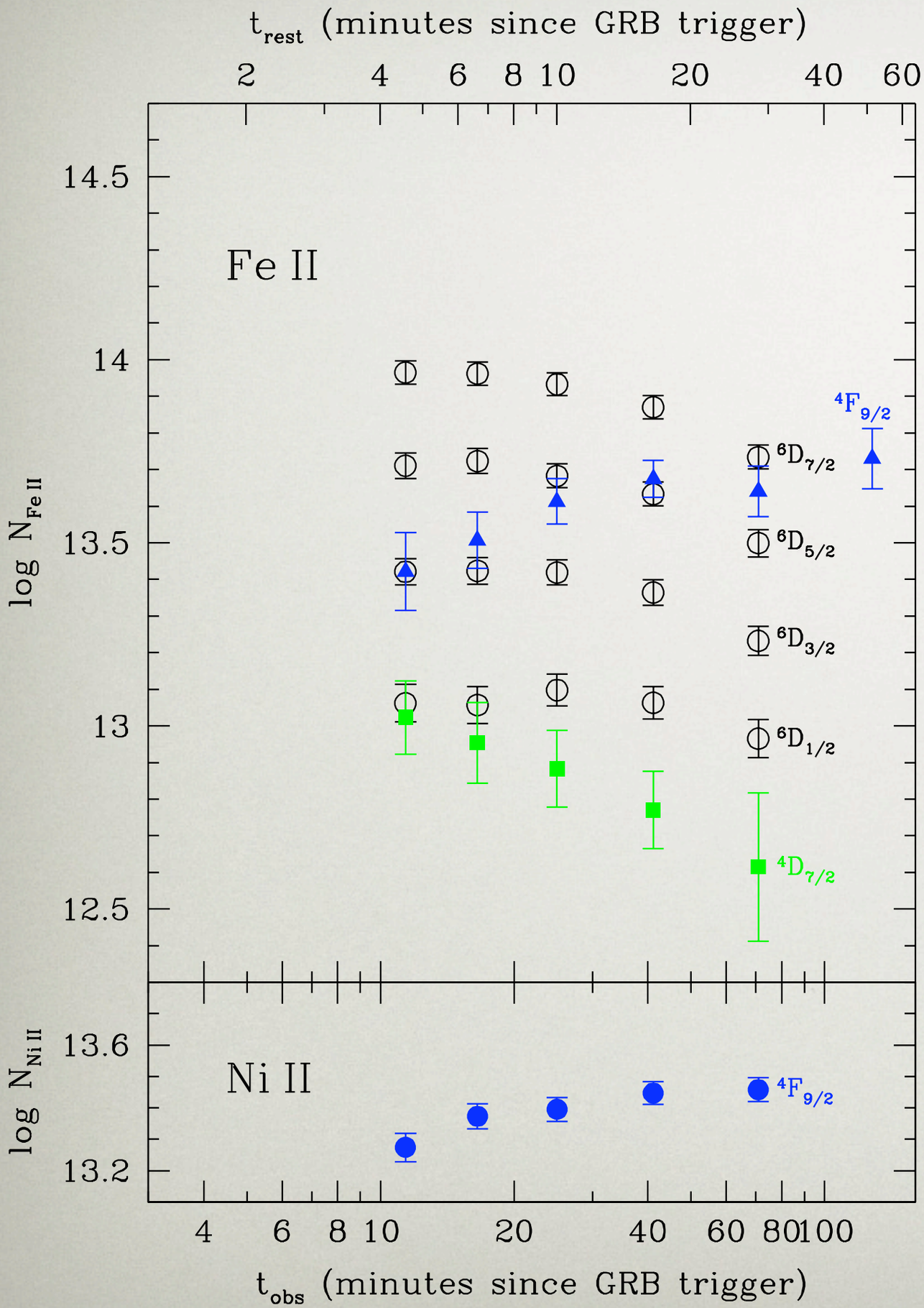
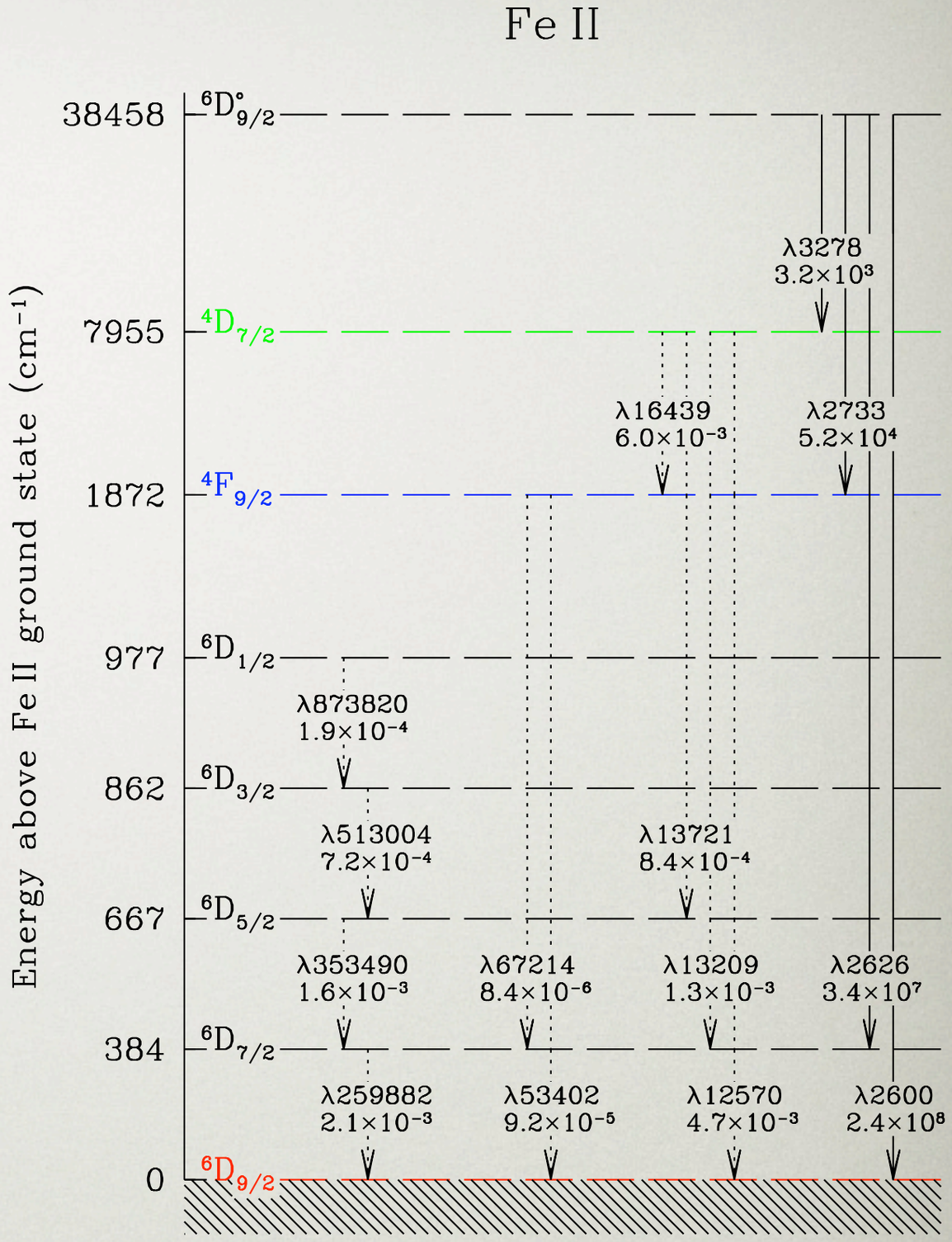
Ni II $^4F_{9/2}$ λ2217
Normalized flux
Relative velocity (km s^{-1})


Fe II $^6D_{7/2}$
Fe II $^6D_{5/2}$
Fe II $^6D_{3/2}$
Fe II $^6D_{1/2}$
Fe II $^4F_{9/2}$
Fe II $^4D_{7/2}$
Ni II $^4F_{9/2}$
Apparent column density (×10^{11} cm^{-2} pixel^{-1})
Relative velocity (km s^{-1})

GRB 060418


t_rest (minutes since GRB trigger)
2
4
6
8
10
20
40
60
Fe II
14.5
14
13.5
13
12.5
log N_Fe II
6D7/2
6D5/2
6D3/2
6D1/2
4F9/2
4D7/2
Ni II
13.6
13.2
log N_Ni II
4F9/2
4
6
8
10
20
40
60
80
100
t_obs (minutes since GRB trigger)

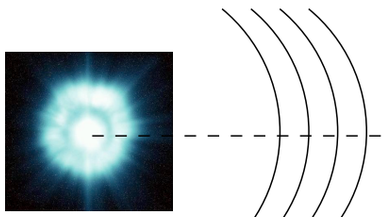

t_rest (minutes since GRB trigger)
2
4
6
8
10
20
40
60
Fe II
log N_Fe II
14.5
14
13.5
13
12.5
⁴F9/2
⁶D7/2
⁶D5/2
⁶D3/2
⁶D1/2
⁴D7/2
Ni II
log N_Ni II
13.6
13.2
⁴F9/2
4
6
8
10
20
40
60
80
100
t_obs (minutes since GRB trigger)

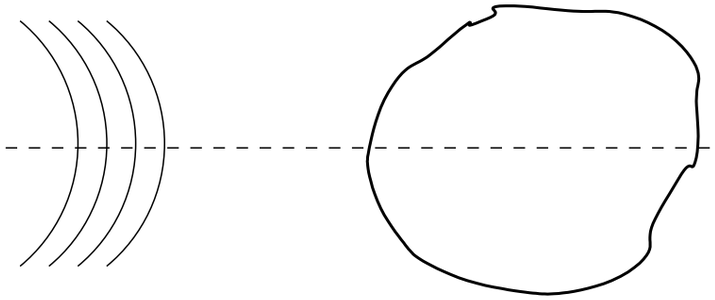

Fe II
Energy above Fe II ground state (cm⁻¹)
38458
7955
1872
977
862
667
384
0
⁶D°9/2
⁴D7/2
⁴F9/2
⁶D1/2
⁶D3/2
⁶D5/2
⁶D7/2
⁶D9/2
λ3278
3.2×10³
λ16439
6.0×10⁻³
λ2733
5.2×10⁴
λ873820
1.9×10⁻⁴
λ513004
7.2×10⁻⁴
λ13721
8.4×10⁻⁴
λ353490
1.6×10⁻³
λ67214
8.4×10⁻⁶
λ13209
1.3×10⁻³
λ2626
3.4×10⁷
λ259882
2.1×10⁻³
λ53402
9.2×10⁻⁵
λ12570
4.7×10⁻³
λ2600
2.4×10⁸

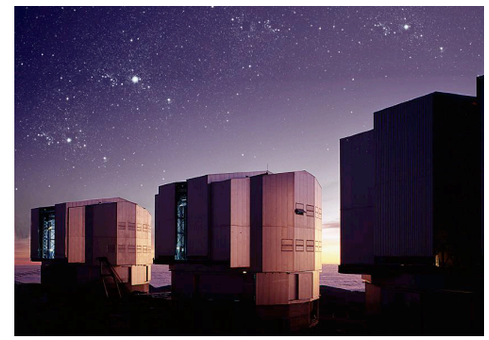
IR EXCITATION / UV PUMPING MODEL

$$F_\nu^{\rm rest} = \frac{1.192\times10^{-25}\left[\frac{t_{\rm obs}}{393\ {\rm s}}\right]^{\alpha}\left[\frac{\lambda_{\rm obs}}{5439\ \mathring{\rm A}}\right]^{-\beta}\left[\frac{1.083\times10^{10}\ {\rm pc}}{d}\right]^{2}}{1+z}$$

N(FeII, NiII)







DISTANCE

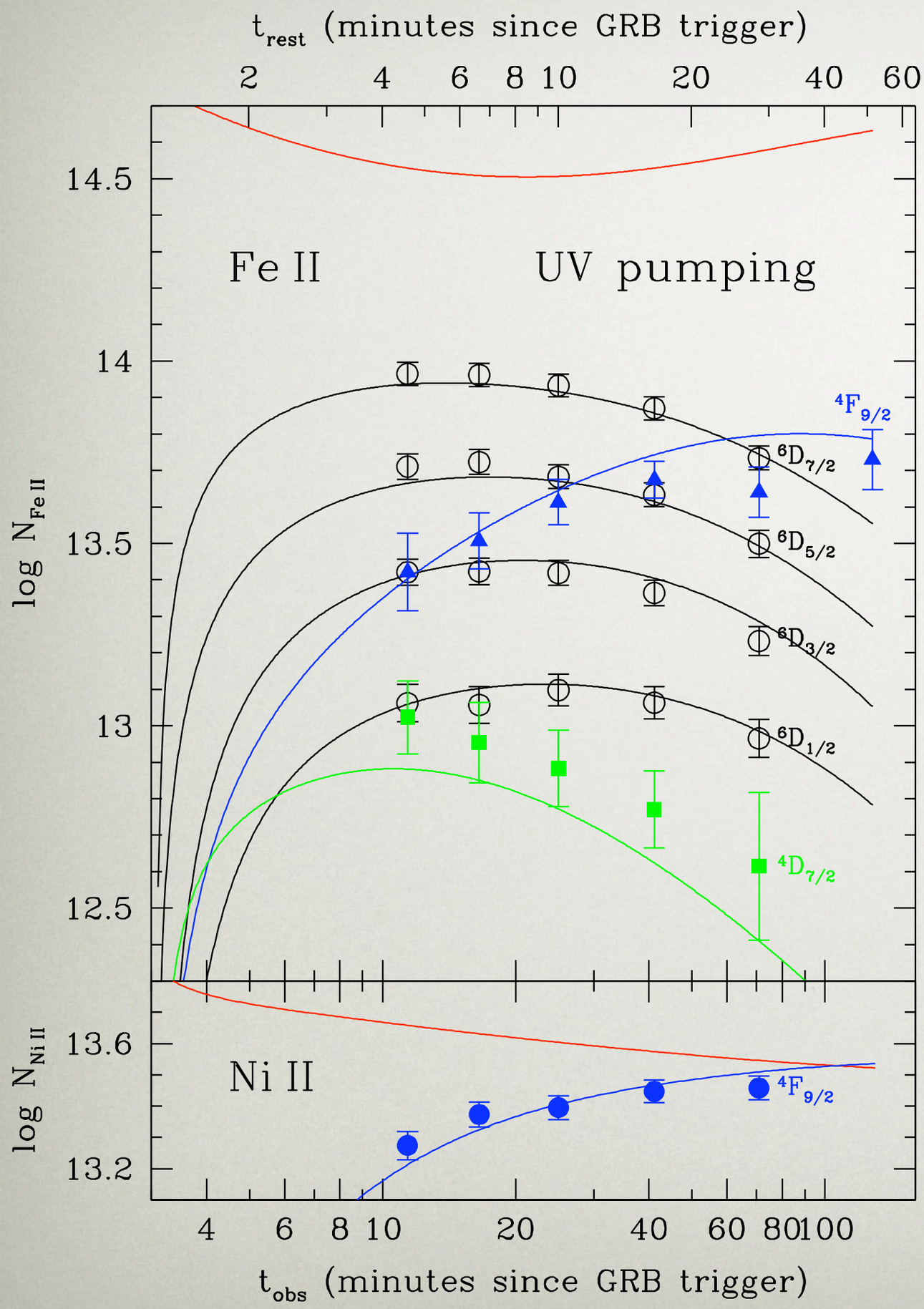
z

$$\frac{dN_{\rm u}}{dt} = N_{\rm l}B_{\rm lu}F_\nu(\tau_0) - N_{\rm u}\left[A_{\rm ul} + B_{\rm ul}F_\nu(\tau_0)\right]$$

$$F_\nu(\tau_0) = F_\nu(0)e^{-\tau_0} + S_\nu(1-e^{-\tau_0})$$

$$B_{\rm ul} = A_{\rm ul}\lambda^3/2hc$$

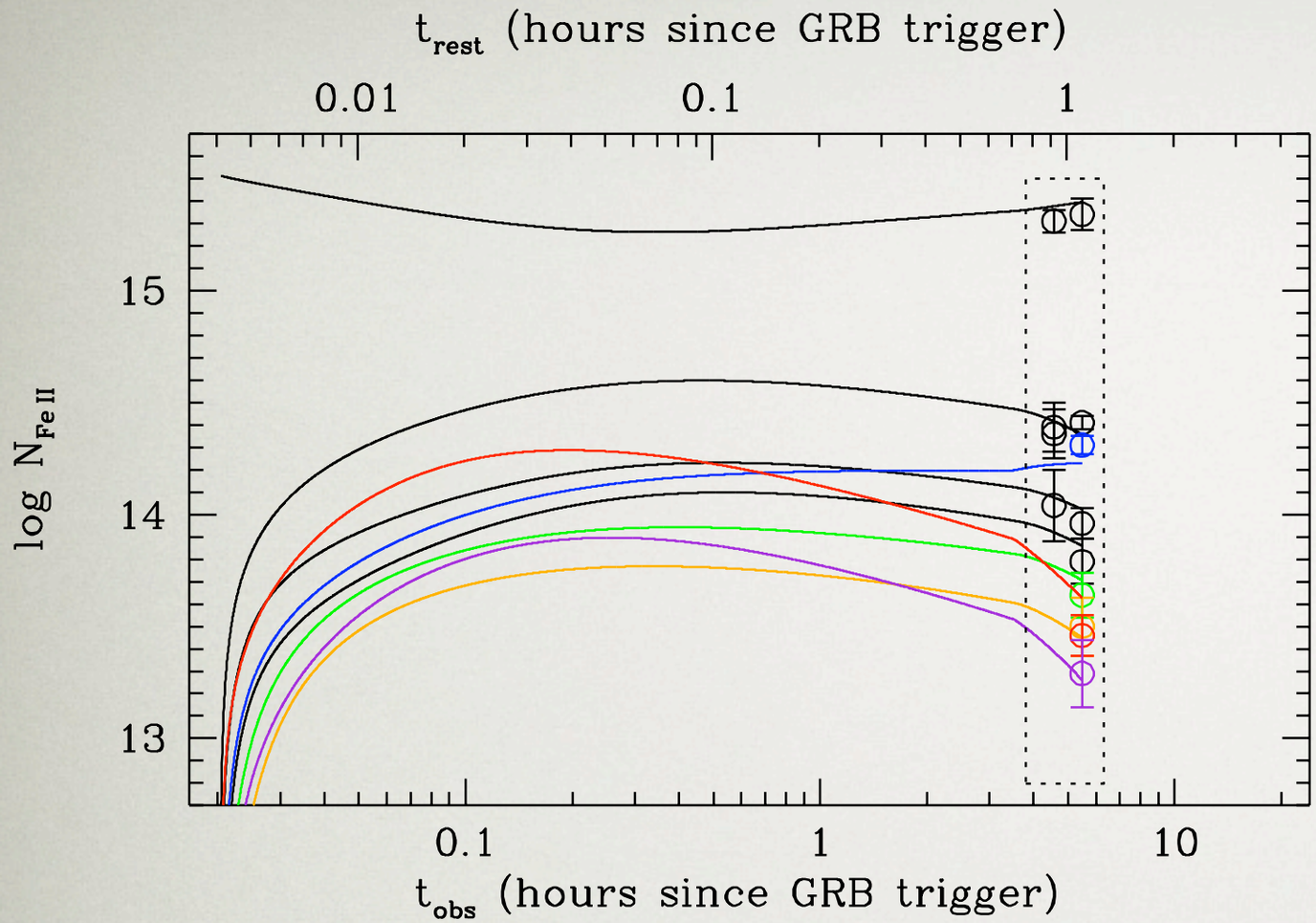
$$B_{\rm lu} = B_{\rm ul}\ g_{\rm u}\ /\ g_{\rm l}$$



UV PUMPING

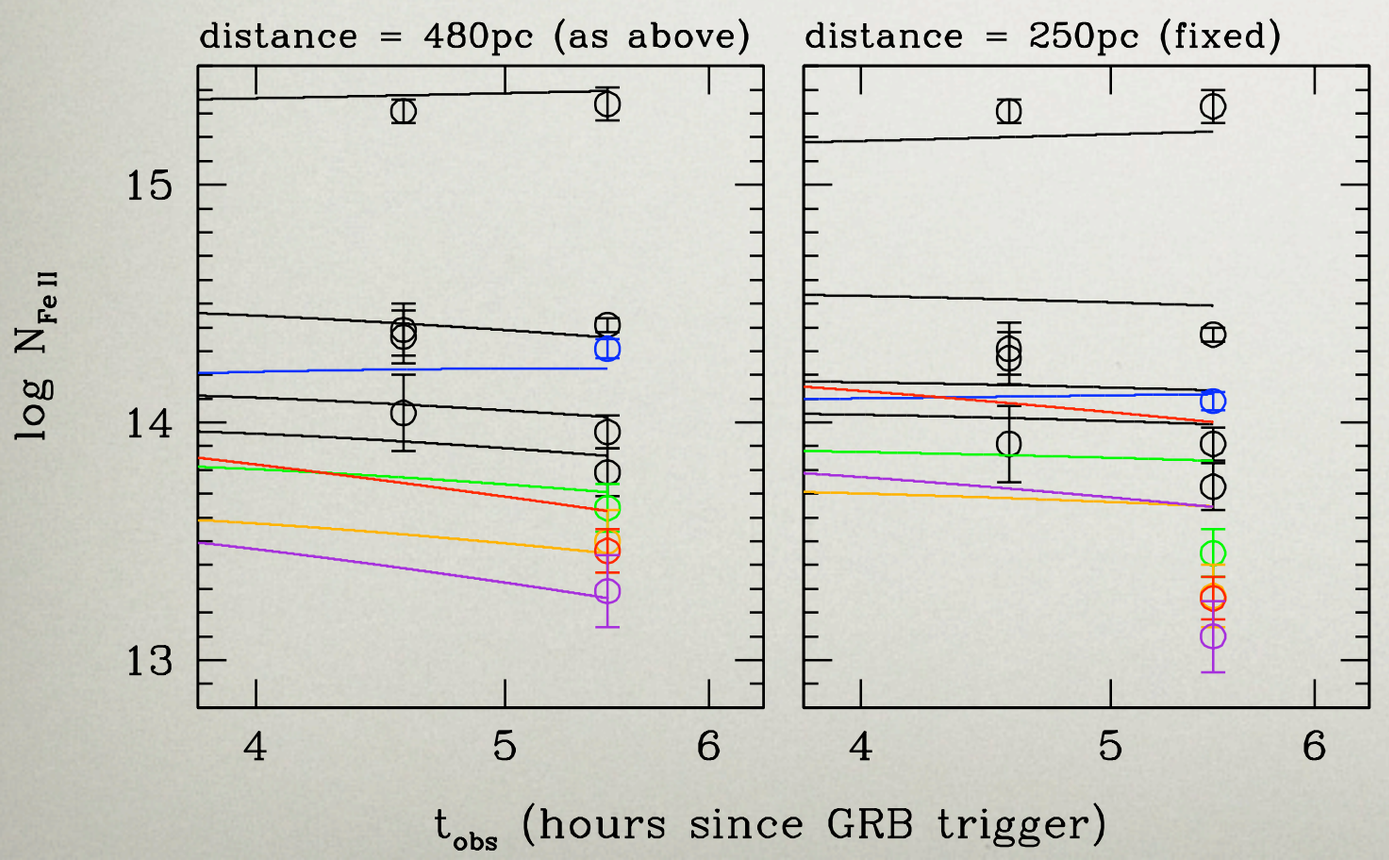
- DISTANCE = 1.7 ± 0.2 KPC
- LOG N (FEII) = 14.75 ± 0.06
- LOG N (NIII) = 13.84 ± 0.02
- BETA = −0.5 ± 1.0
- T_0 = 74 ± 12 S
- B = 25 ± 3 KM/S
- CHI-SQUARE = 26.2/(31-5)

VREESWIJK, LEDOUX, SMETTE ET AL. (2007)



GRB 050730

- Distance = 480 pc (250)
- Log N (FeII) = 15.51 (15.44)
- Beta = −0.56 (fixed)
- T_0 = 15 s (27)



- b = 10 km/s (fixed)
- chi^2 = 1.76 (7.30)

Ledoux, Vreeswijk
Smette et al. (2008)

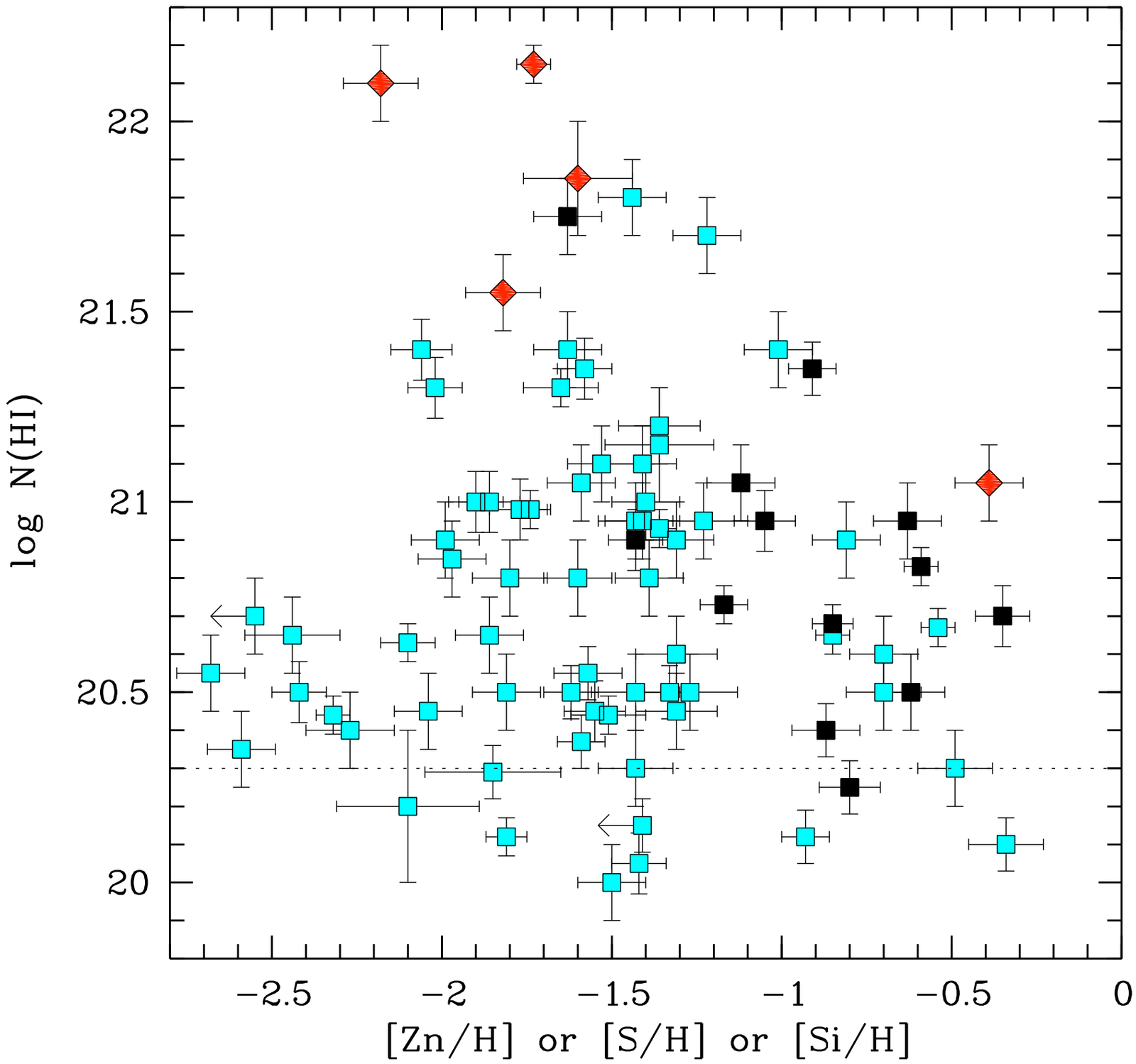
Excited-line variability

- detection of **variability of absorption lines** from fine-structure and metastable levels in several hosts
- modeling shows that **UV pumping is the responsible excitation mechanism** with a GRB-cloud distance range of 0.5-2 kpc (cf. MgI limits of Prochaska et al. (2006): > 50-100pc)

→ neutral material not in GRB immediate environment

→ any significant pre-burst neutral absorption system closer in must have been ionized

Where is H_2 in GRB hosts?



VLT/UVES samples:

- GRB-DLAs (z>1.8)
- QSO-DLAs without H_2
- QSO-DLAs with H_2

QSO data from Noterdaeme, Ledoux, Petitjean & Srianand (2008)

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Ledoux, Vreeswijk, Smette et al. (2008)

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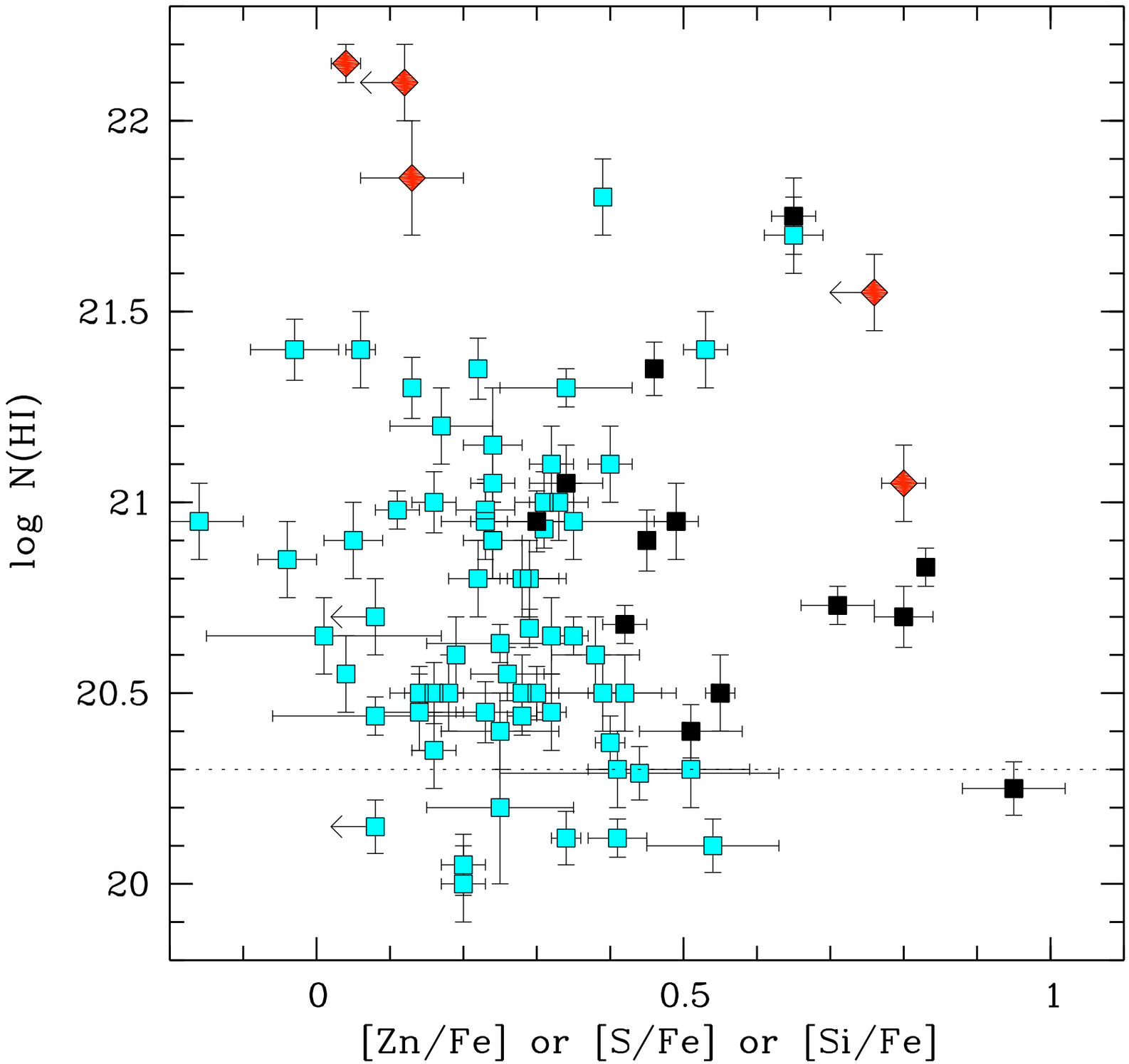

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QSO data from Noterdaeme, Ledoux, Petitjean & Srianand (2008)

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Ledoux, Vreeswijk, Smette et al. (2008)

Conclusions

- **30% of UVES GRB host absorbers have log N(HI) < 19**
  good news for GRBs as probes of re-ionization
- **intervening absorbers**: CIV systems or weaker MgII systems do not show any overdensity, as do strong MgII systems
- **high-ionization analysis** suggests the detection of OVI outflows from GRB hosts
- **FeII and NiII excited-line variability** by GRBs allows relative distance determinations of neutral gas in high-z (GRB) star-forming galaxies
- **non-detection of H_2** in GRB sightlines **not inconsistent with QSO-H_2 statistics**