Dissecting the close environment of gamma-ray bursts: overview and new perspectives in the Athena era

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Exploring the Hot and Energetic Universe:
The second scientific conference dedicated
to the Athena X-ray observatory

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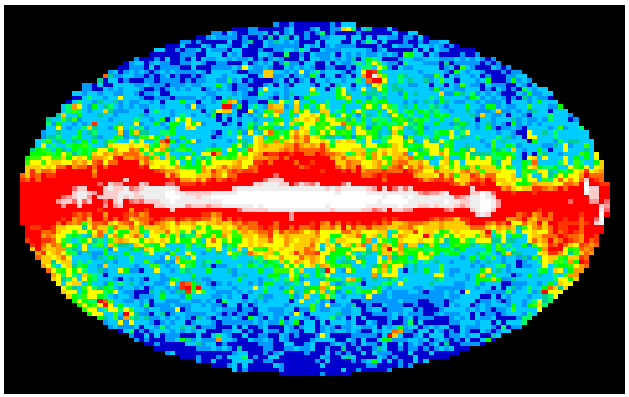
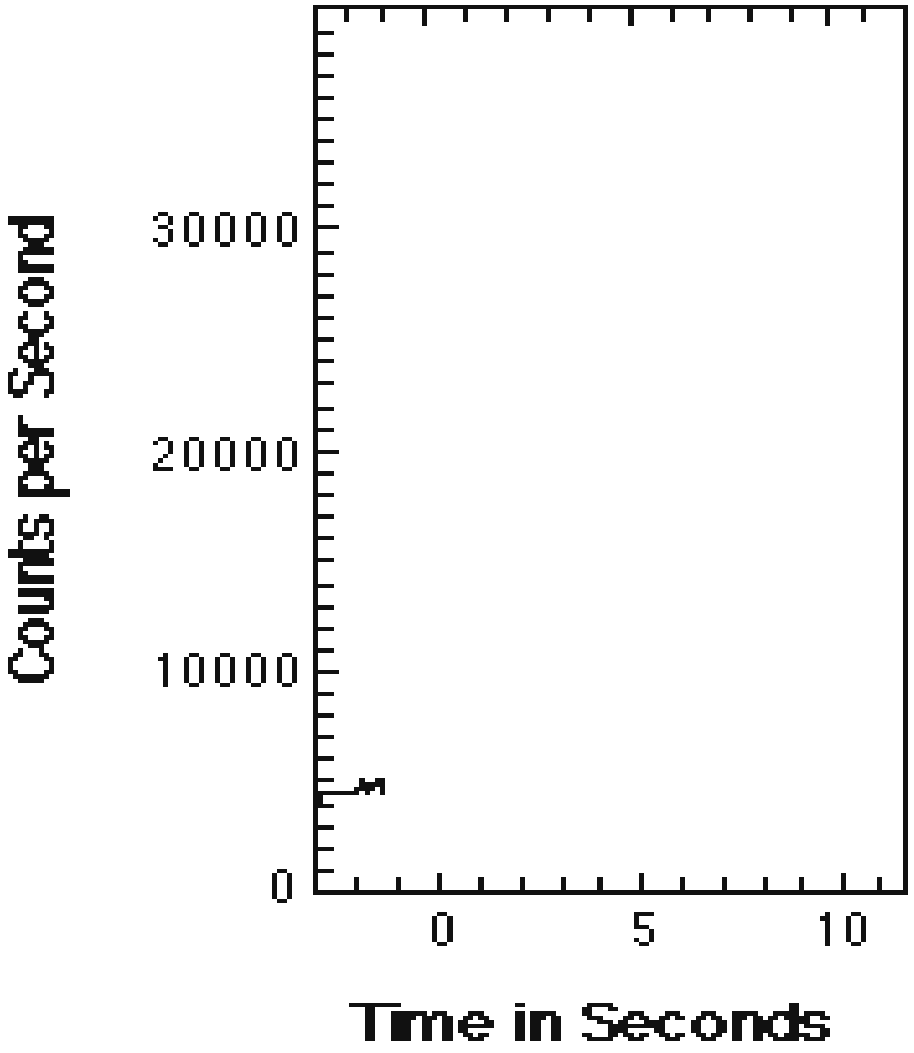
OUTLINE

- GRBs: a brief overview
- GRB Absorption Spectroscopy
- GRB spectral features in high resolution
- Distance diagnostics with excited levels
- New perspectives in the Athena era

GRBs: a brief overview

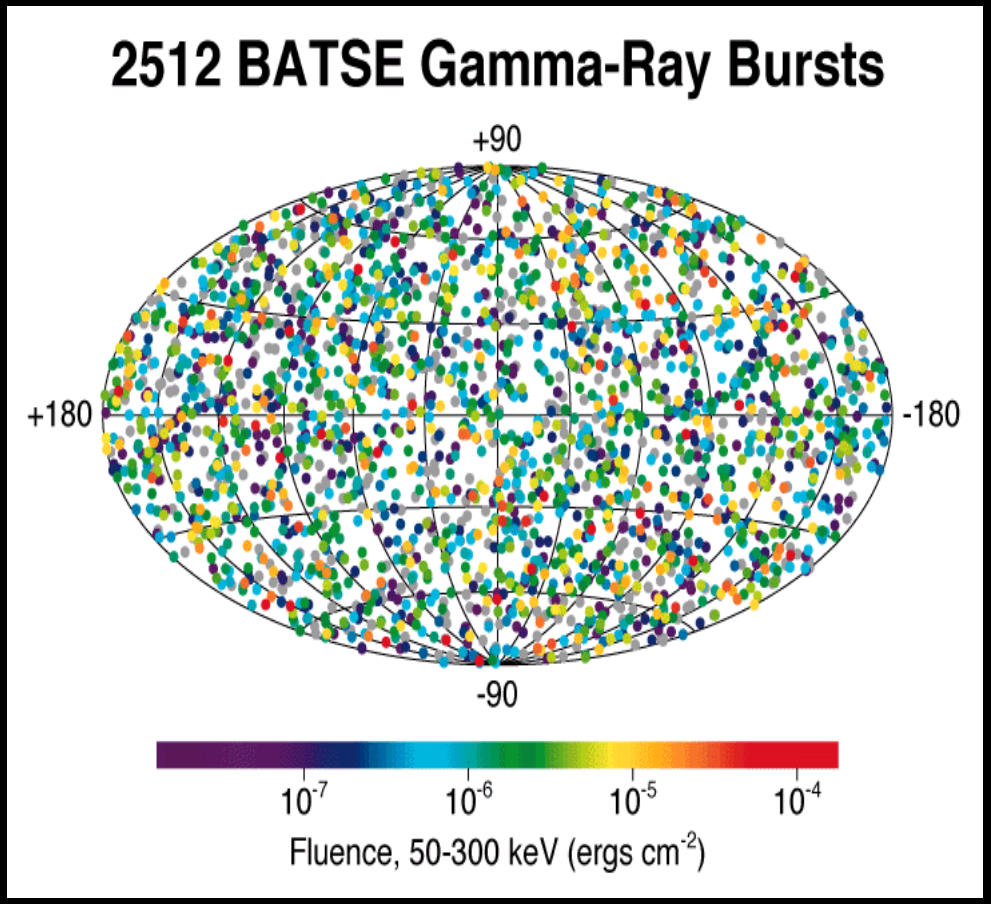


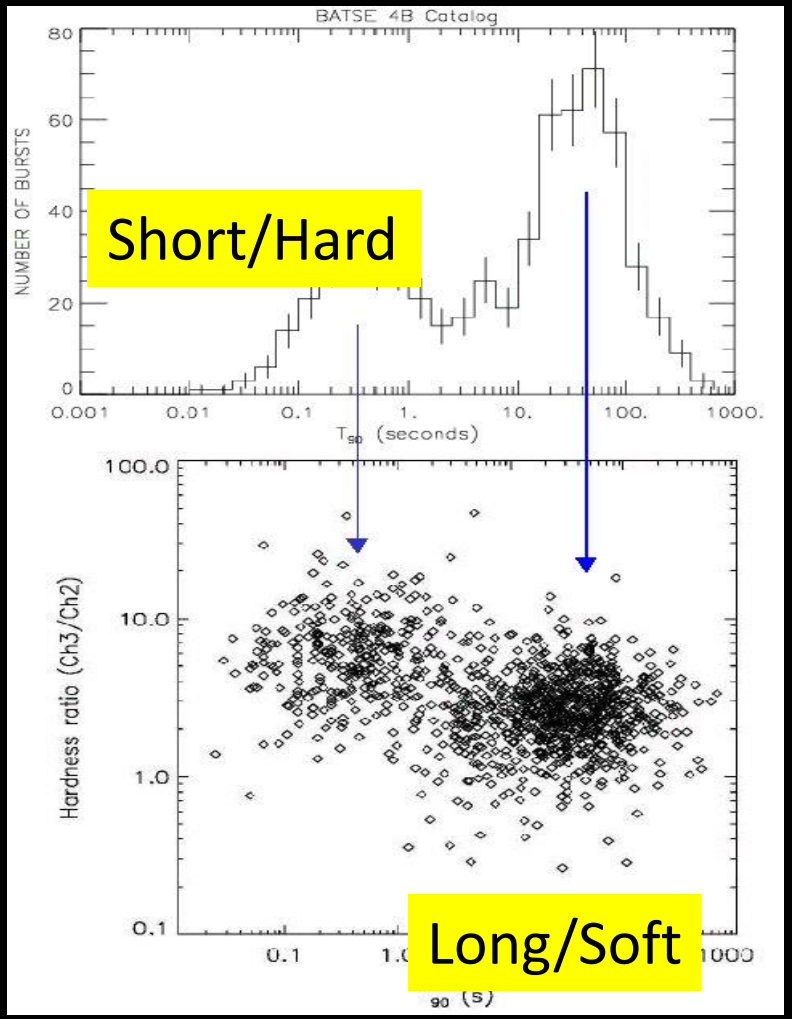


GRBs are seconds to minutes lasting flashes of gamma rays

GRBs: a brief overview

They are distributed:





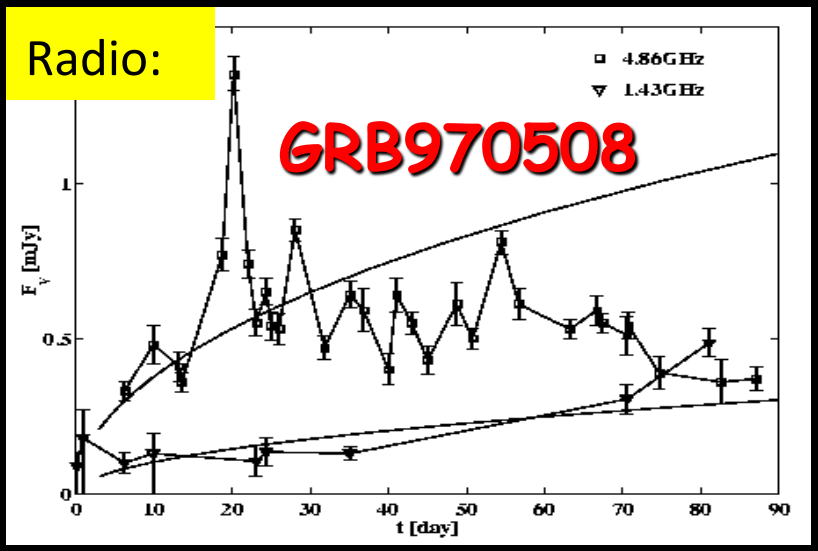
Isotropically in space

Bimodally in time / hardness ratio

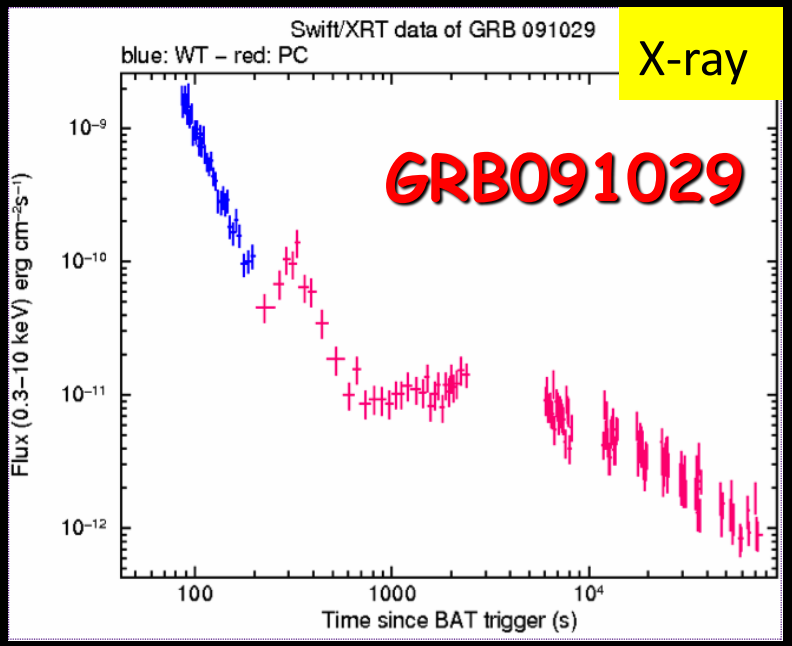
GRBs: a brief overview

The gamma (prompt) radiation is followed by emission in all bands (afterglow)

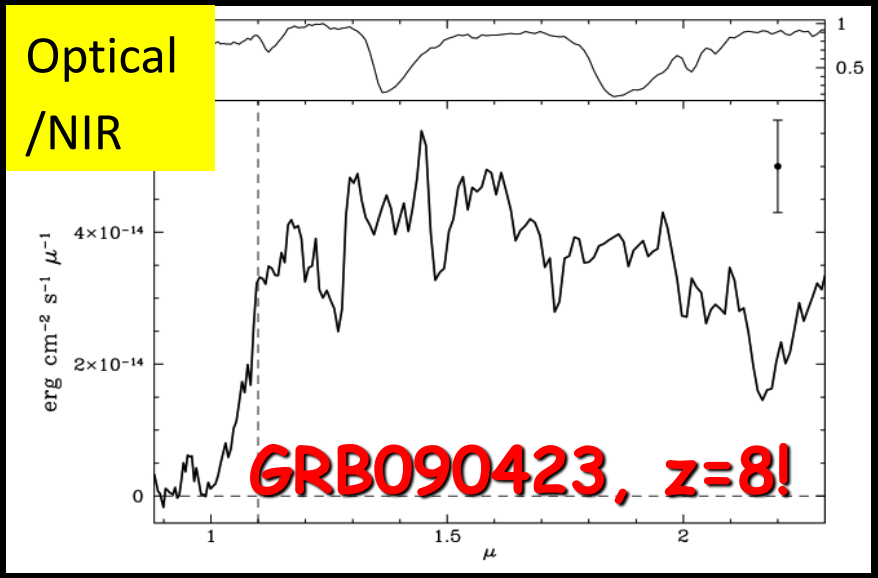
Radio:



X-ray



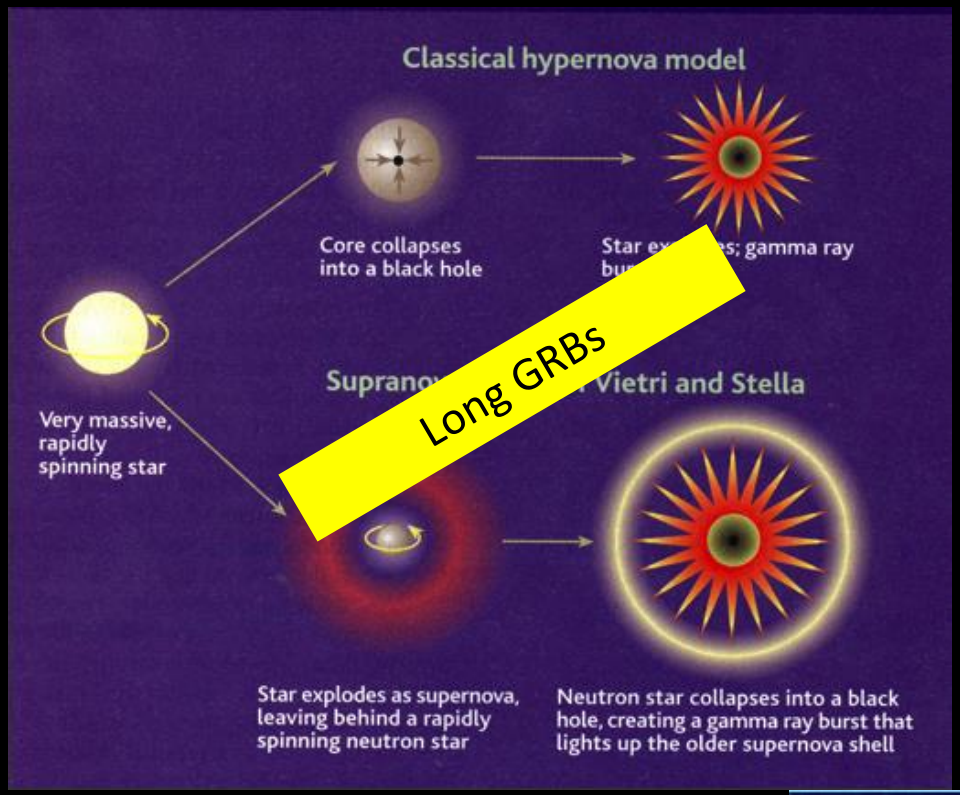
Optical /NIR



The GRB optical/NIR follow-up allowed us to determine the GRB cosmological nature. GRBs are the most distant, powerful and violent phenomena of the Universe

GRBs: a brief overview

GRBs are thought to be associated with a newly born, stellar mass black hole



Two channels of BH production:

1) "Fast channel":
Hypernova/collapsar model
Collapse of a star with several tens of solar masses

2) "Slow channel":
BH-NS (NS-NS) merging
2 SN explosions and angular momentum loss through GWs

GRB Absorption spectroscopy

Suitable to:

- Find redshifts, compute energetics, and build the GRB luminosity function
- Estimate the metal content in high redshift galaxies
- Characterize the circumburst environment
- Explore the interaction between the GRB and the surrounding medium
- Study the intervening absorbers along GRB sightlines

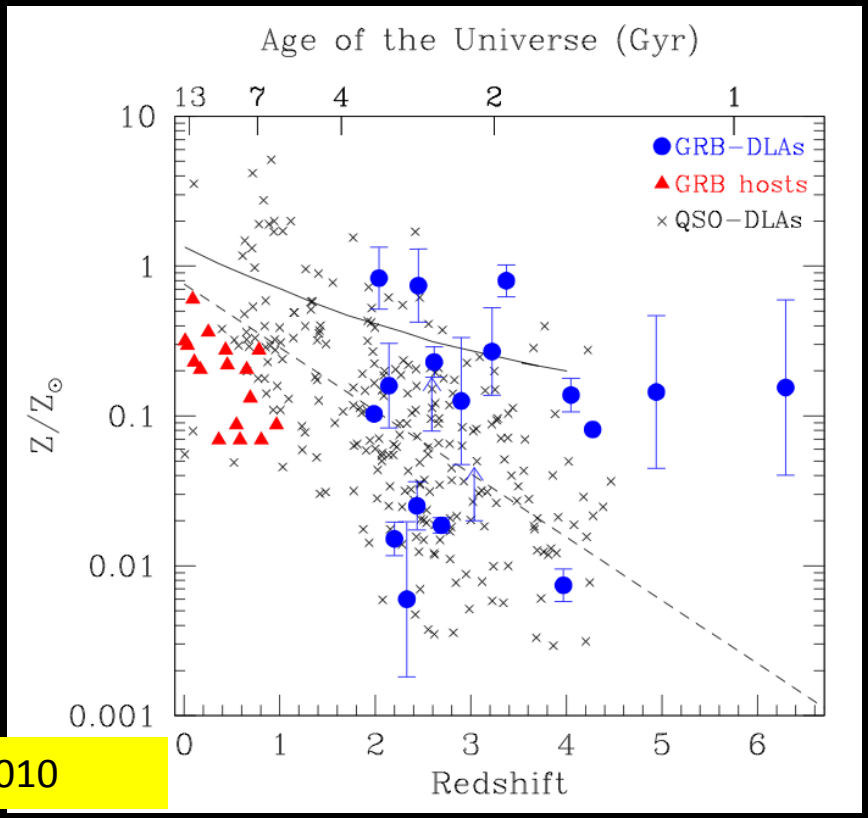
GRB Absorption spectroscopy

In the past, metal enrichment in galaxies at high z has been studied using:

- Lyman Break Galaxies (not representative of the Galaxy population)
- Galaxies along the line of sight of quasars, i.e., DLA (preferentially probe galaxy outskirts)

Advantages in using GRBs:

- Probing central galaxy regions
- No luminosity bias
- ISM can be studied up to higher redshift than DLA systems.



Savaglio 2010

High resolution Absorption spectroscopy

Advantages of hi-res spectroscopy:

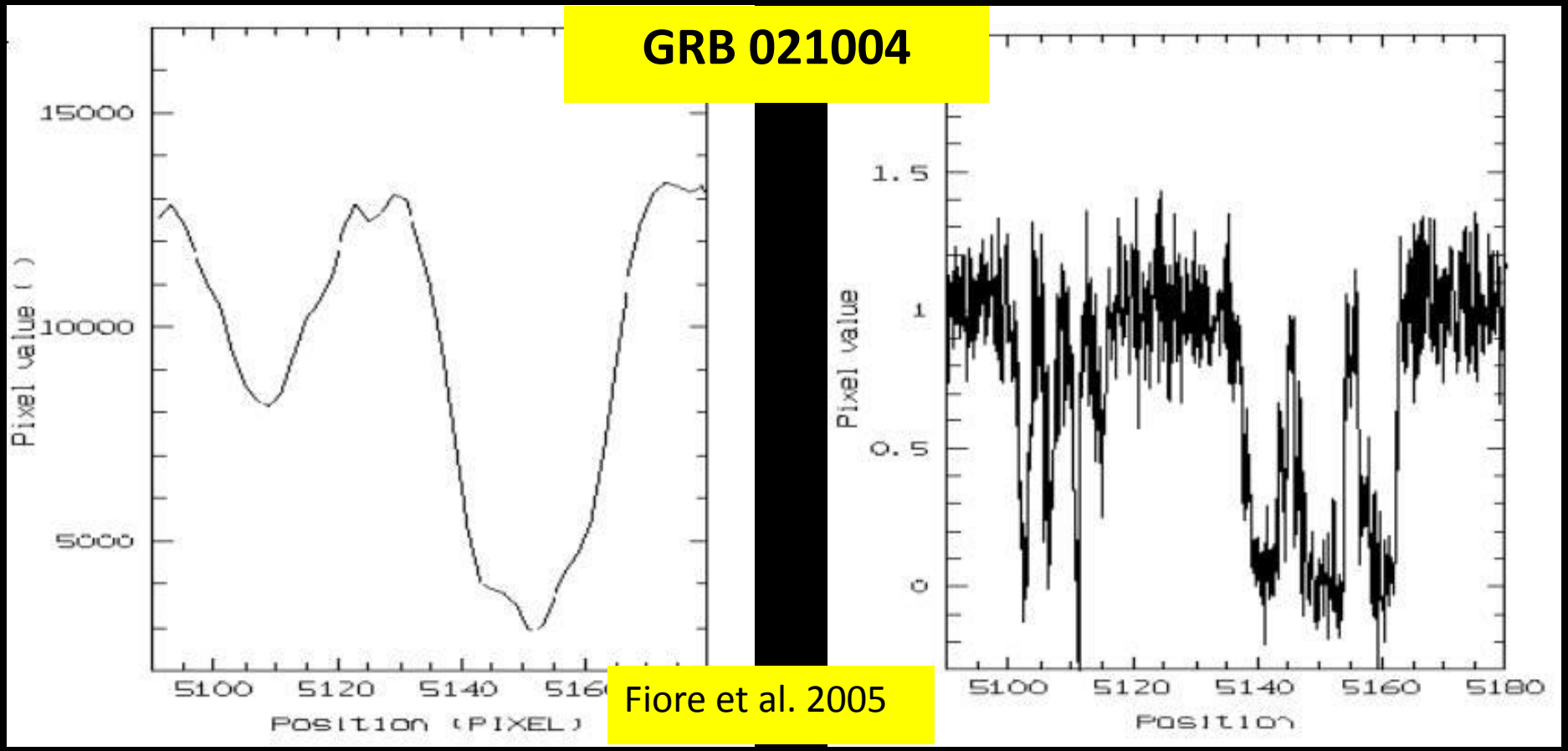
- Is necessary to disentangle the ISM from the absorption coming from the GRB surroundings.
- Separates the GRB surrounding medium in components, allowing a more accurate study of the composition, density, kinematics and physics of the absorbing gas.
- Is our only tool to fully explore the wealth of information carried by the lines absorbed by the excited (in particular fine structure) levels.

Disadvantages

- Suitable for high luminous afterglows only
- A fast reaction to the trigger is needed (Swift + RRM)

High resolution Absorption spectroscopy

Advantages of hi-res spectroscopy:

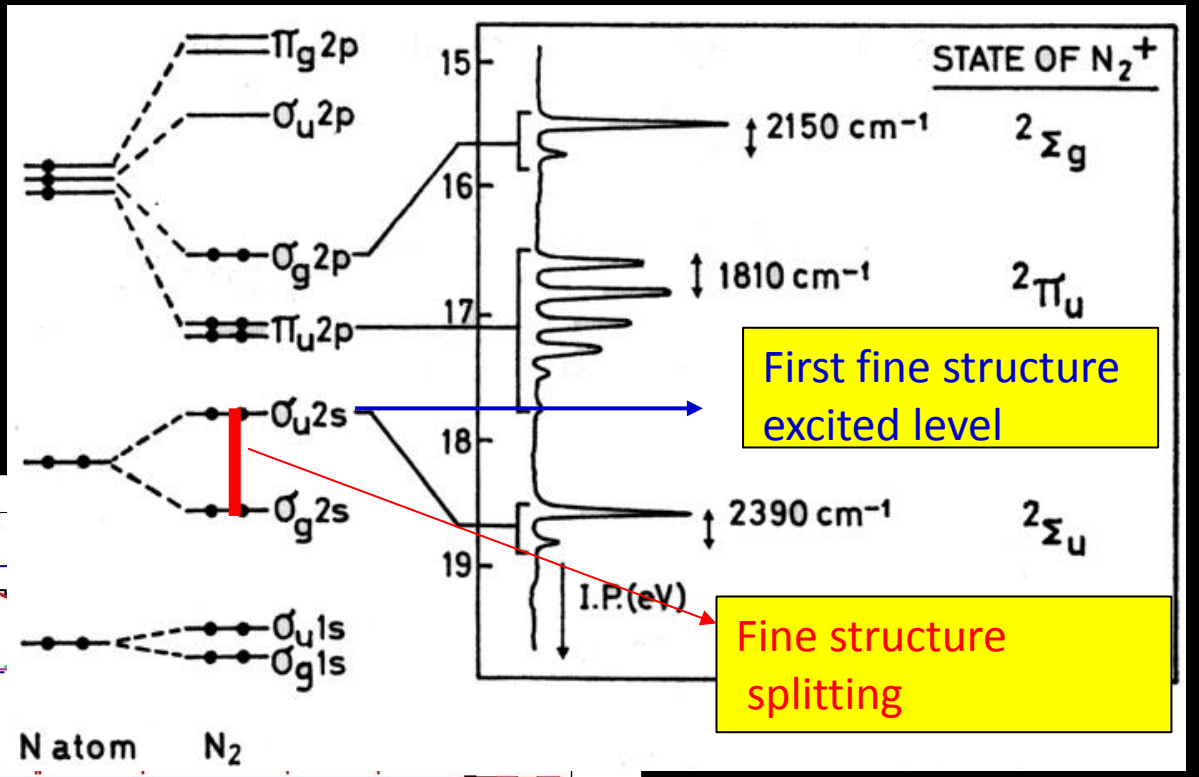


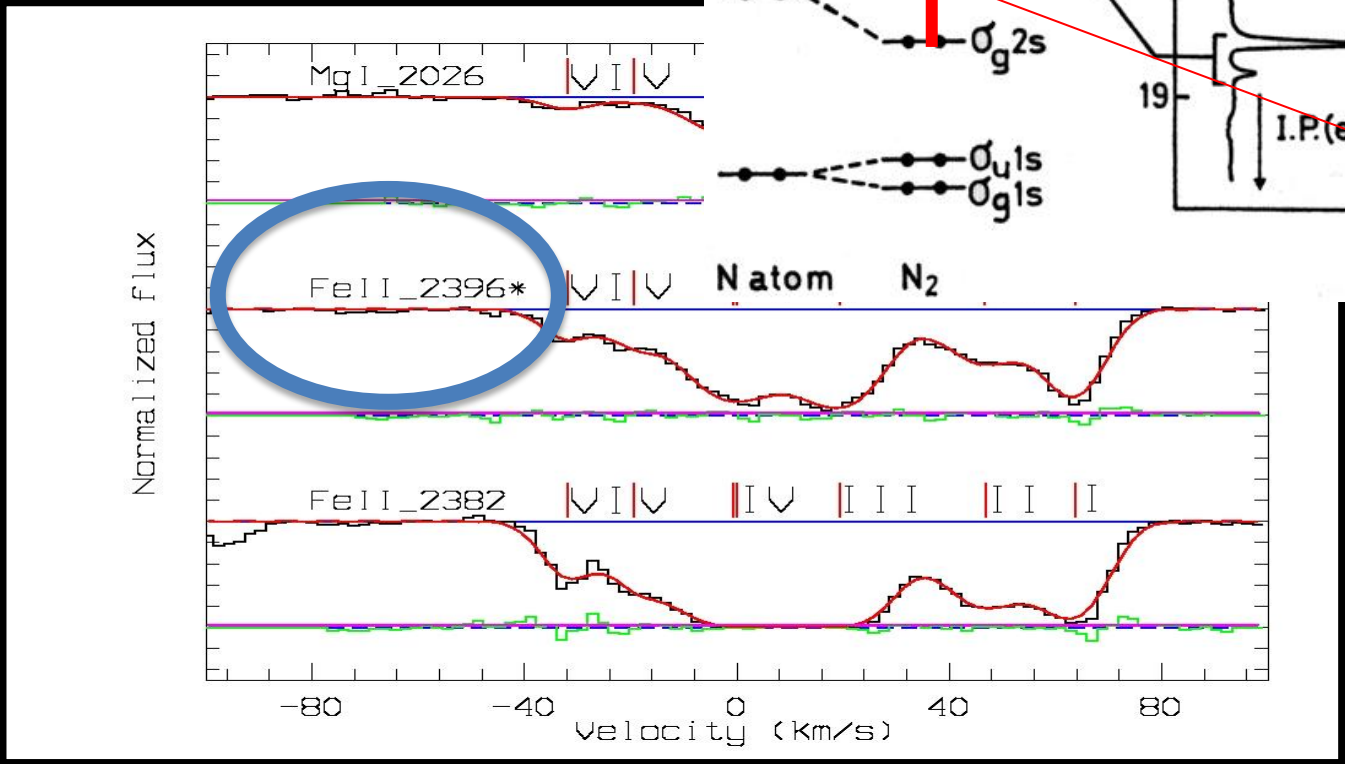
FORS, R=1000

UVES, R=40000

High resolution Absorption spectroscopy

Excited levels

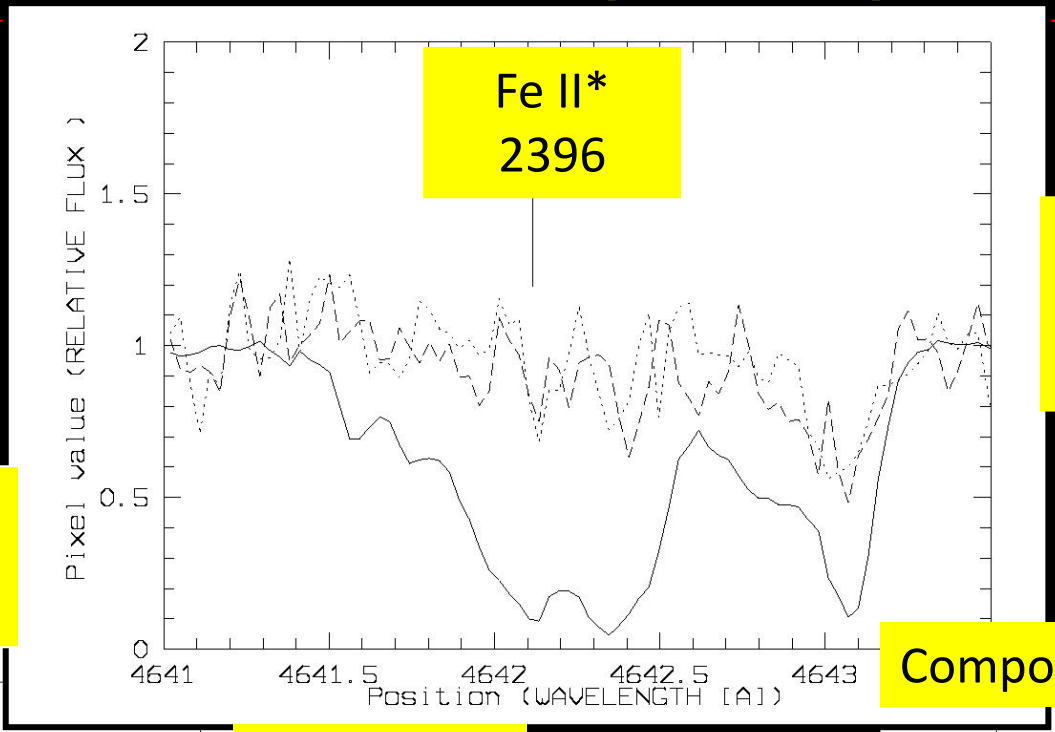




D'Elia et al. 2009
ApJ, 694,332

High resolution Absorption spectroscopy

Strong variability!

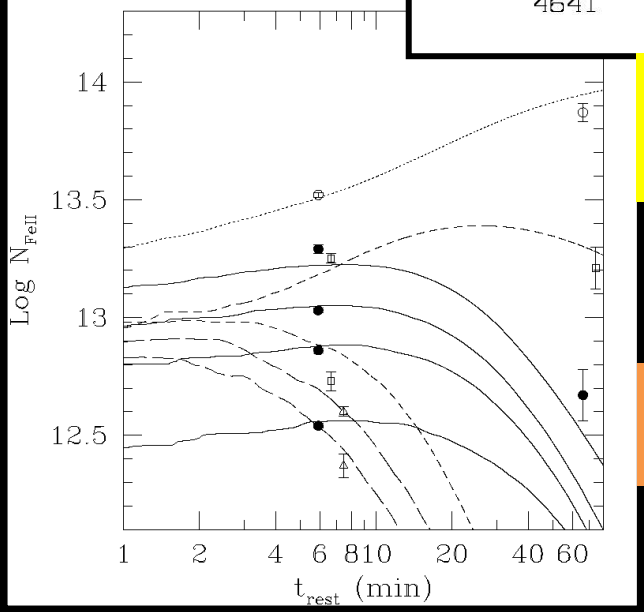


D'Elia et al. 2009, see also Vreeswijk et al. 2007

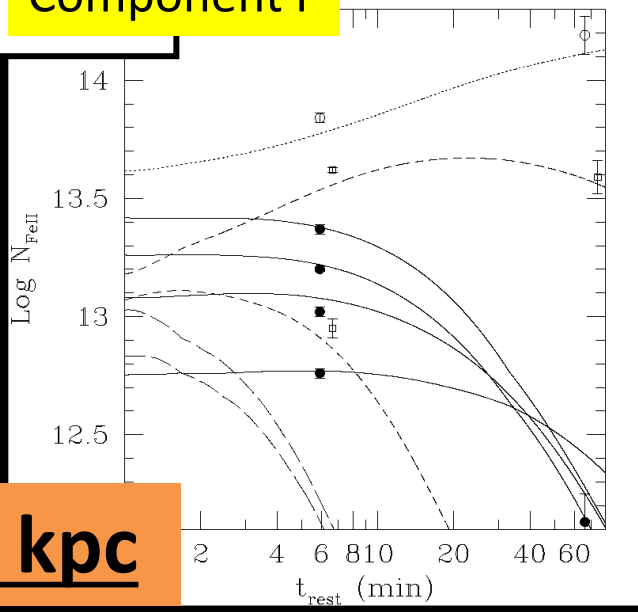
The "naked eye" GRB080319B

Component I

Componen t III



d = 2 kpc



d = 0.5 kpc

High resolution Absorption spectroscopy

Burst	#	Δt_{obs}	instrument	ion	levels/lines	z_h	log N_{HI}	d/pc	/pc	ref.
020813	2	~ 16h	KECK/LRIS VLT/UVES	Fe II	$^6D_{7/2}$ λ2396	1.25	-	50 – 100		1
050730	2	~ 1h	VLT/UVES	Fe II	$^6D_{7/2}$, $^6D_{5/2}$, $^6D_{3/2}$, $^6D_{1/2}$, $^4F_{9/2}$, $^4F_{7/2}$, $^4F_{5/2}$, $^4F_{3/2}$, $^4D_{7/2}$, $^4D_{5/2}$	3.97	22.10	124 ± 20	47^{+68}_{-54}	2, 3, 4
051111	1		KECK/HIRES	Fe II Si II	$^6D_{7/2}$, $^6D_{5/2}$, $^6D_{3/2}$, $^6D_{1/2}$, $^2P^o_{3/2}$	1.55	-	a few times 10^2		5, 6
060206	2[a]		WHT/ISIS	Si II O I C II	$^2P^o_{3/2}$, $^3P^o_0$, $^3P^o_1$, $^2P^o_{3/2}$	4.05	20.85 ± 0.1	~ 10^3		7, 8
060418	6	5 – 30 min	VLT/UVES	Fe II Ni II	$^6D_{7/2}$, $^6D_{5/2}$, $^6D_{3/2}$, $^6D_{1/2}$, $^4F_{9/2}$, $^4D_{7/2}$, $^4F_{9/2}$	1.49	-	480 ± 56		9, 3
080310	2 – 4	10 – 20 min	VLT/UVES	Fe II Fe III	$^6D_{7/2}$, $^6D_{5/2}$, $^6D_{3/2}$, $^6D_{1/2}$, $^4F_{9/2}$, $^4D_{7/2}$, ^5D, $^7S_3$,	2.43	18.70 ± 0.1	200 – 400	– 100	10, 11
080319B	3	40 – 60 min	VLT/UVES					560 – 1700		12, 3
080330	1		VLT/UVES					79^{+11}_{-14}		13, 3
081008	4[a]	7 – 25 min	VLT/UVES VLT/FORS2	Fe II Si II Ni II	$^6D_{7/2}$, $^6D_{5/2}$, $^6D_{3/2}$, $^4F_{9/2}$, $^4D_{7/2}$, $^2P^o_{3/2}$, $^4F_{9/2}$	1.97	21.11 ± 0.10	52 ± 6 and 200^{+60}_{-80}		14
090926	4[a]		VLT/X-shooter	Fe II Si II O I C II Ni II	$^6D_{7/2}$, $^4F_{9/2}$, $^2P^o_{3/2}$, $^3P^o_0$, $^3P^o_1$, $^2P^o_{3/2}$, $^4F_{9/2}$	2.11	21.60 ± 0.07	677 ± 42 and 5×10^3		15, 3
100219A	1		VLT/X-shooter	Si II	$^2P^o_{3/2}$	4.67	21.14 ± 0.15	300 and 10^3		16
100901A	4	1 h - 1 wk	Gemini-N/GMOS VLT/X-shooter	Fe II Ni II	$^6D_{7/2}$, $^6D_{5/2}$, $^6D_{3/2}$, $^6D_{1/2}$, $^4D_{7/2}$, $^4F_{9/2}$	1.41	-	a few times 10^2	– 1000	17

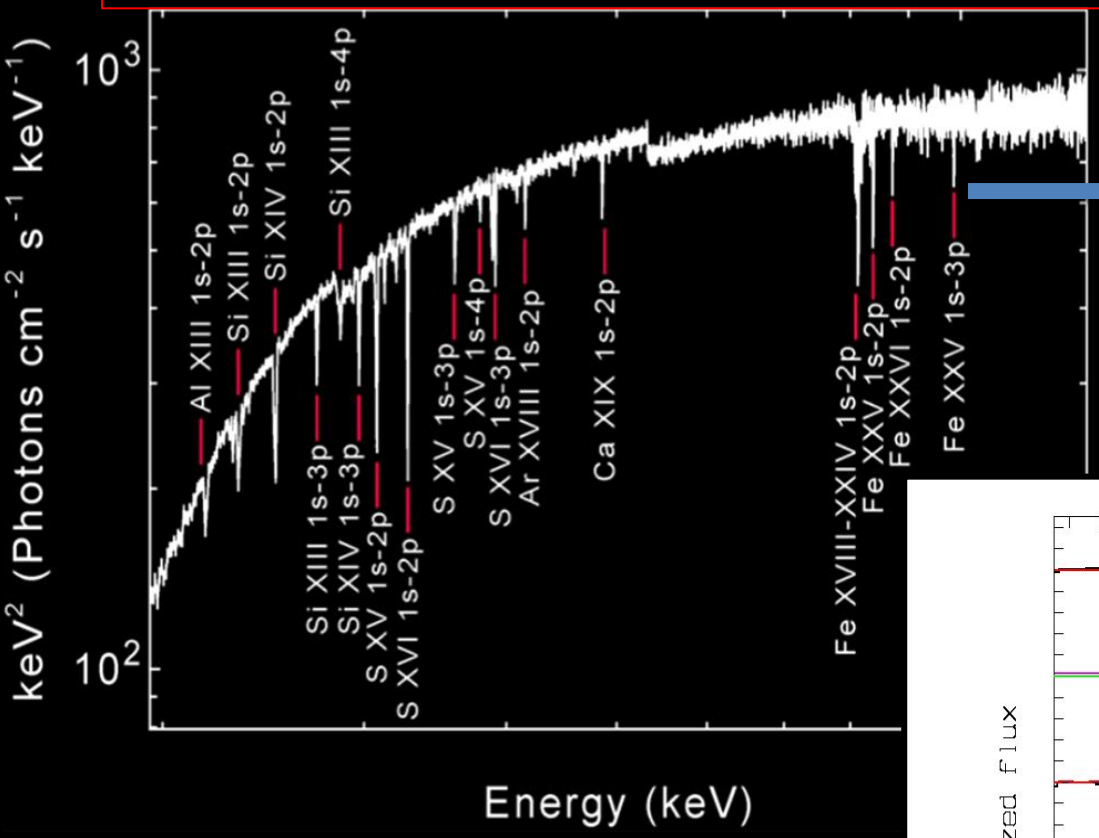
d > 50 pc: LARGE!

Hartoog et al. 2013

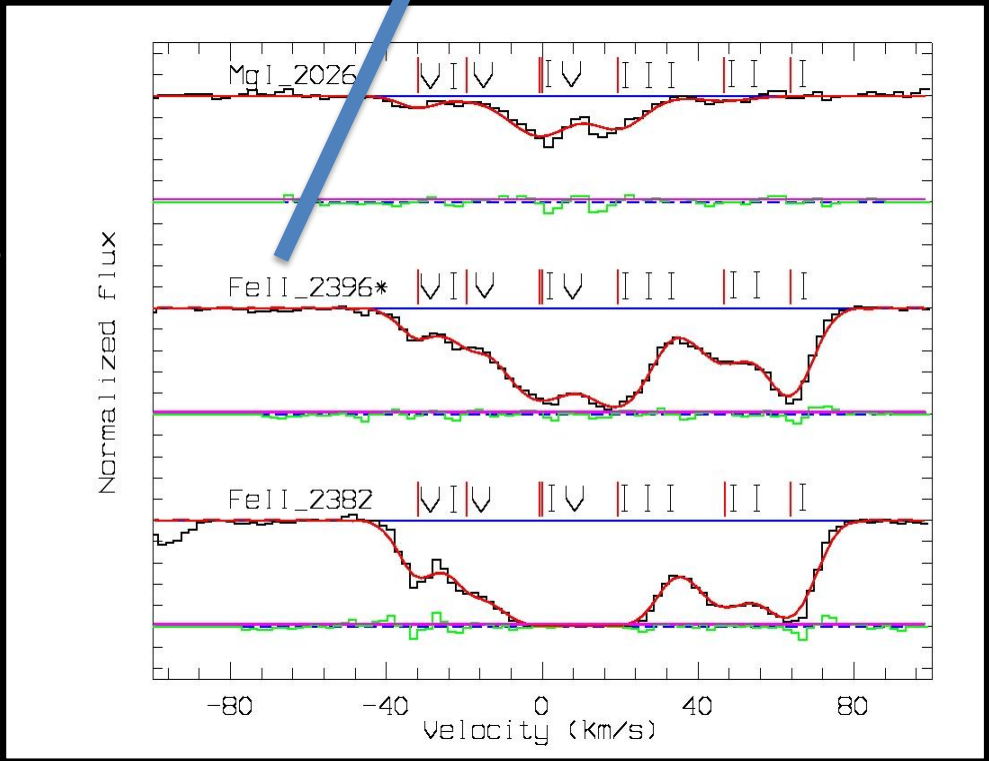
Next steps

- Is there any gas closer to the GRB? Is it highly or fully ionized?
- Answering these questions can give important clues on the GRB progenitors, their emission mechanisms and the way they deposit energy in the surrounding medium
- Optical spectroscopy cannot penetrate further the GRB surroundings
- We need high resolution, high throughput X-ray spectroscopy to address these issues
- Athena X-IFU spectrograph can achieve up to R>2000: an unprecedented combination of collecting area, resolution, and re-pointing capabilities in X-rays

Next steps



Comparing Fe features in X-rays with excited ones in optical…



… can give access to regions of the GRB environment beyond the reach of optical spectroscopy