# Spectroscopic observations of the line of sight to GRBs

-> Reionization of the universe
-> Gas in the host galaxy
-> The GRB proximity effect - Infall – Outflows
-> Intervening absorbers : Don’t waste time here
-> Wind from progenitor ?
-> Fundamental tests :
Tcmb ; variations in fundamental constants

-> SVOM and the high-z universe

J. Wang
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Patrick Petitjean
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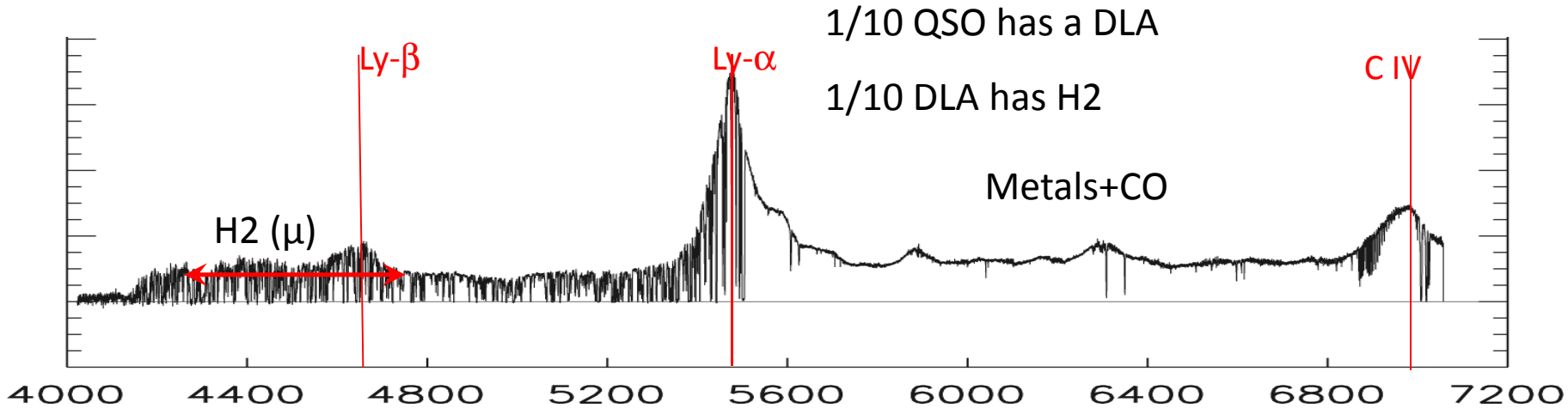
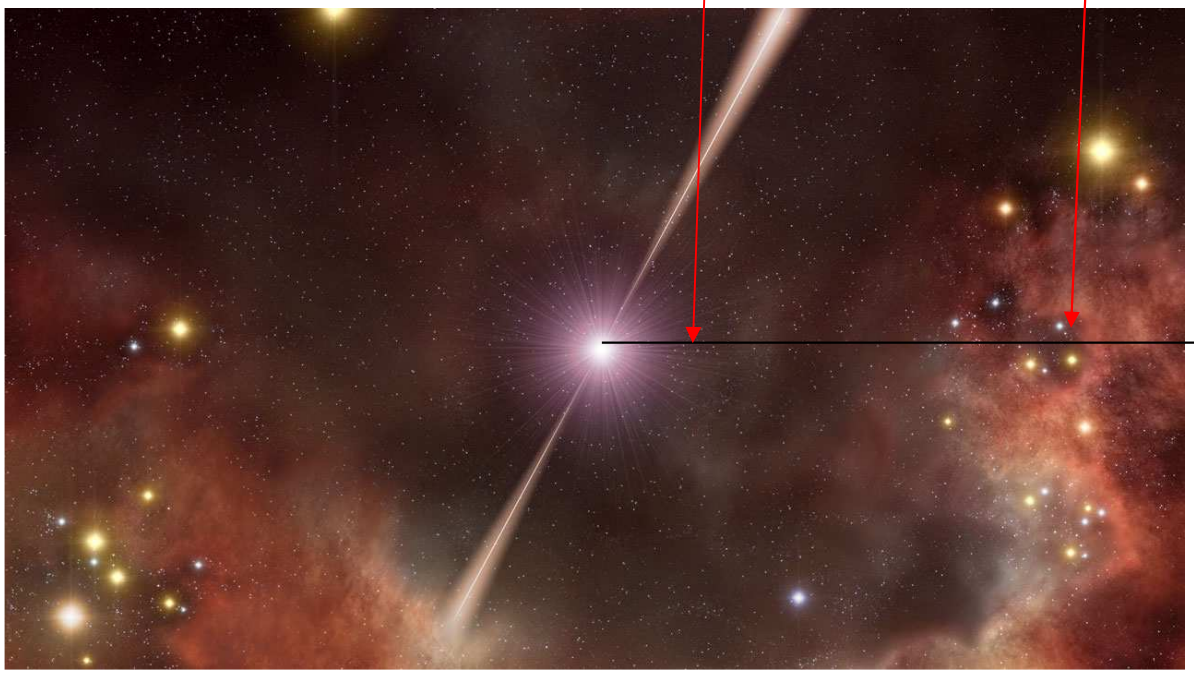



Ejecta – Wind ?

Kinematics ?

The ISM of the host galaxy:
Ionized by the GRB ?

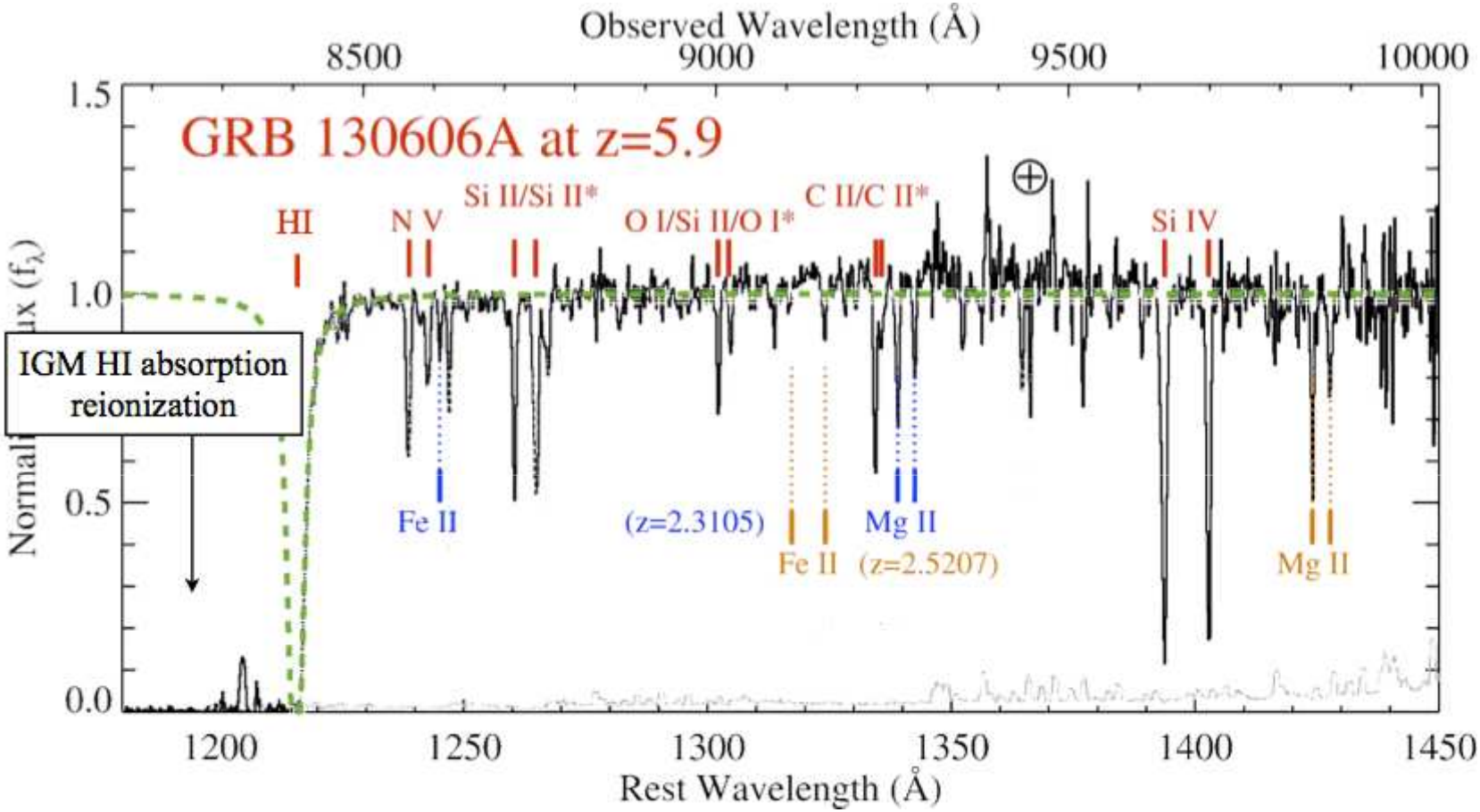


Space and

History

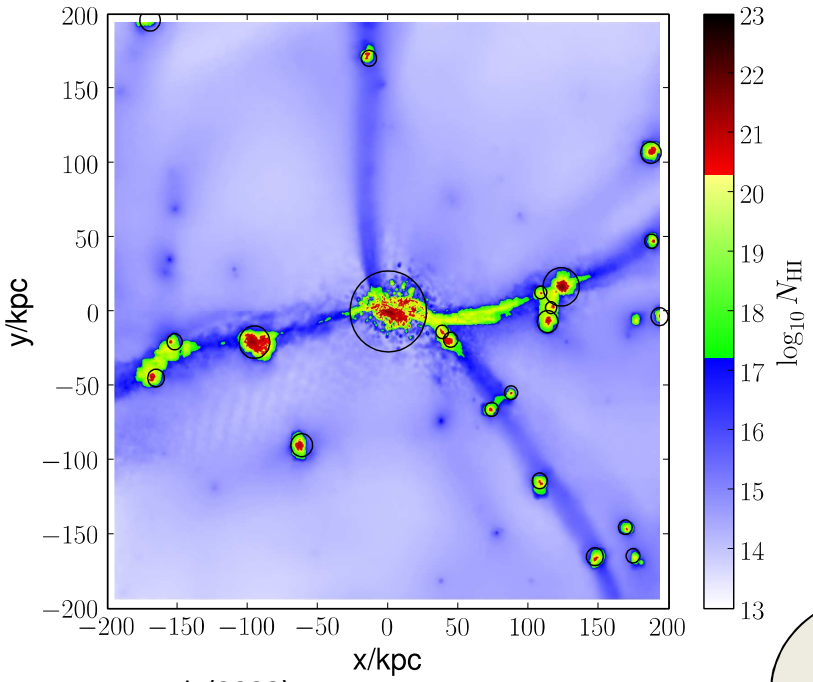
The OB server

# Direct probe of reionization of the universe

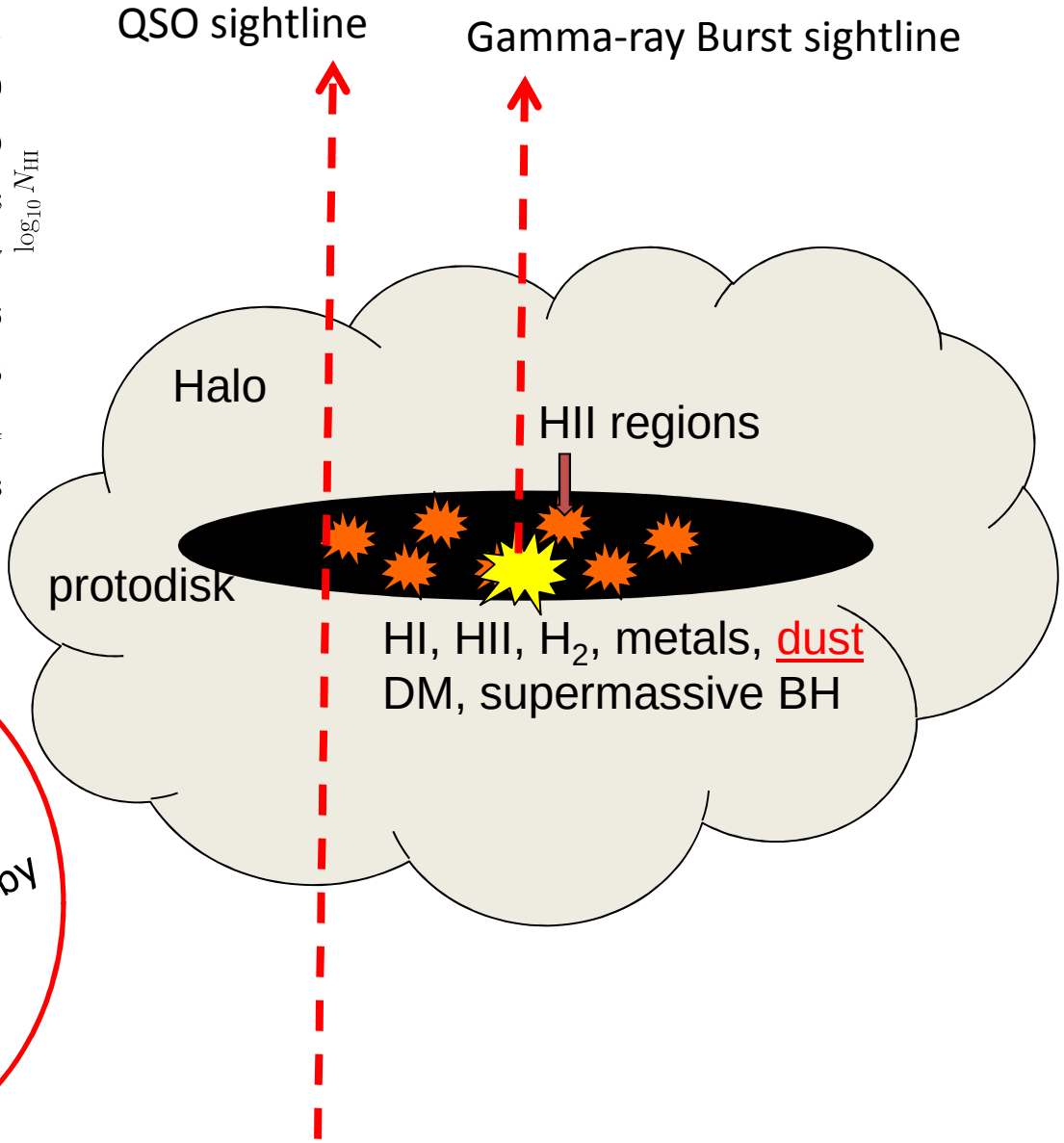


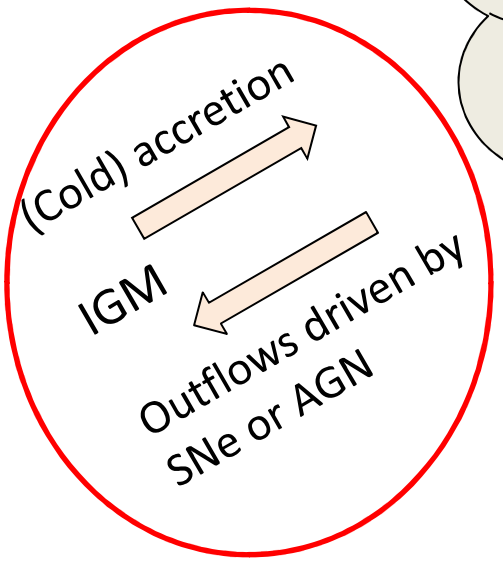

- GRB at the highest redshift
- Fit the DLA wing from the IGM (disentangle the DLA from the host galaxy)
- Needs statistics and simulations
- Lowish resolution ; high SNR (NHI in DLA > NHI in ISM) ; good flux calib

# The ISM in the host galaxy



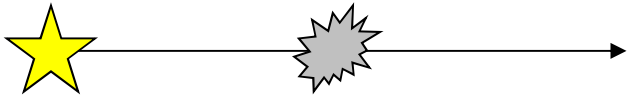

Pontzen et al. (2008)



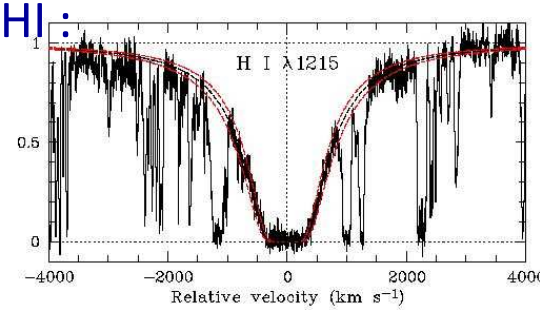



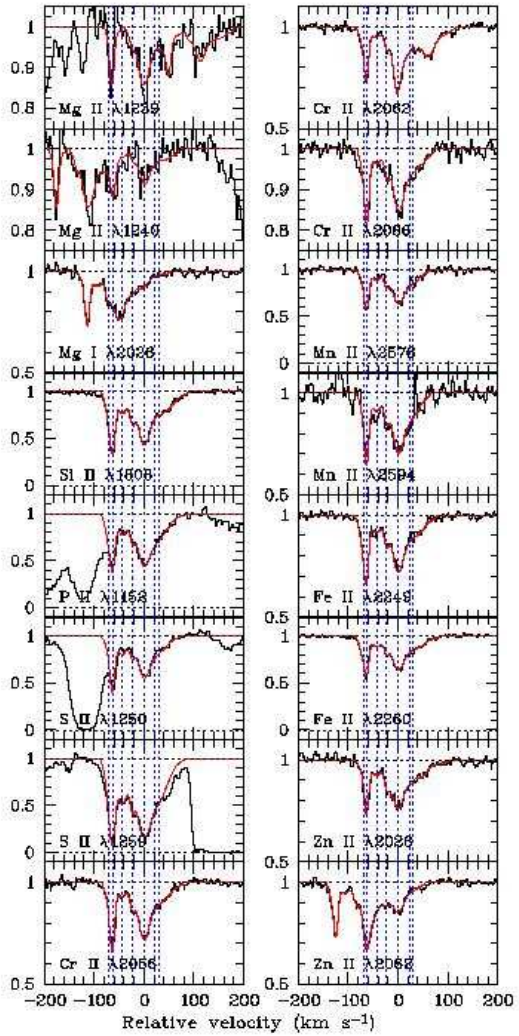

Credit: Johan Fynbo

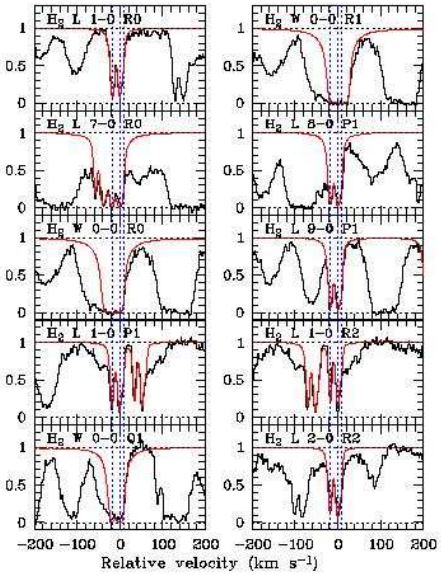
# Damped Ly-α Systems



HI :




Metals :

-> Metallicities

-> Dust content

-> Kinematics

Star- Formation => detection of the host

Winds ?

Lowish resolution?

Molecules H2 + CI, CI* :

-> Density/Temperature

-> UV flux (excitation)

+ Other molecules: HD+CO

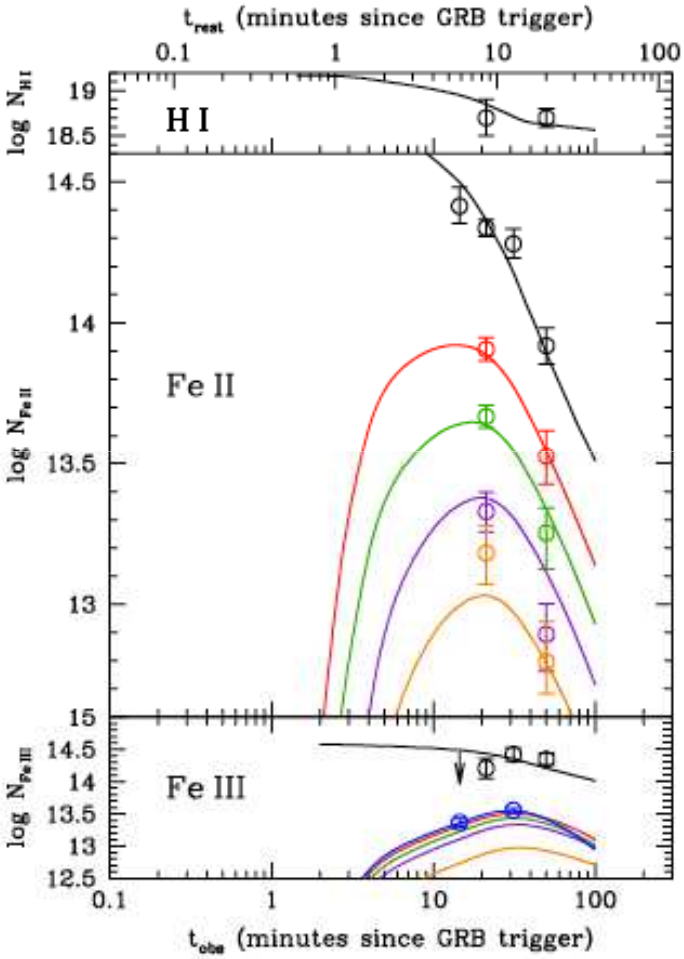
Complex profiles + narrow lines => High Res

# Ionization/Excitation of the medium surrounding the GRB

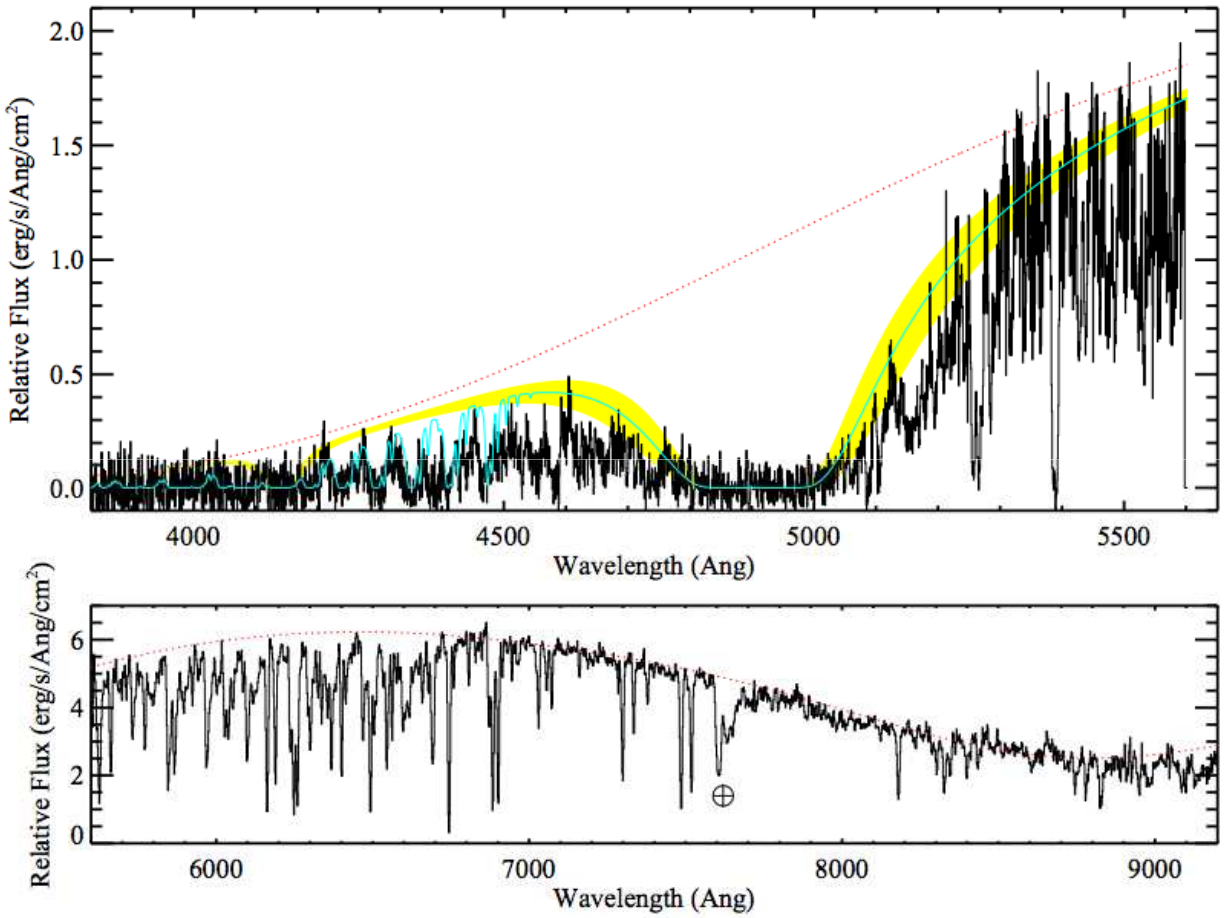
-> Variations of excited lines
(need for several spectra)
Gas at >100pc

-> Wind from the progenitor : high ionization species ?

-> Highish resolution



# Dust and molecules: "Dark" Bursts




If missed this can affect a number of studies (metallicities of the gas close to the GRB vs mean metallicity in the host)

=> Lowish resolution

GRB080607

Very bright afterglow observed 12 minutes after the burst

$z = 3.04$

$\log N_{HI} = 22.7$

$H_2$ and CO

Forest of metal lines!

Solar metallicity

$A_V = 3.3$ mag

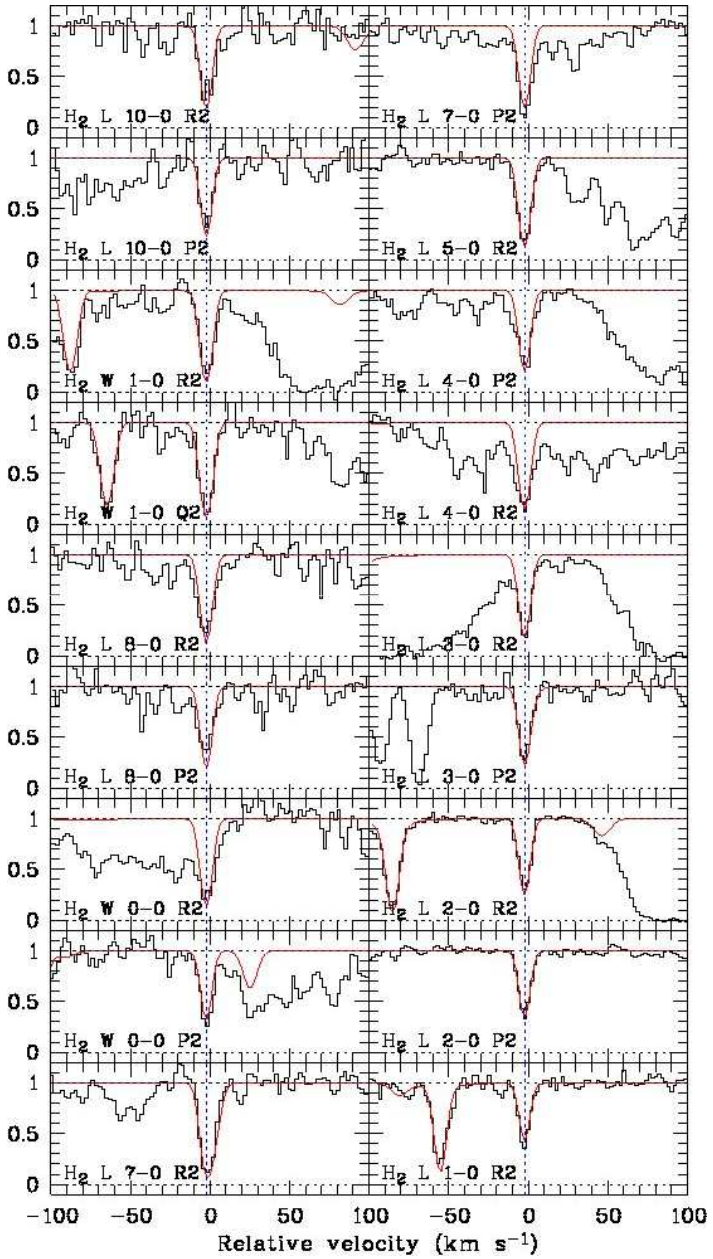
2175Å extinction bump.

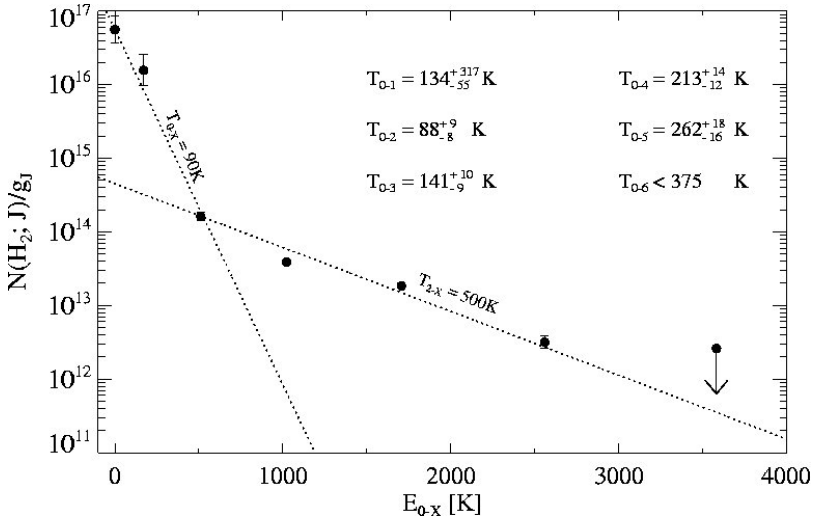
Bright/massive and dusty host

SFR = 10 $M_\odot$/yr

Prochaska et al. (2009)

# Heating processes: Molecular excitation

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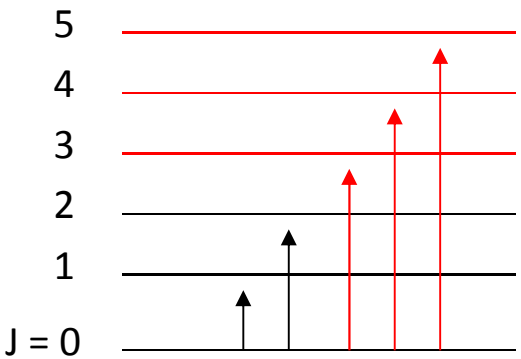
No velocity shift




Fluorescence -> UV flux

Collisions -> Tk, density

CI+ CI*

Doppler parameter increases with J

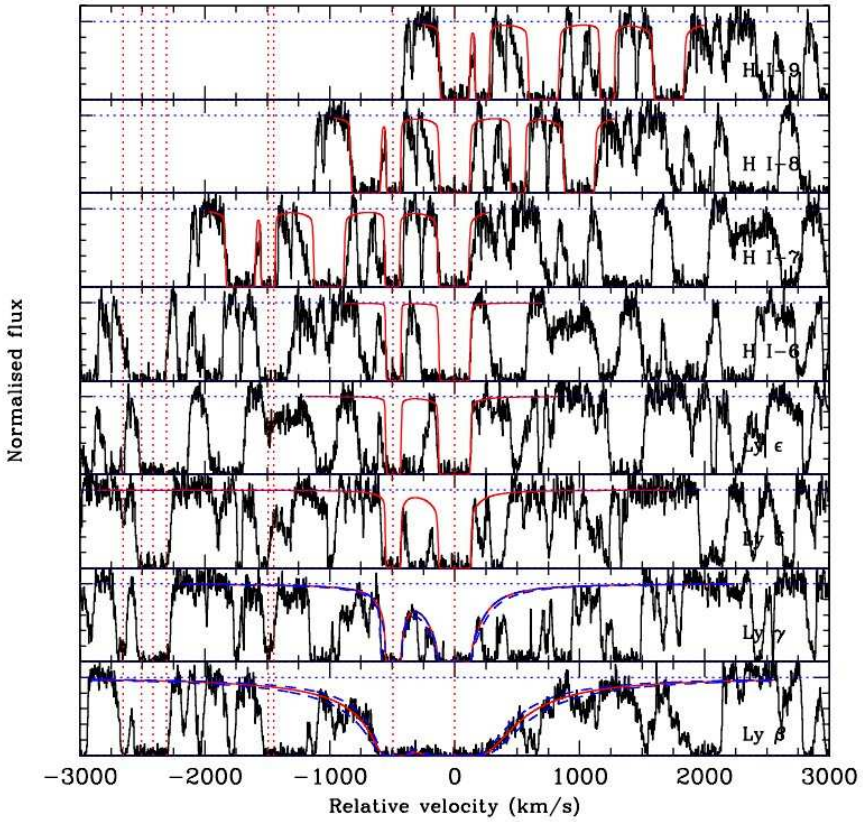
$n_H$=30-100 $cm^{-3}$ (3-10pc)  T=70-150 K

UV flux 10xGal

# The GRB proximity effect :

Infall to and outflows from the galaxy : Metallicity in absorption systems

Covering factor much larger in case of GRBs (converging flows + interaction ; geometry)

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+ Overdensities

- GRBs:
Inside the galaxy : variability of excitations
Outside the galaxy: no dominant ionizing flux

- Direct view of the kinematics of the gas with larger covering factor

-Pb: The DLA blocks the Lya absorption => should be at z>2.5

- Best way to look at outflows/infalls from metals in LLS close to the DLA

# Fundamental tests : Molecules (Speculations?)

Variations of constants: $\alpha$ ? $\mu$, electron/proton mass ratio:
Probably more interesting

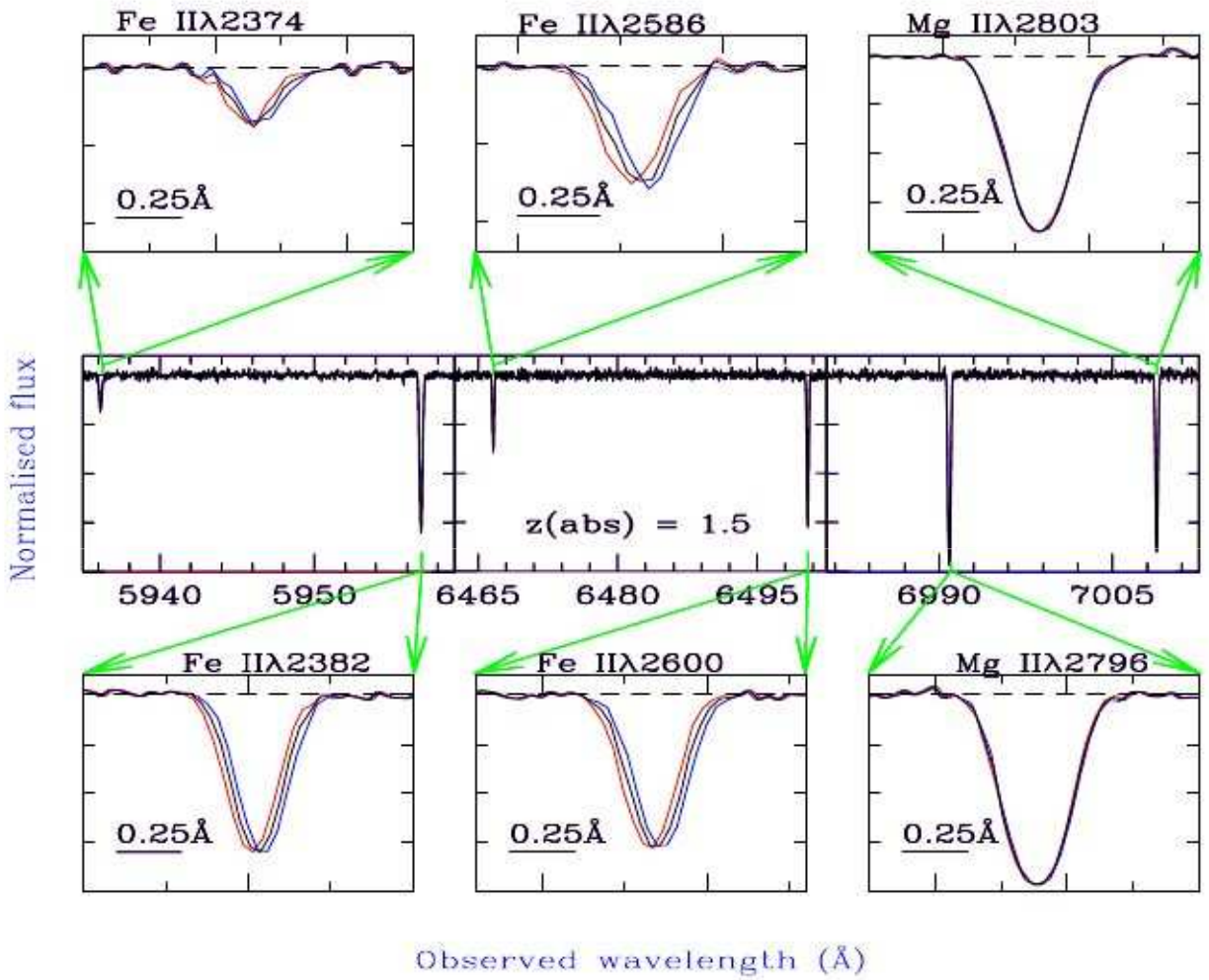
-> DLA at the redshift of the GRB (highest z)

-> Few detections of $H_2$ but.... rapid response at high resolution

Temperature of the CMB radiation at high-z

# Variations of constants

Need to know the position of each line

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or 1/5 of a pixel for $\delta\alpha/\alpha=10^{-5}$ 0.2 km/s

# GRB Absorption Lines -> Diffuse IGM and dense ISM

- UV Lines : MgII, FeII, SiII etc… (in the optical)

  -> $\alpha$

- H2 and HD (in the UV)

  -> $\mu=m_p/m_e$

- 21cm and molecular absorbers (in the radio)

  -> $x=\alpha^2 G_p/\mu$

The ideal system : H2+HD, UV and 21cm

* Only one case with quasars ; DLA J1337+3152

# H2 absorption lines to be used to constrain μ

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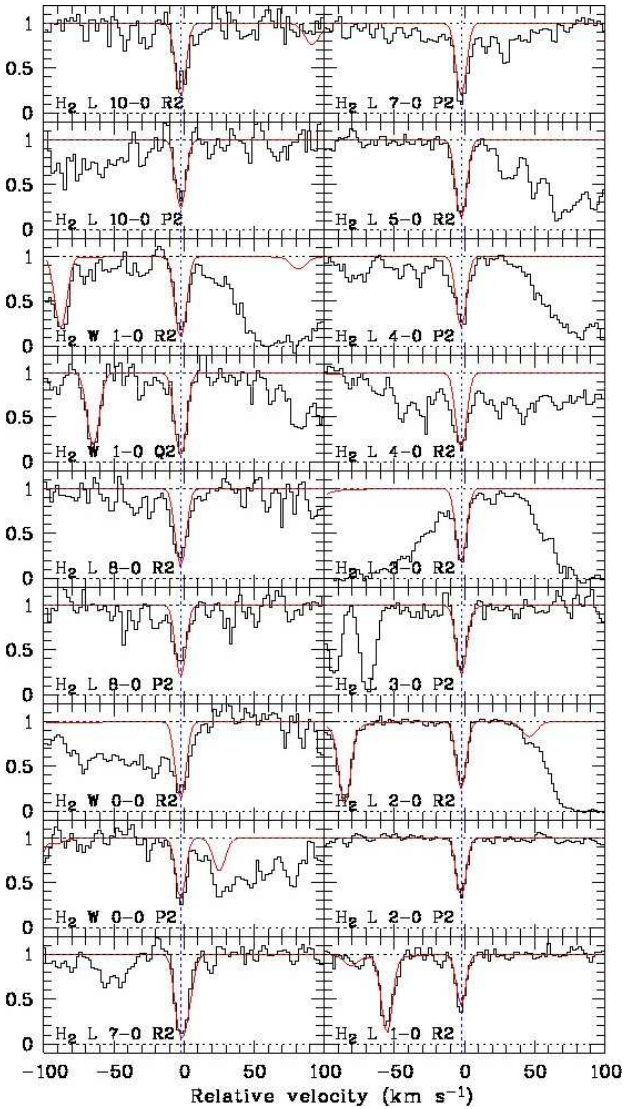


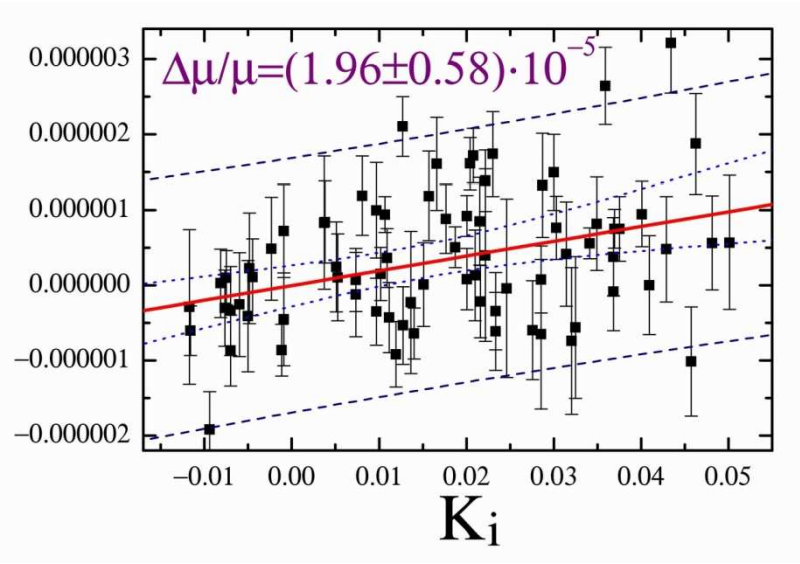


Blue and rapid response at high resolution

# CO and HD

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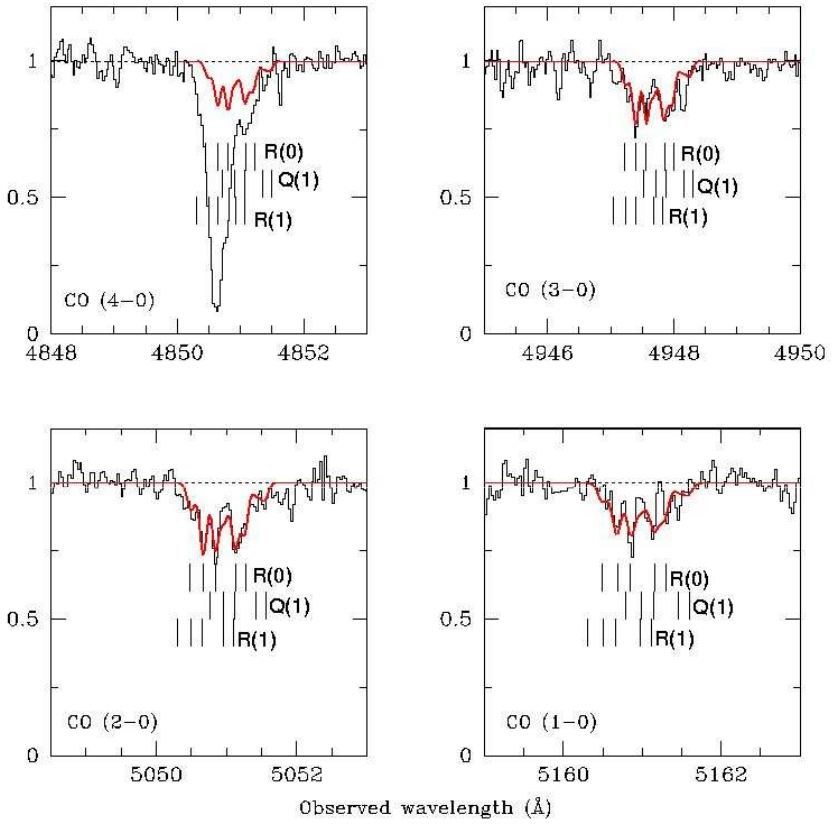


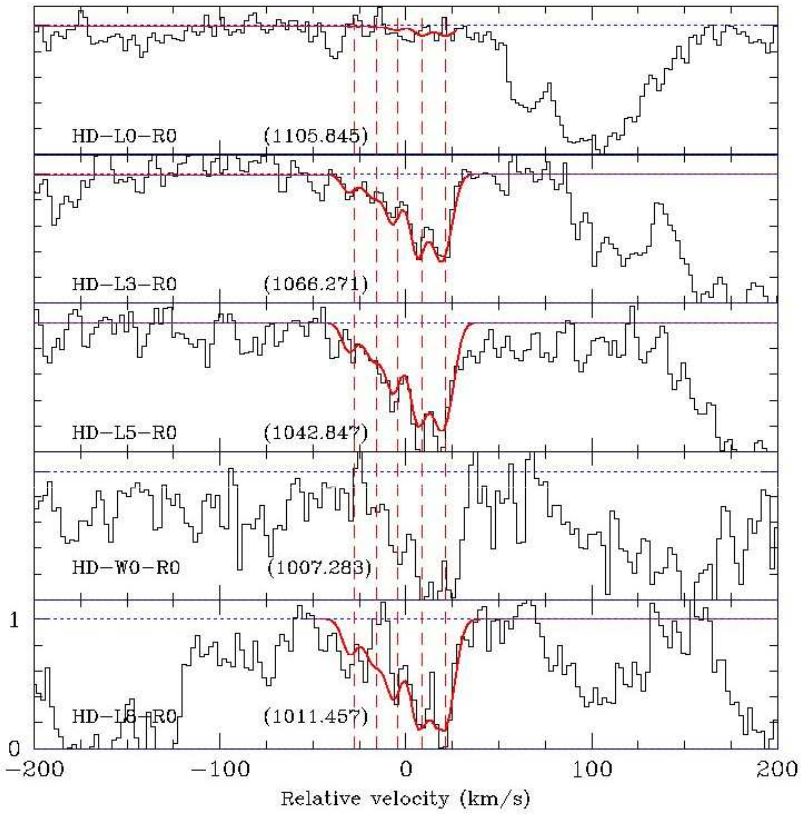


CO bands are at 1600A -> beyond the Lya forest => Probability much higher to see it in GRBs

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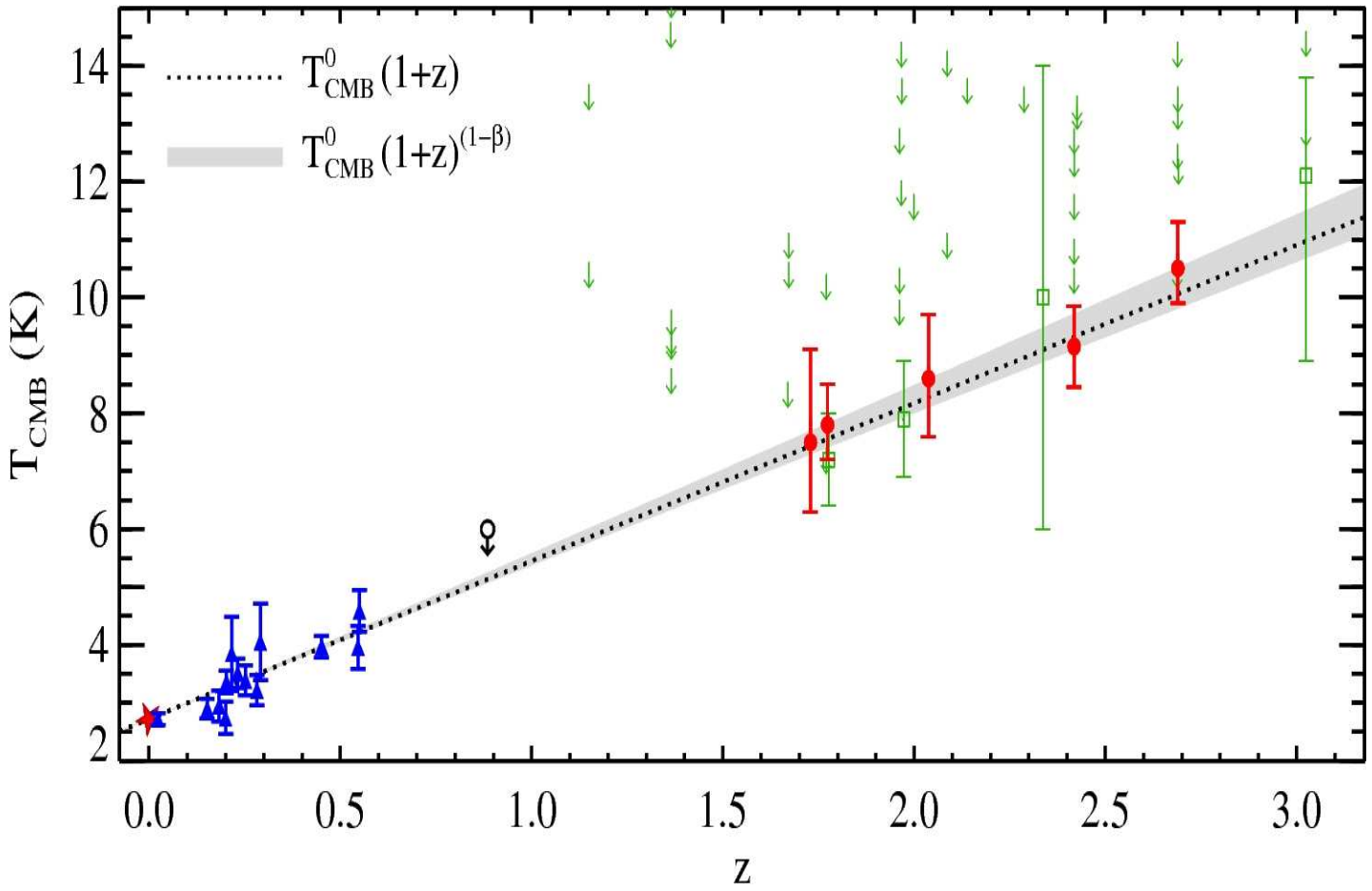
Srianand et al. (2008) A&A, 482, L39

# Excitation of CO: Redshift evolution of $T_{CMB}$

CO rotational levels directly excited by CMB




$\beta$ = 0.007±0.027 (we've tried… see also Hurier et al. : sigma=0.017)

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-> Reionization of the universe => lowish res
-> Gas in the host galaxy => lowish AND highish resolution
-> The GRB proximity effect - Infall – Outflows
-> Intervening absorbers : Don't waste time here
-> Fundamental tests :
Tcmb ; variations in fundamental constants => high res in the IR

-> SVOM and the high-z universe : Xshooter and ELTs (TMT?)

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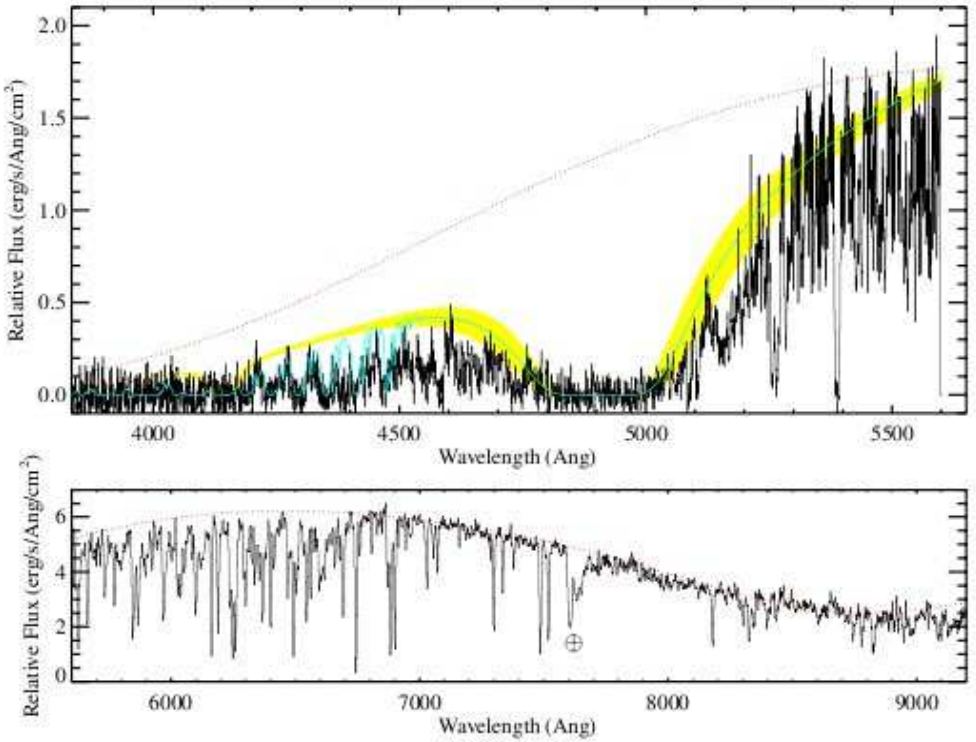
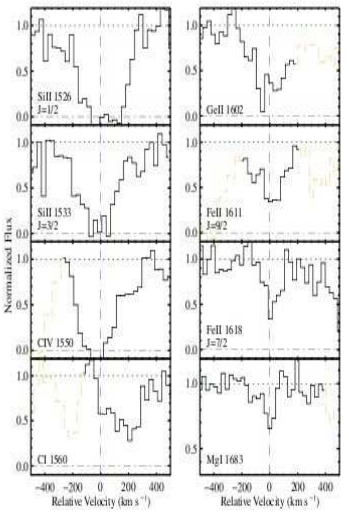
Need SVOM AND ELTs with HIRES

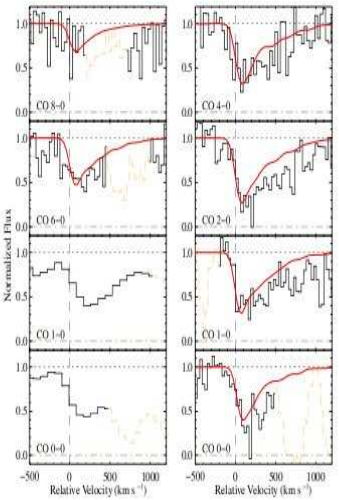
-> Star formation activity
-> Fundamental tests : Std candel (see Wang et al. 2015)
Tcmb – alpha
-> The GRB proximity effect - Infall – Outflows

Thank you !

# H2 and CO in GRB080607 z=3.036

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Res : R=2800

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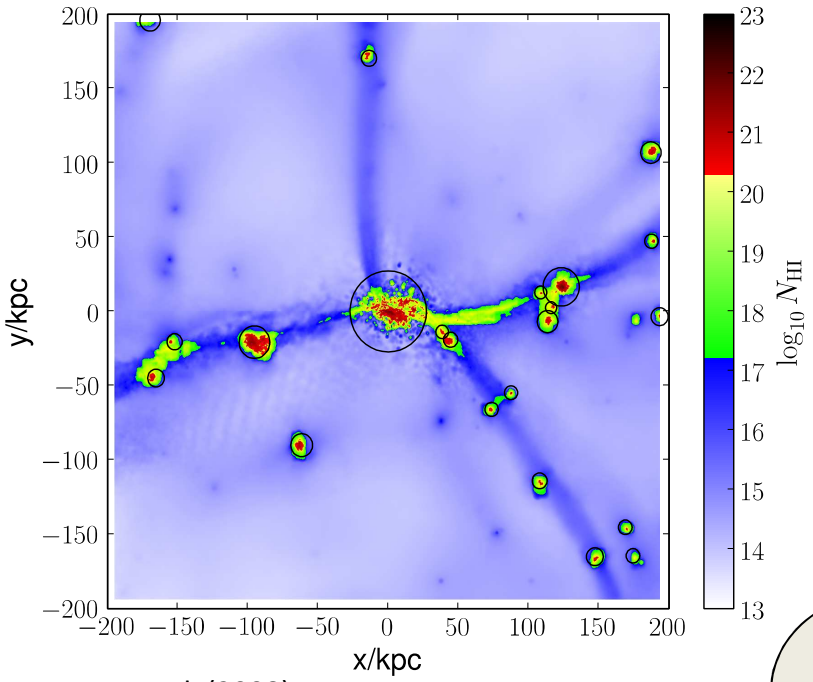
Complementarity

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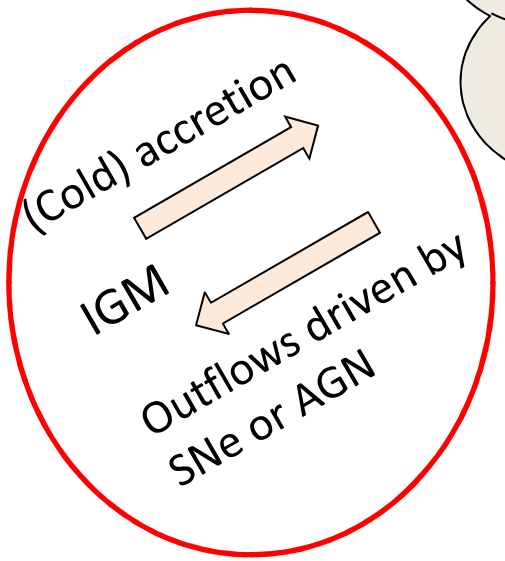


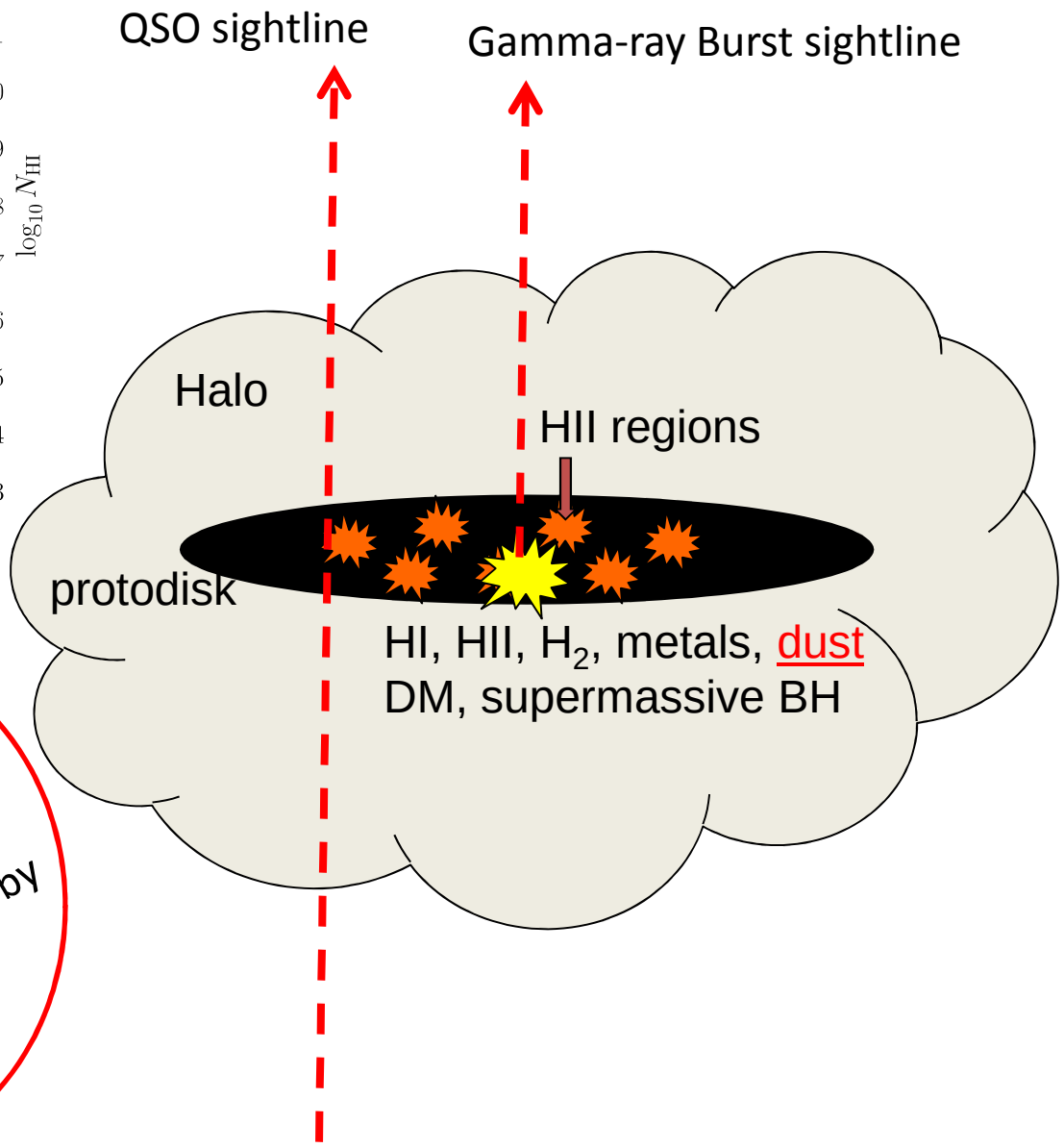


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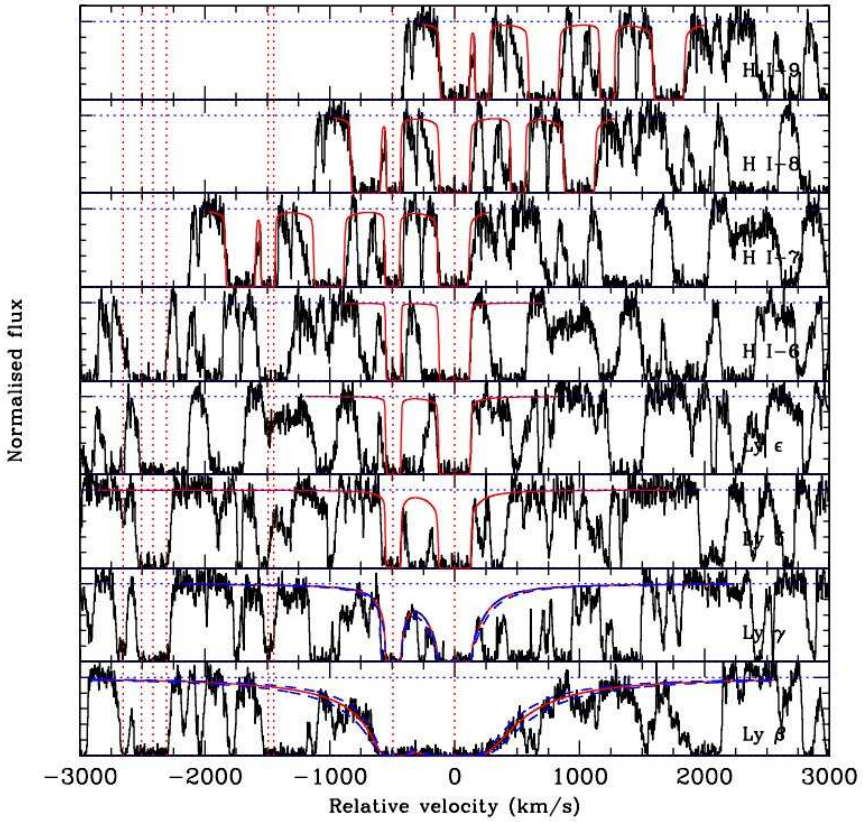


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Cosmology: The Universe for the average astronomer
(No dating, probably around year 2013)
Depressing is not it ?

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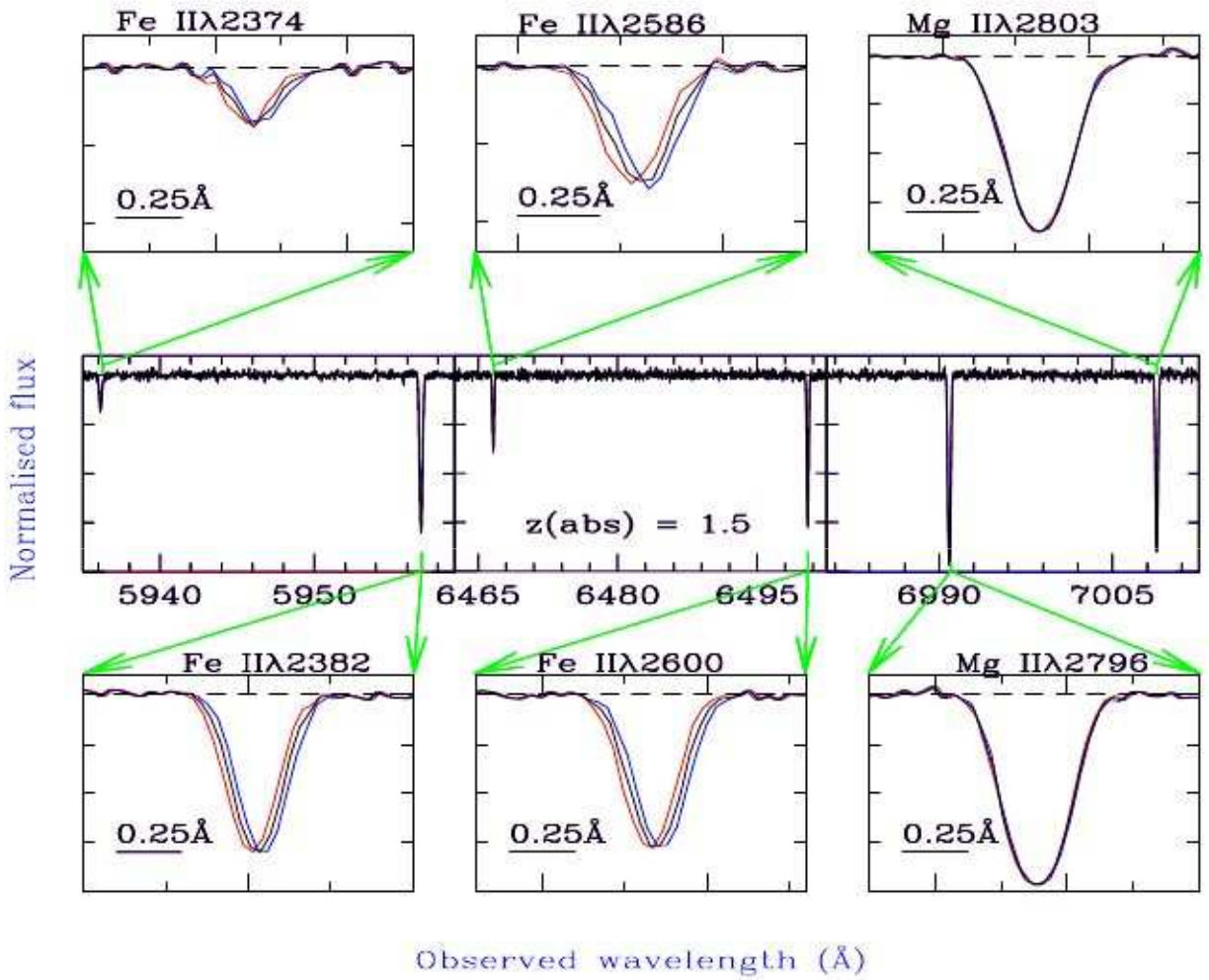


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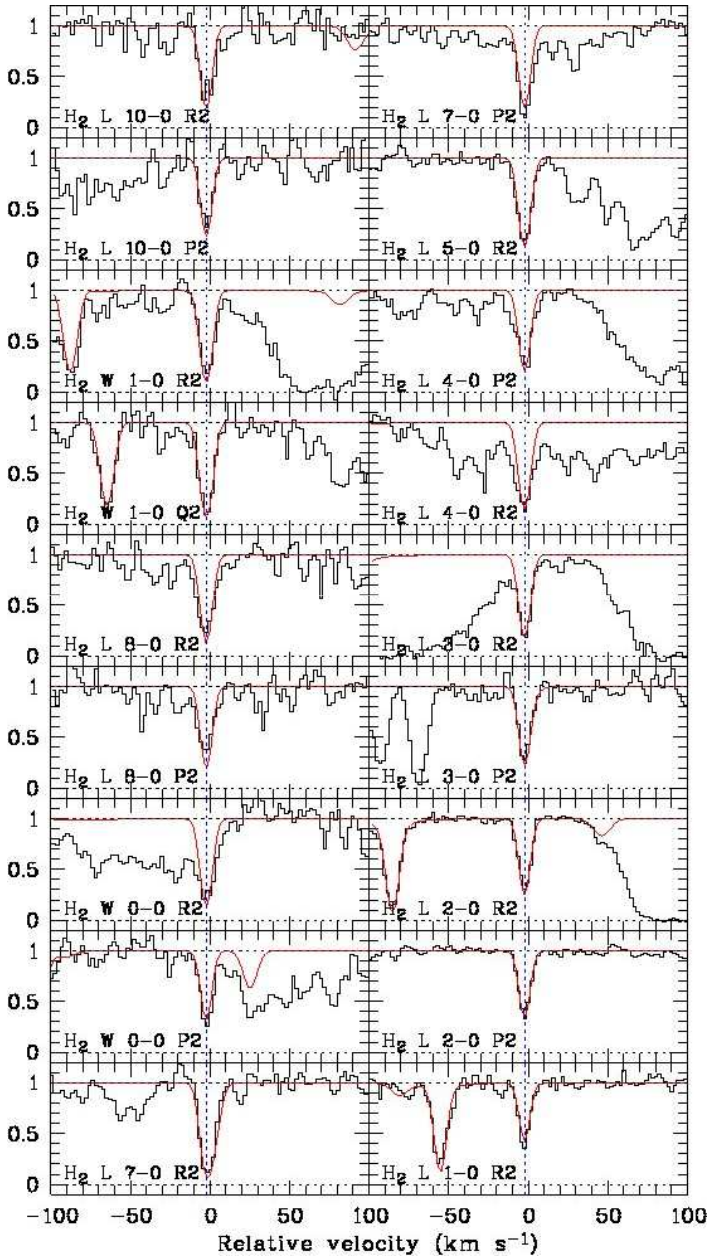


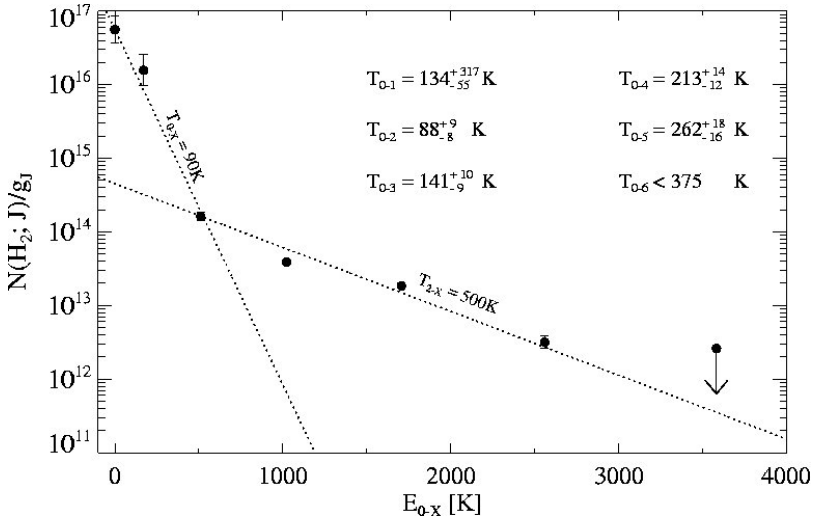


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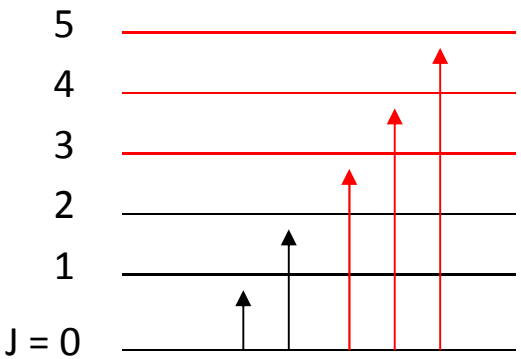


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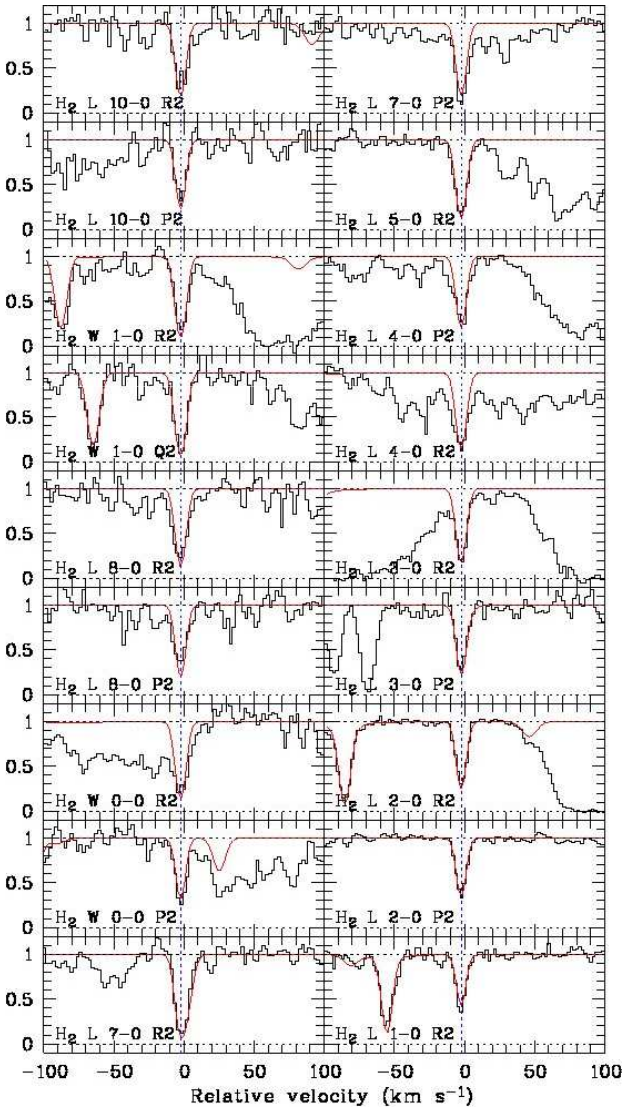


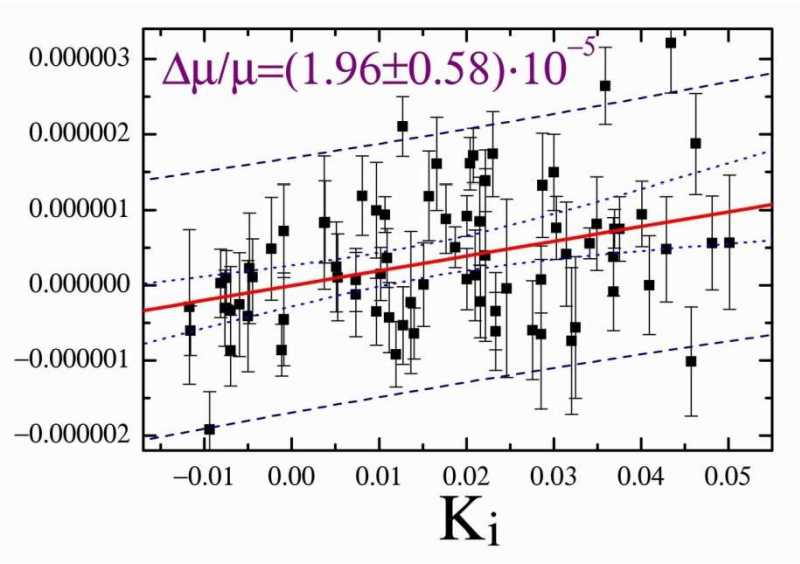


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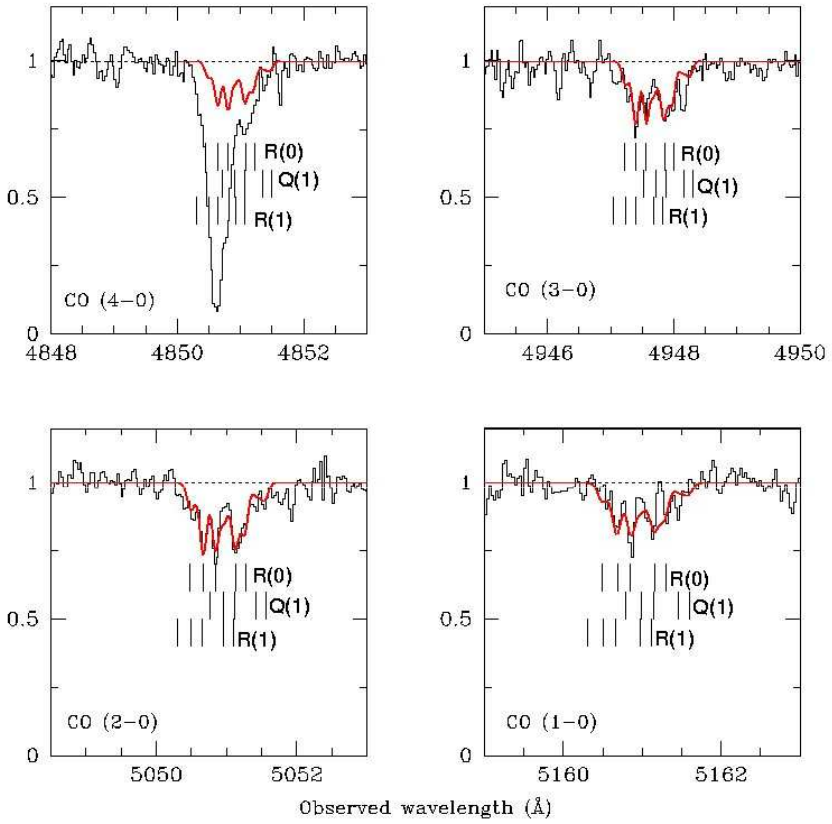


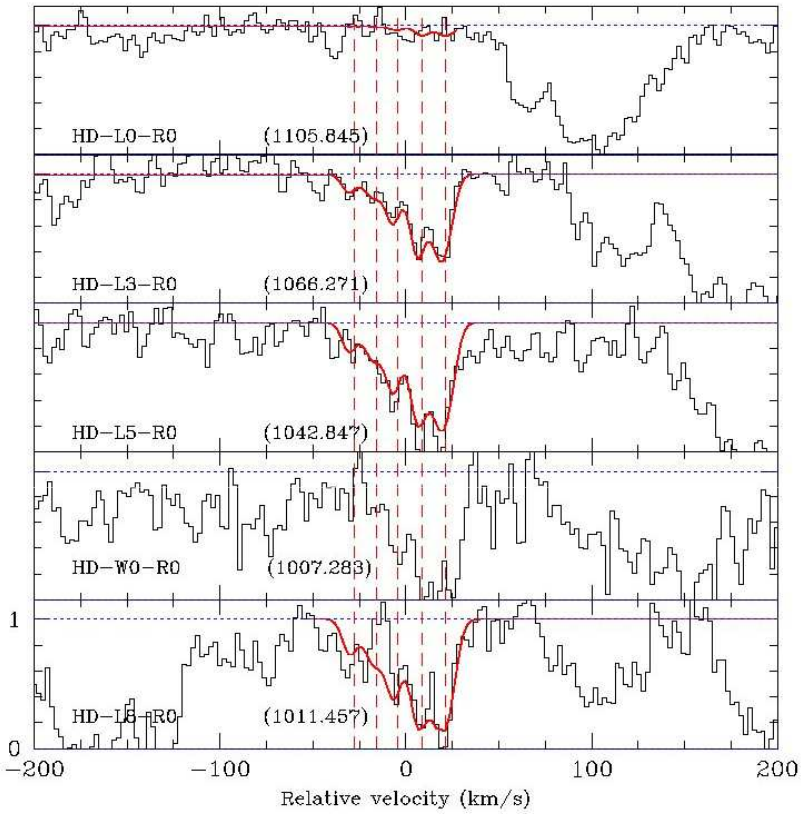


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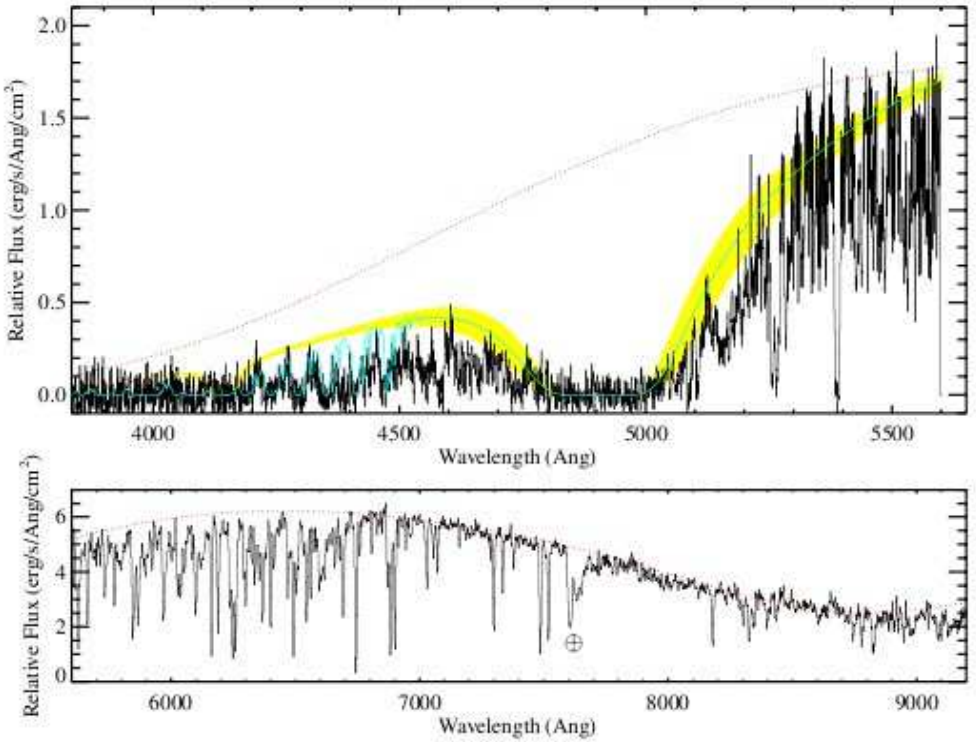


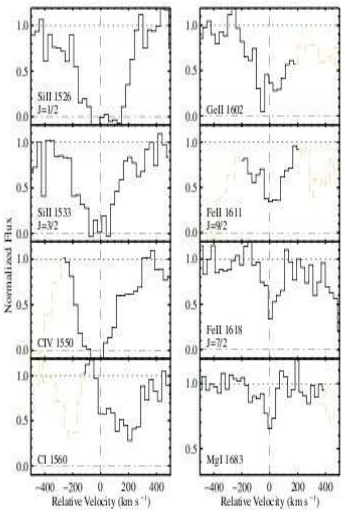


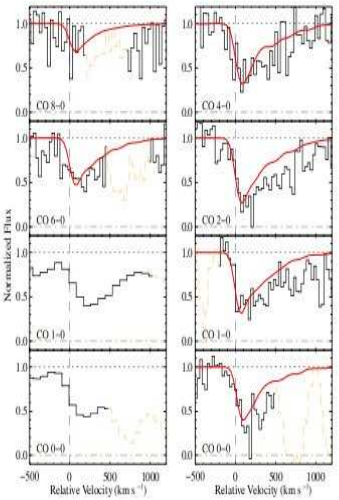


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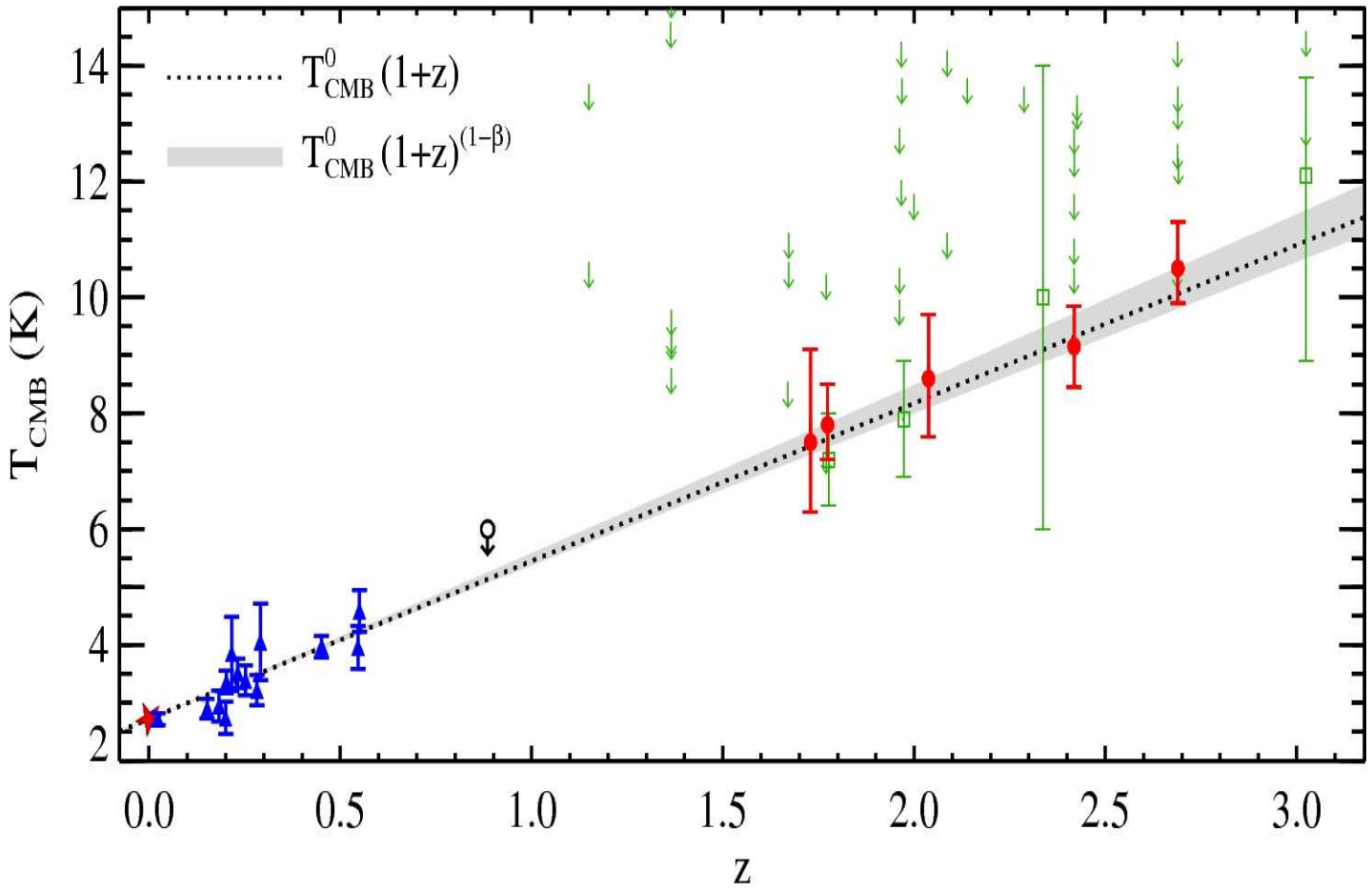


$\beta$ = 0.007±0.027 (we've tried… see also Hurier et al. : sigma=0.017)

## Need SVOM AND ELTs with HIRES and RRM

-> Fundamental tests => high resolution and ELTs

-> The reionization => High redshift GRBs

-> Ionization of the ISM => RRM

-> Host galaxy => Statistics

Thank you !