Dissecting the interstellar medium of a z=6.3 galaxy.

X-shooter spectroscopy and HST imaging of the afterglow and environment of the Swift GRB 210905A

Stargate Collaboration

V Congresso Nazionale GRB - Trieste
12-15 Settembre 2022

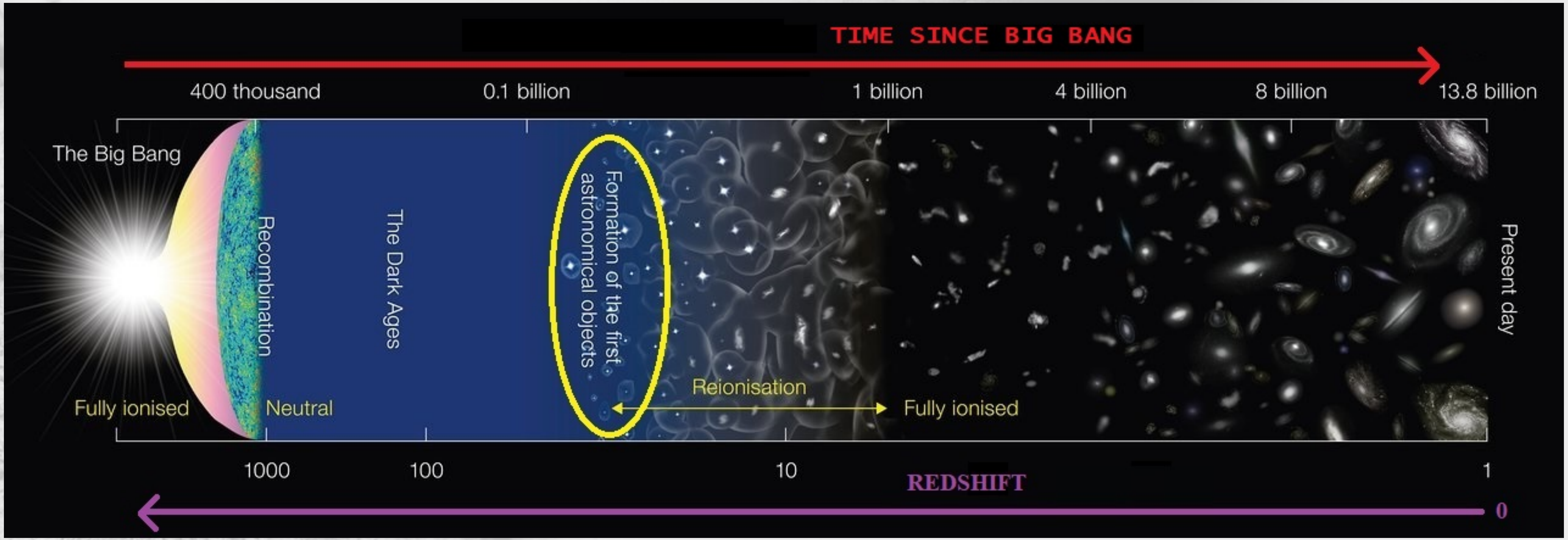
Speaker
ANDREA SACCARDI
Observatoire de Paris - GEPI
Supervisor: S.D. Vergani

Credits: Futura Science

GRBV

Major issues of extragalactic astronomy

-What are the first objects to be formed in the Universe?
-How do galaxies form and evolve?
-What is their impact on the reionization?
-What is the interplay between star formation and the inter-stellar gas?



Credits: ESO

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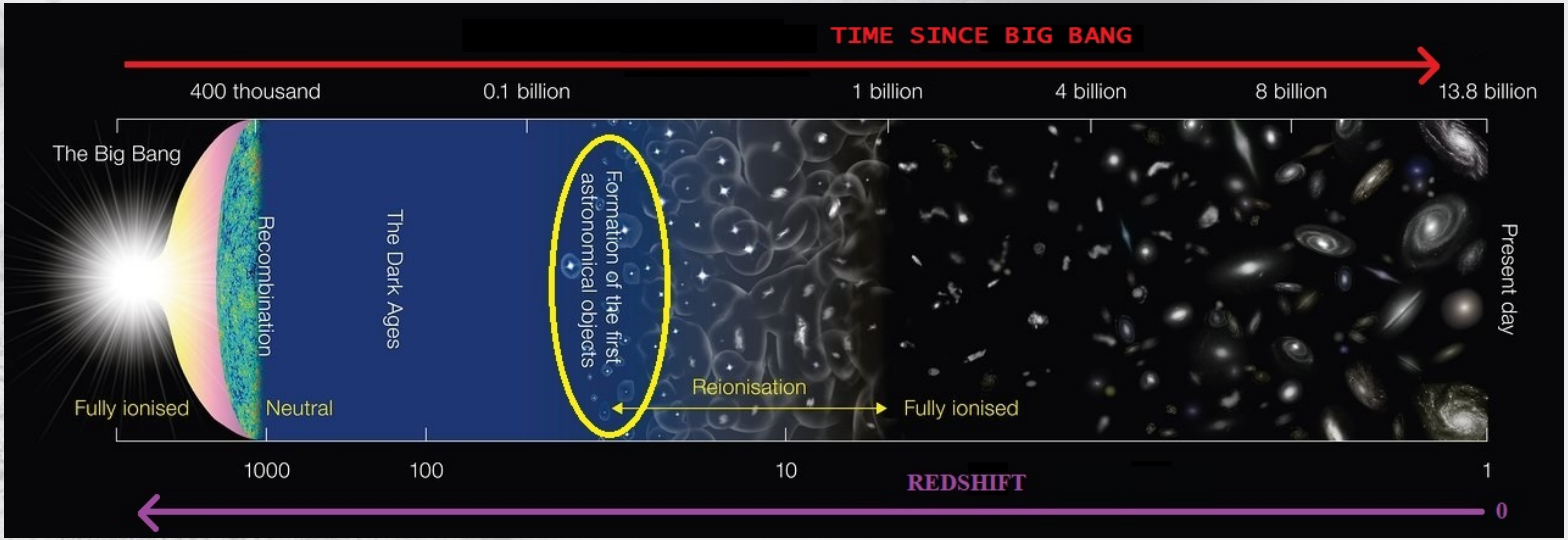
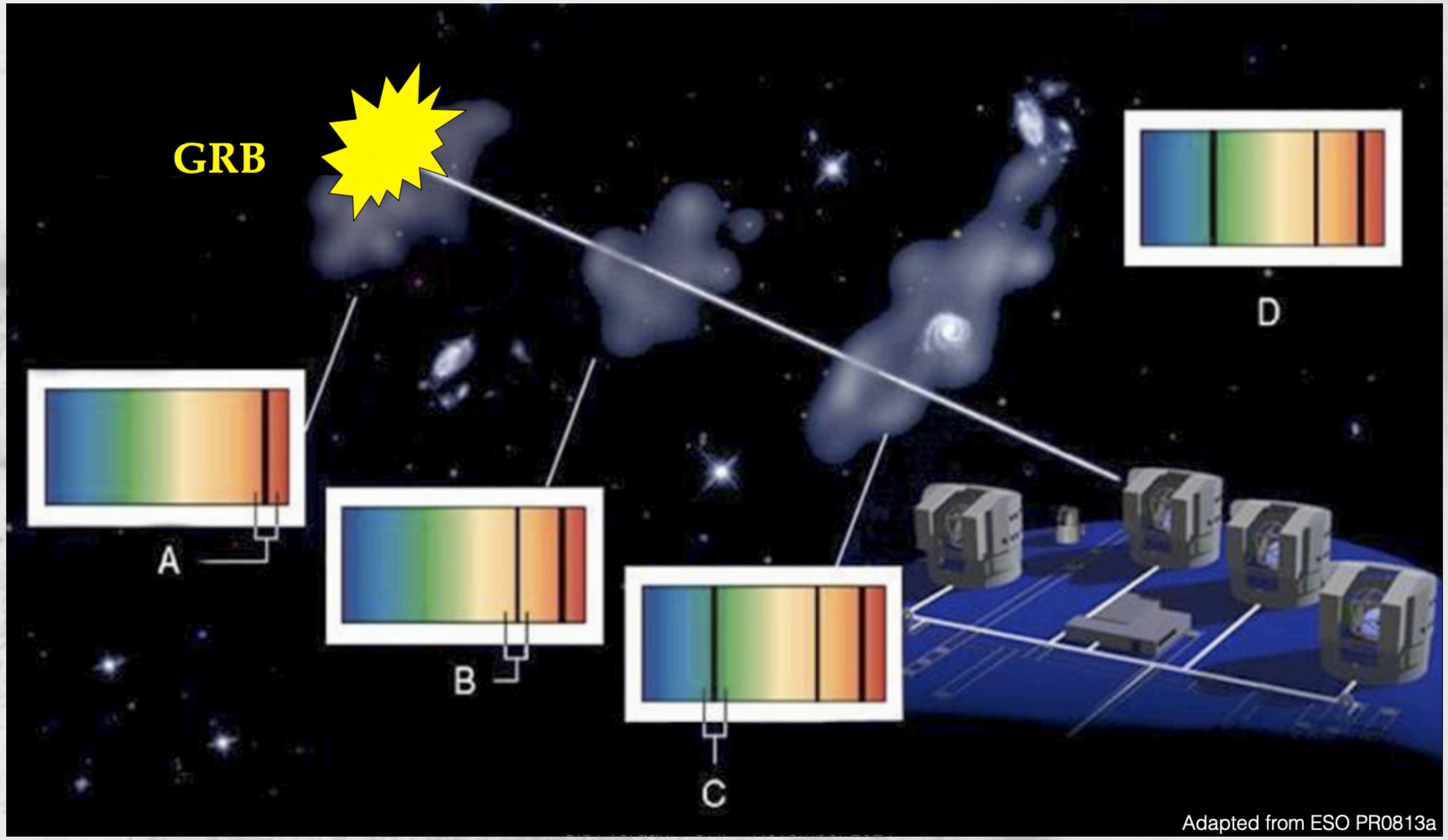


Credits: ESO

→ **GRBs ARE IDEAL TOOLS TO TACKLE THESE ISSUES**

LGRBs afterglows are unique powerful background sources to probe first galaxies



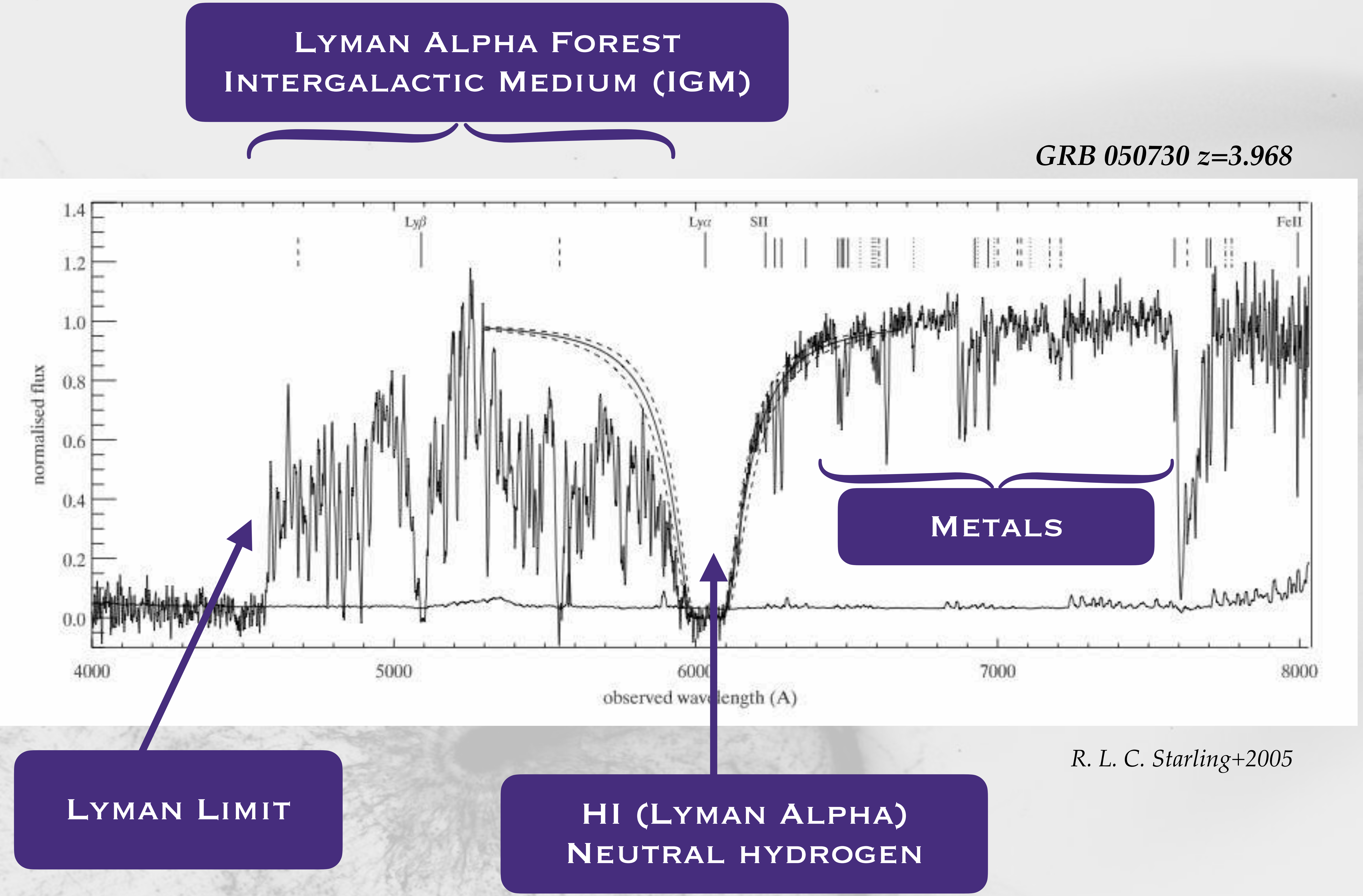
Credits: ESO

- Extremely bright at all redshift
- Trace star formation to the highest redshift
- Afterglow emission fades —> Study of LGRB host
- Gas in the ISM (absorption lines Afterglow spectra)

+

Ionised gas (emission lines host galaxy spectra)

GRB 050730 z=3.968

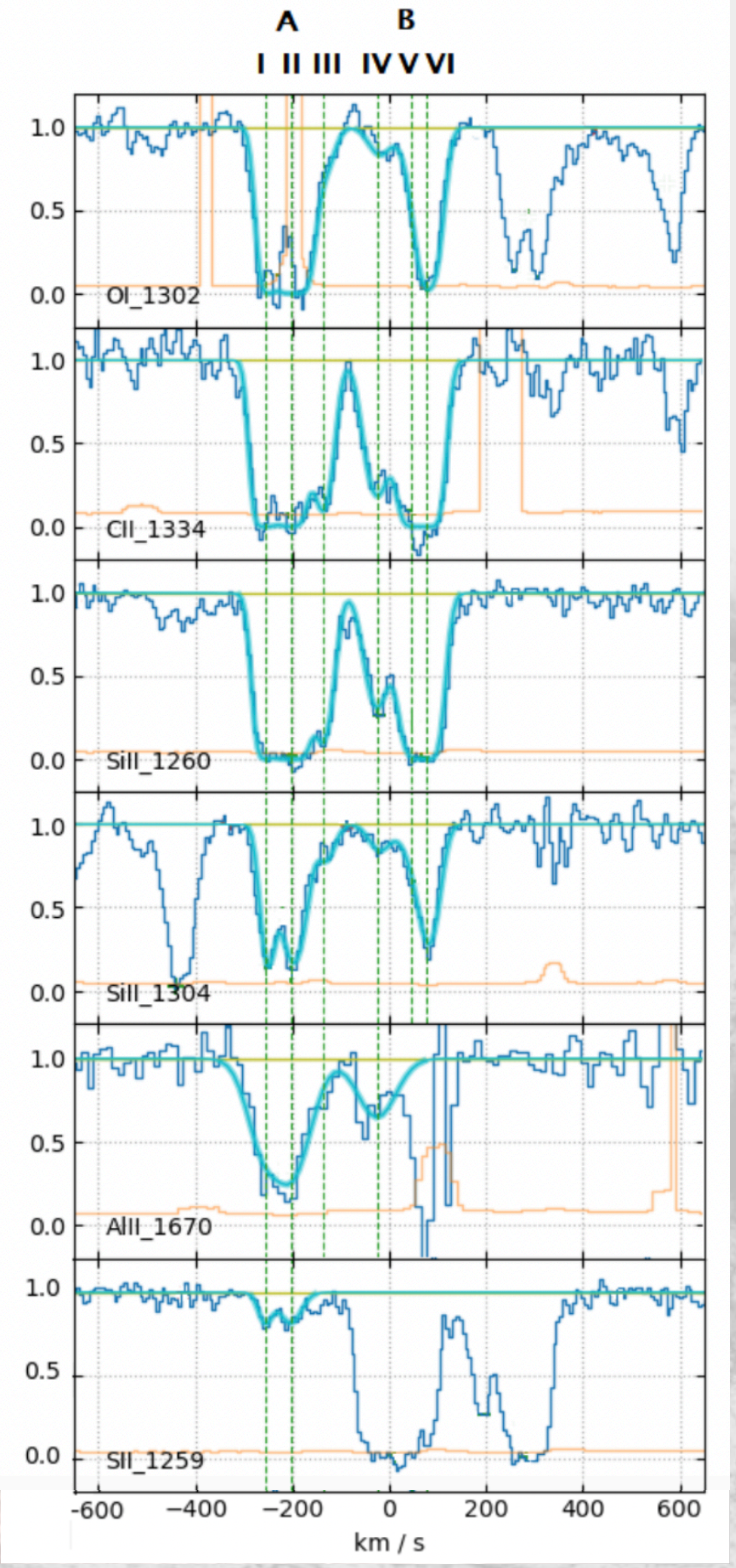


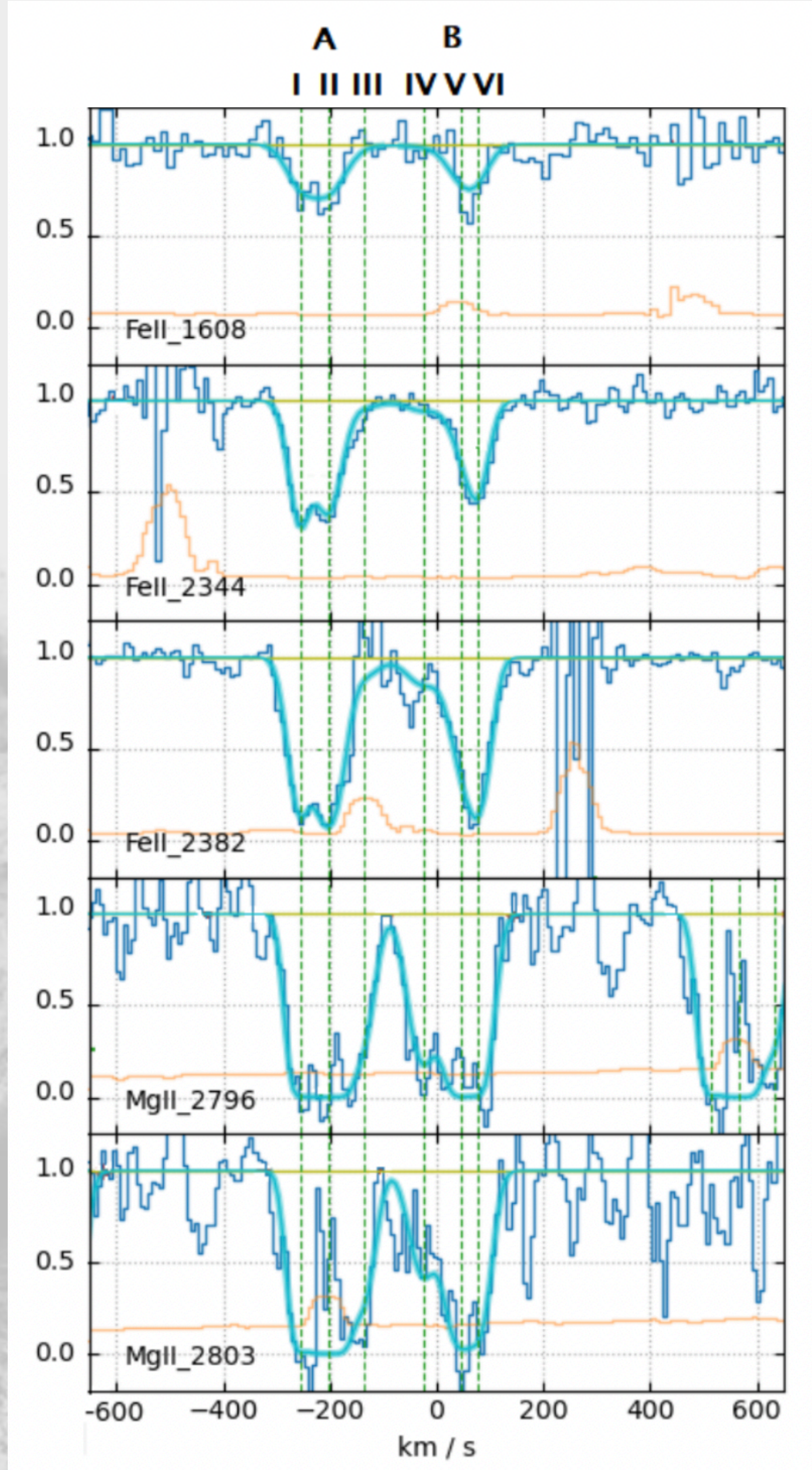
R. L. C. Starling+2005

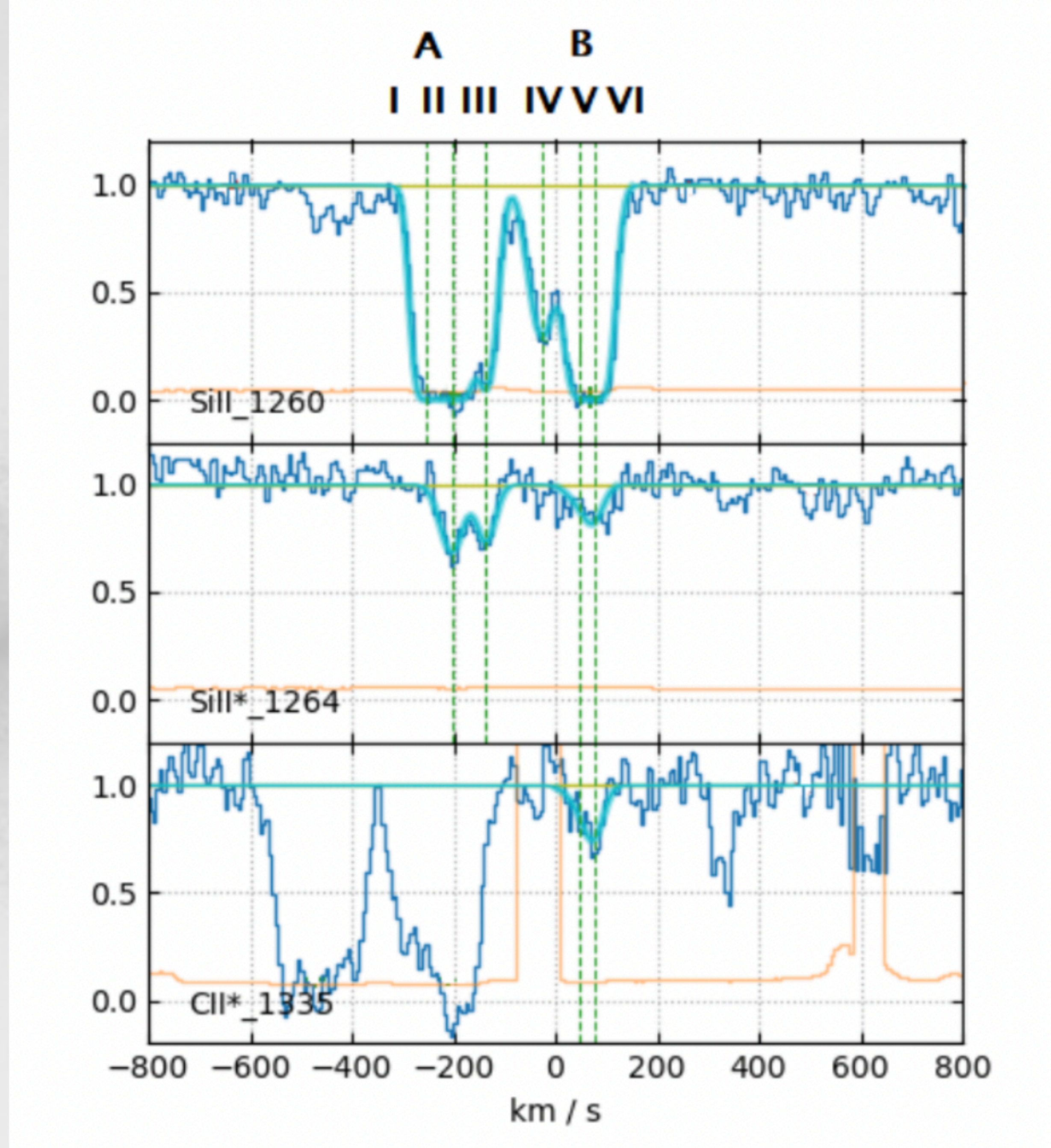
From the analysis of the absorption lines we can measure:

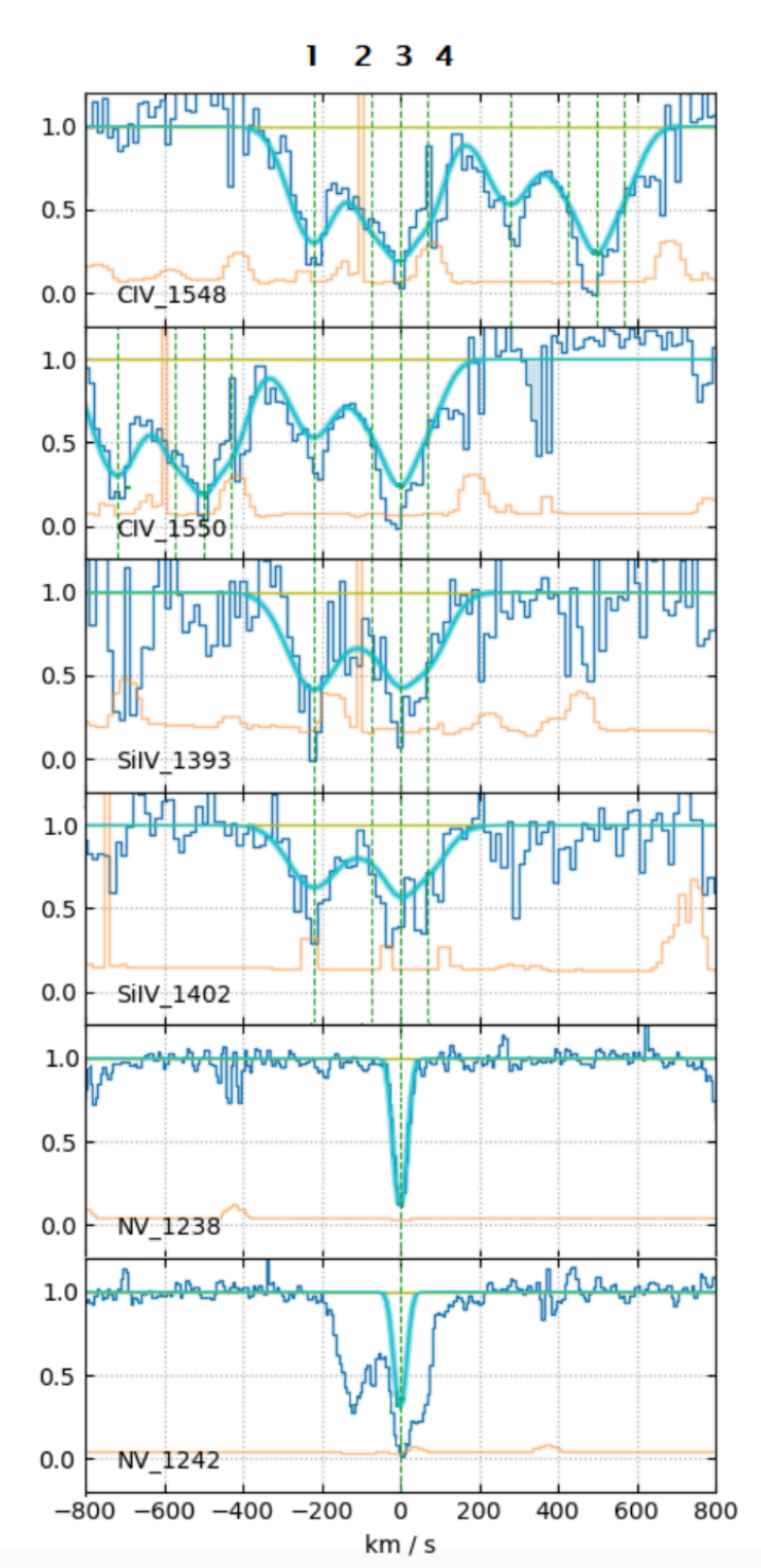
- ➡ *Redshift of the absorbers*
- ➡ *Column densities of the ions of different chemical elements*

GRB 210905A HOST GALAXY z ~ 6.3









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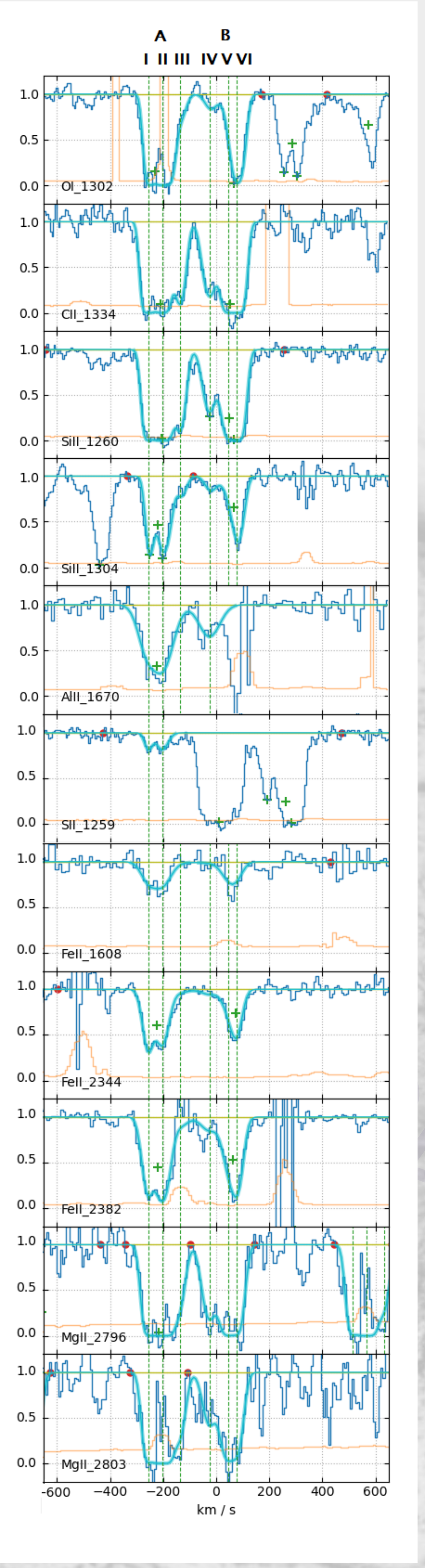
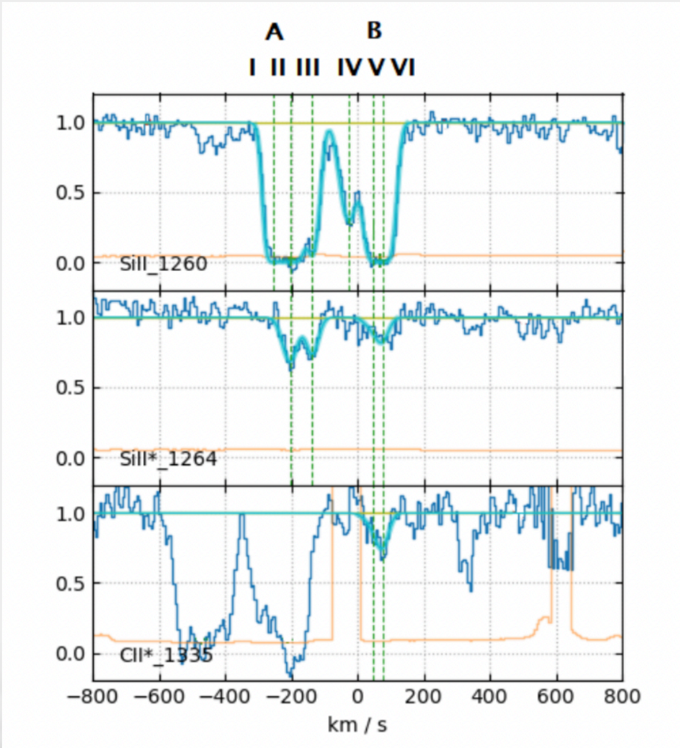
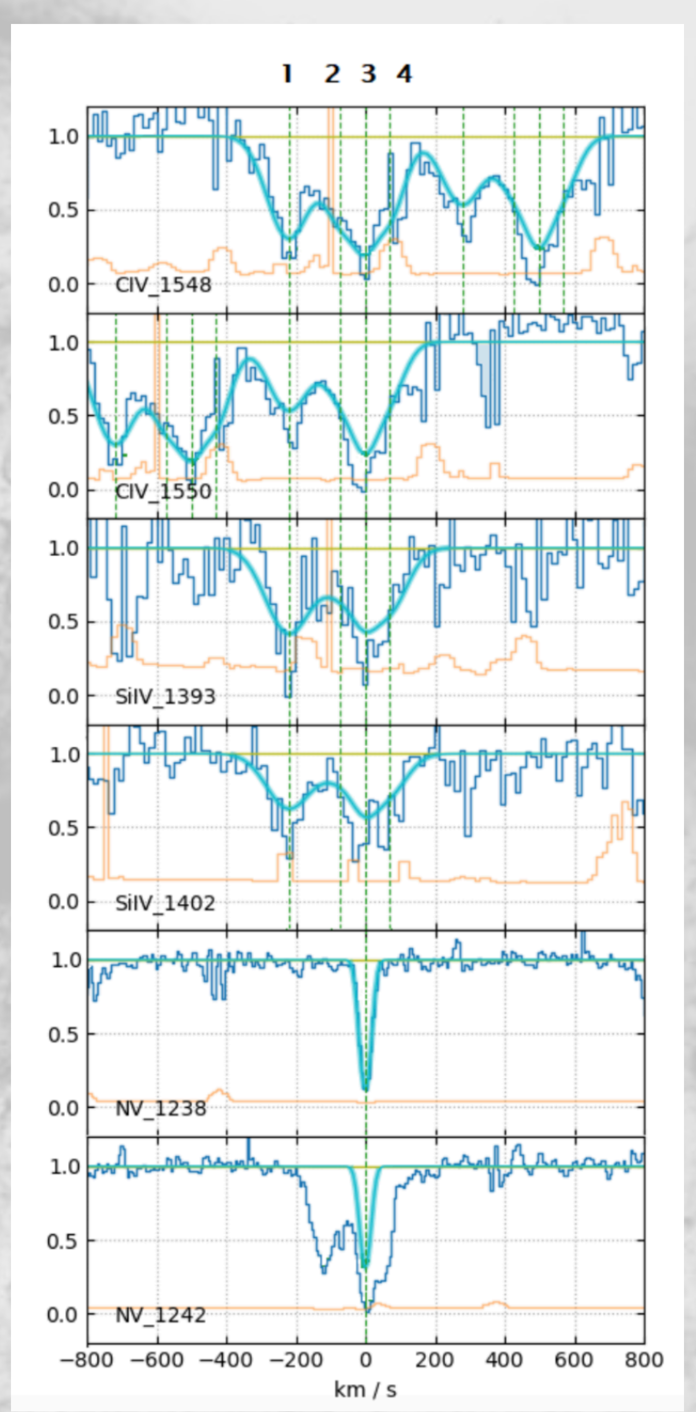






VLT/X-shooter spectrum

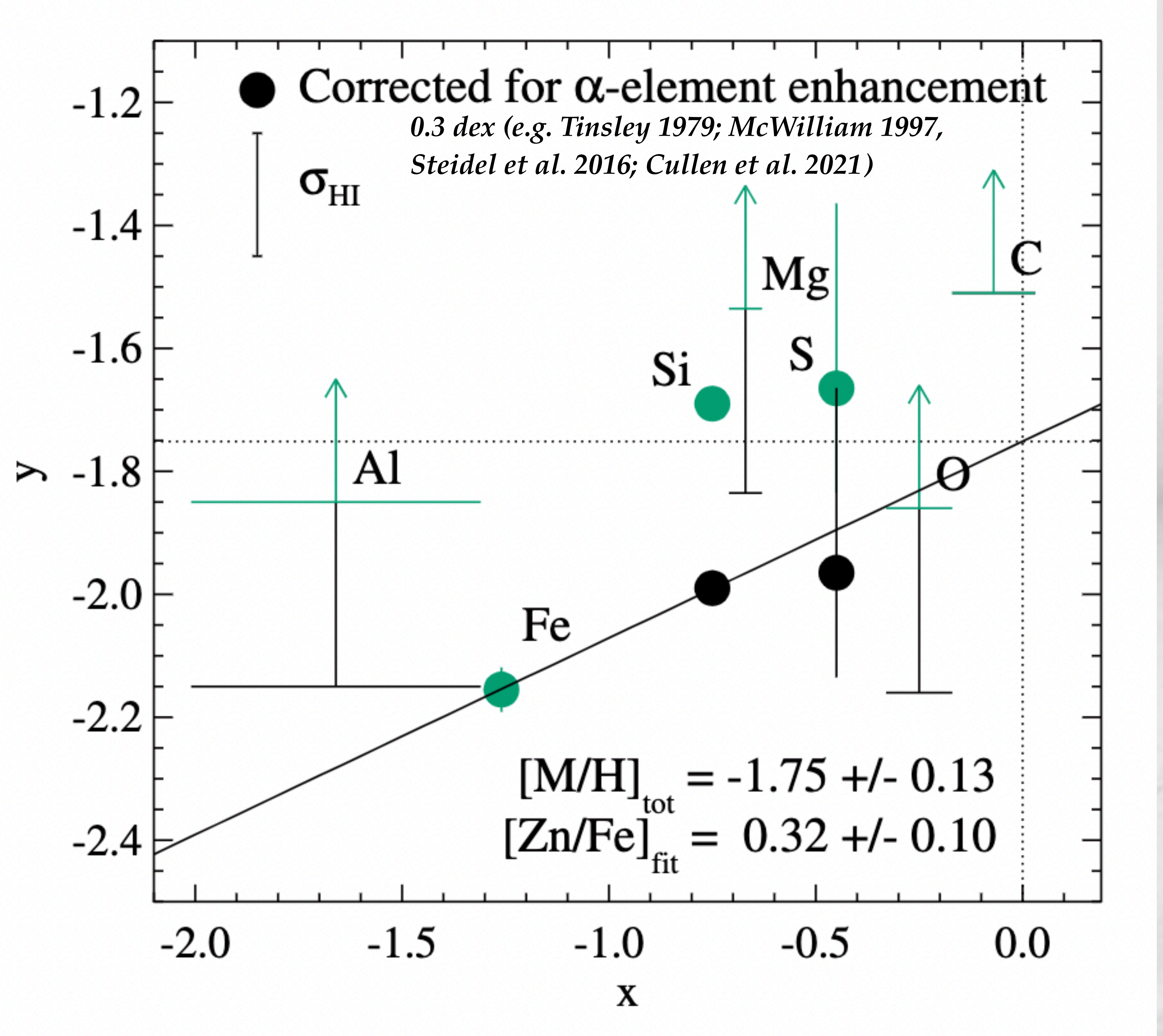
Epoch	Arm	Exp. Time	λ range	Resolution
(Hours)		(s)	(nm)	(λ/δλ)
2.53	UVB	4x1200	300-560	5400
2.53	VIS	4x1200	560-1020	8900
2.53	NIR	4x1200	1020-2100	5600

From the absorption properties :

- ➡ *Metallicity and dust depletion*
- ➡ *The distance of the corresponding gas clouds*
  (From the fine structure lines e.g. Vreeswijk+2007; D'Elia+2009)
- ➡ *Kinematic of the gas*
- ➡ *Chemical abundance pattern*

We perform a detailed analysis of metallicity, chemical enrichment and dust depletion

The overall host galaxy



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Following De Cia et al. 2016, De Cia et al. 2021

AXIS

X = How refractory is an element

Y ~ Elements abundances

FIT

Slope —> $[Zn/Fe]_{fit}$

Intercept —> $[M/H]_{tot}$

GRBV

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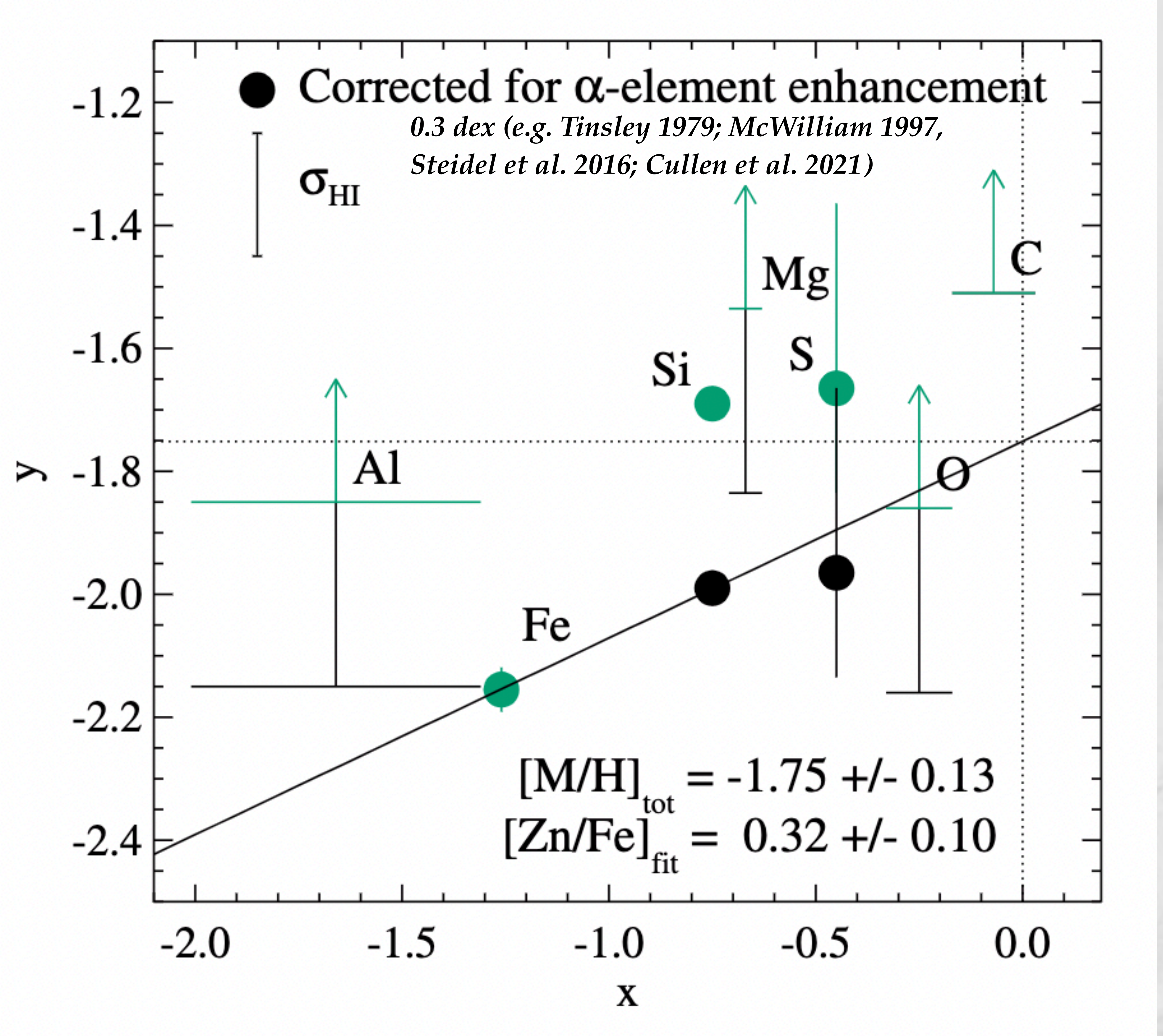

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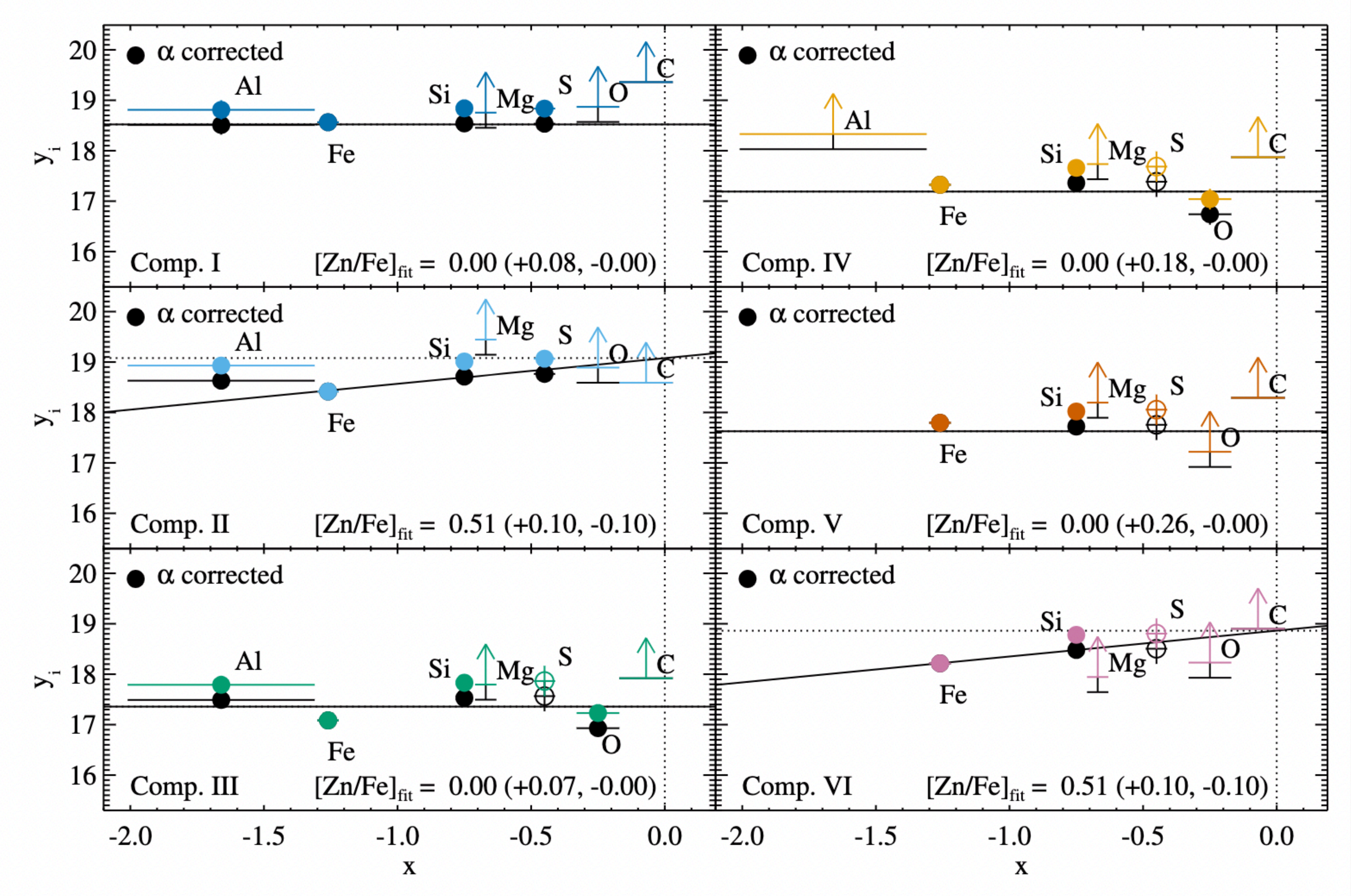
Component-by-component



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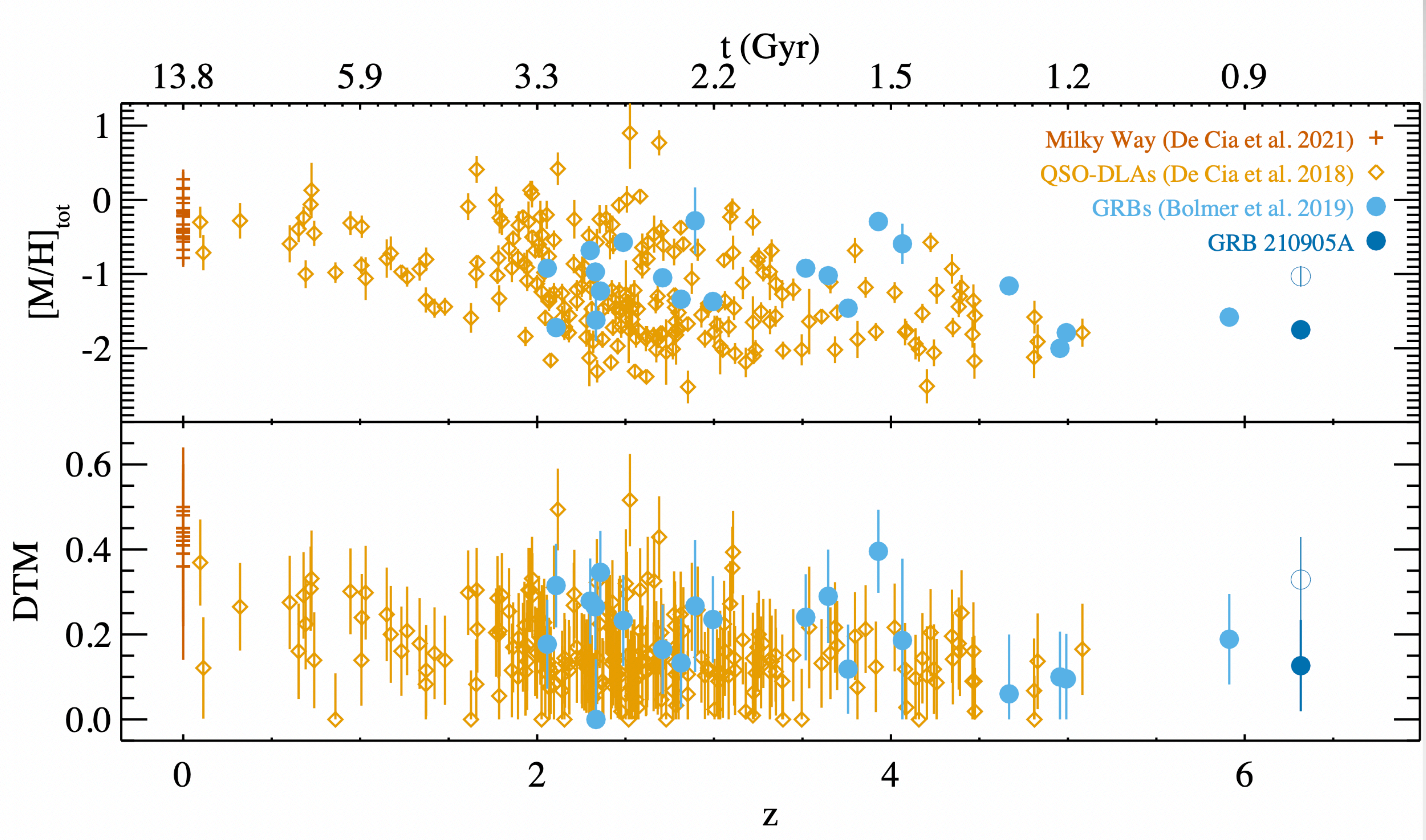
RESULTS

1. We find that the dust-corrected metallicity of the GRB host is [M/H] = -1.75 +/- 0.13 and DTM = 0.13 +/- 0.11



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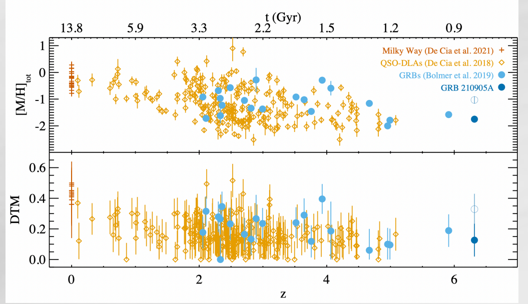

RESULTS

1. **We find that the dust-corrected metallicity of the GRB host is [M/H] = -1.75 +/- 0.13 and DTM = 0.13 +/- 0.11**

2. **We determine the abundance pattern for each component: The deviation from the linear fits, $[X/Fe]_{nucl}$, are due to the effect of nucleosynthesis**

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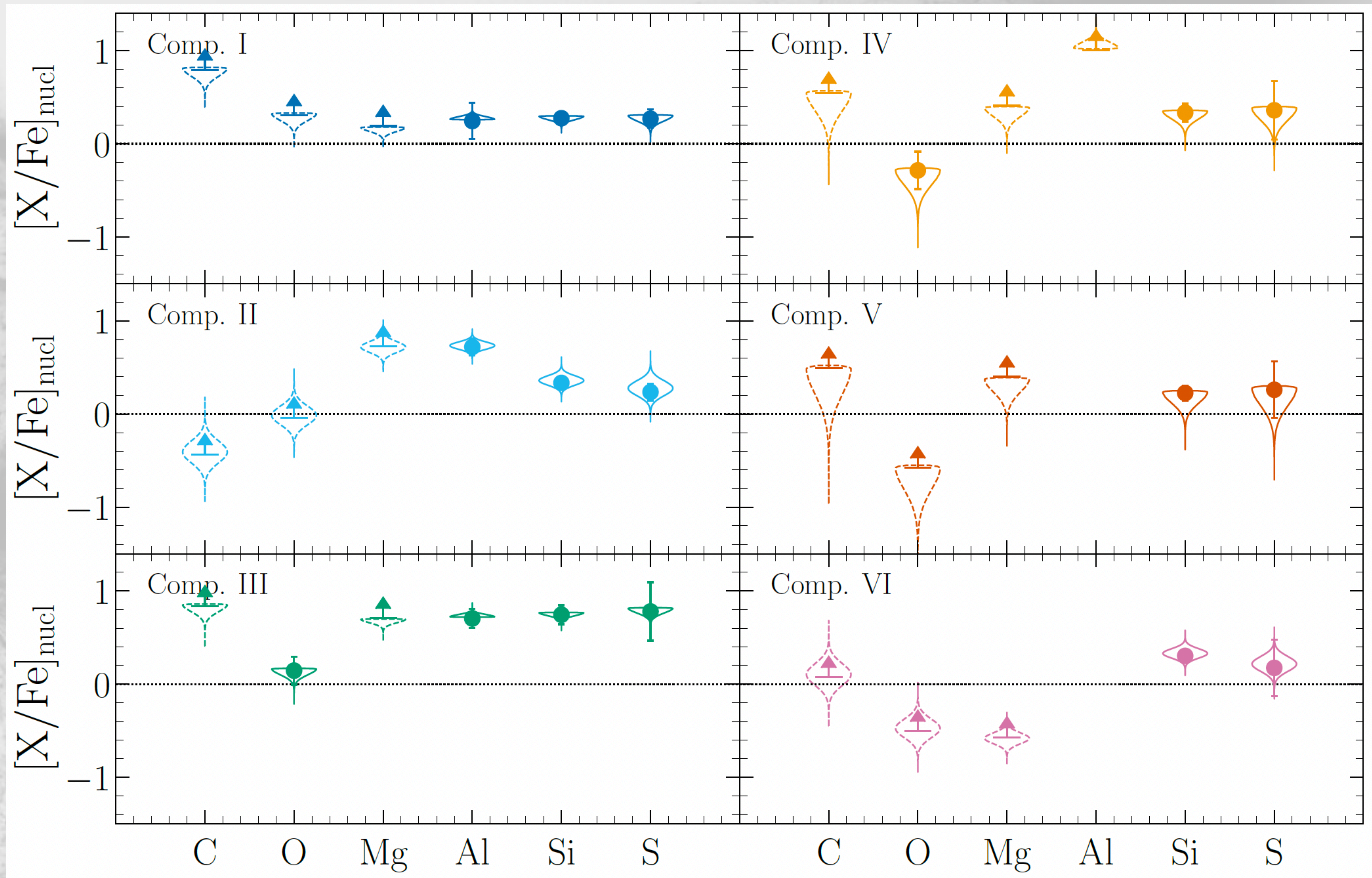

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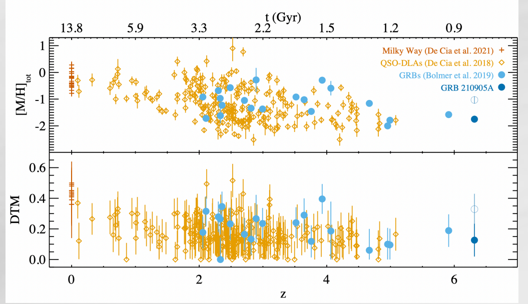

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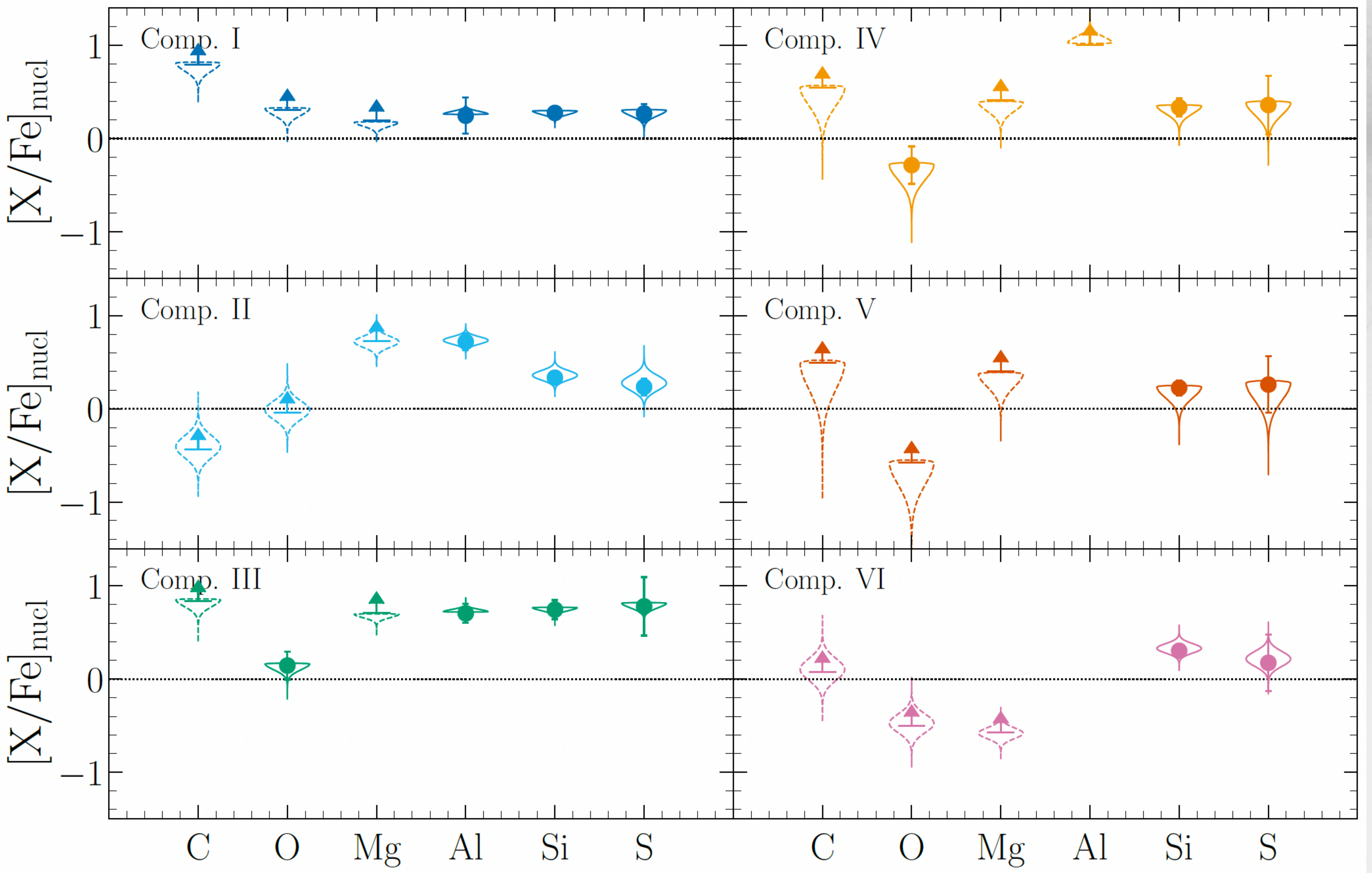

High enhancement of alpha elements:

- high production from core-collapse SNe

-a high fraction of massive stars

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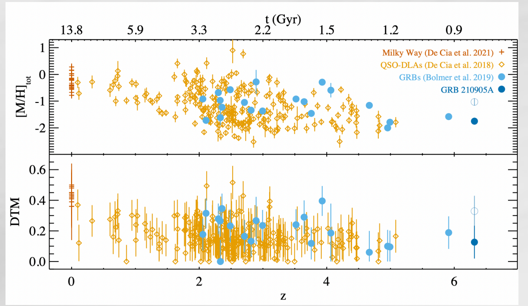

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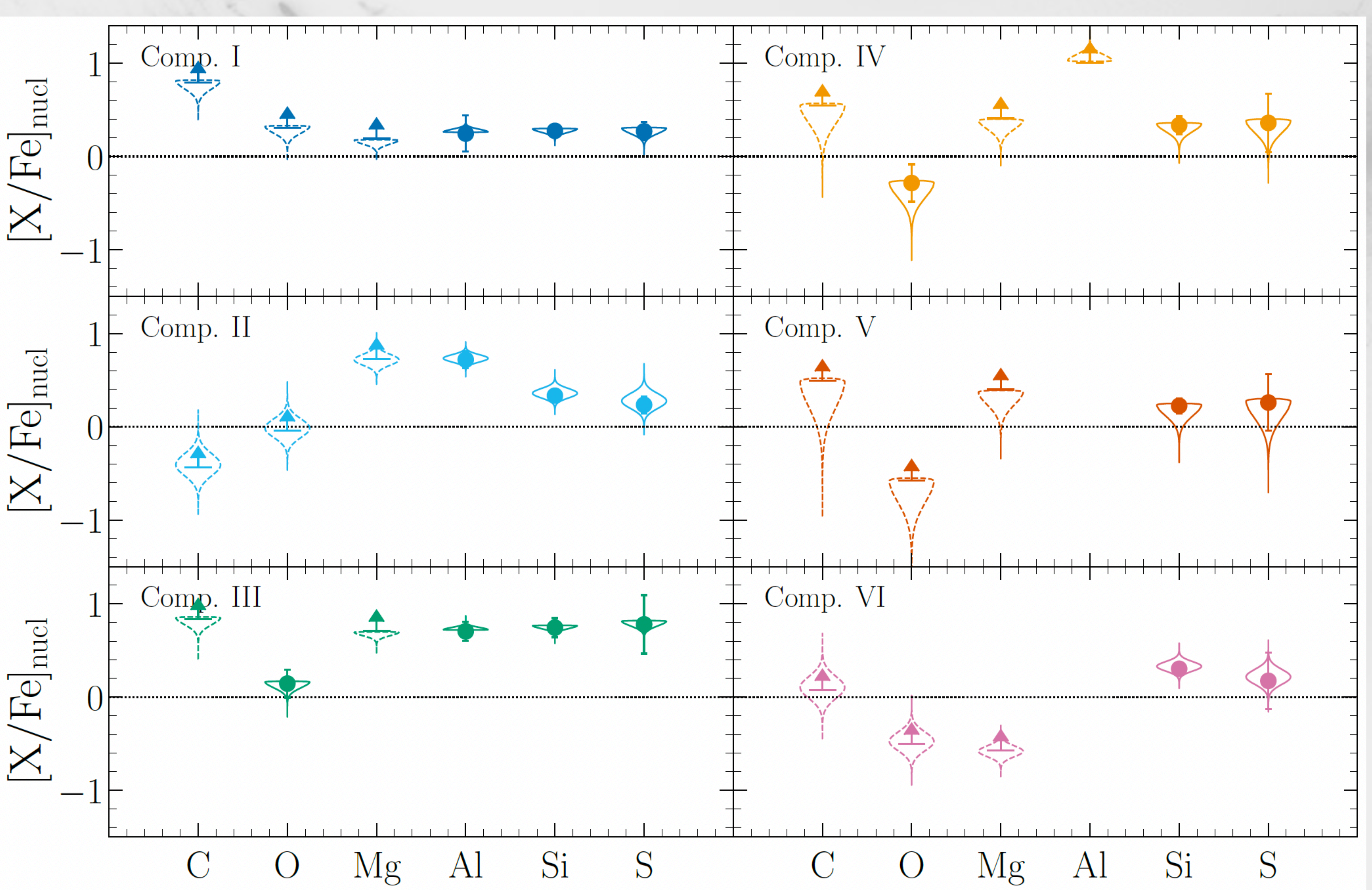

High enhancement of alpha elements:

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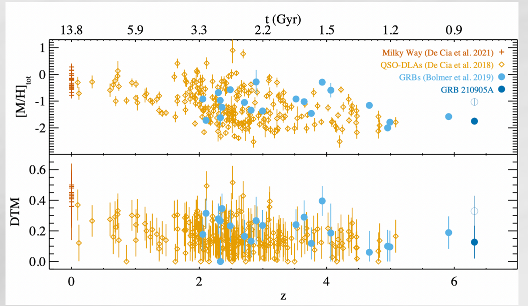
Over-abundance of aluminium
Under-abundance of oxygen:

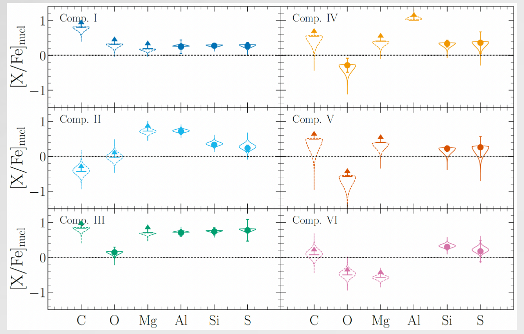
-typical of some stars found in globular clusters and dwarf galaxies

-the best candidates are massive AGB stars and fast rotating massive stars

(e.g., Prantzos et al. 2007; Fulbright et al. 2007; Alves-Brito et al. 2010)

GRB 210905A HOST GALAXY z ~ 6.3





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3. We calculate the distance of the corresponding gas clouds from the GRB (~7kpc)

UV-Pumping

↓

Excite the absorber atoms and ions to a principal quantum number above the fundamental

↓

By a spontaneous emission, the fine structure lines of the fundamental state are populated

+

Photoionization code

INPUT:
-INCIDENCE FLUX
-INITIAL COLUMN DENSITIES

↓

OUTPUT:
-DISTANCE

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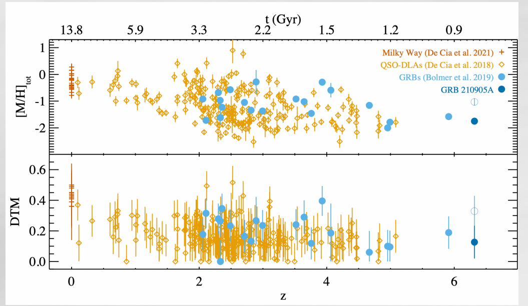

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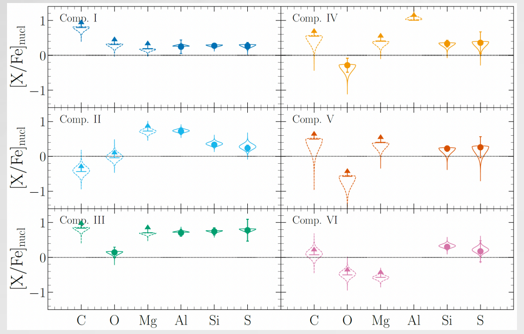

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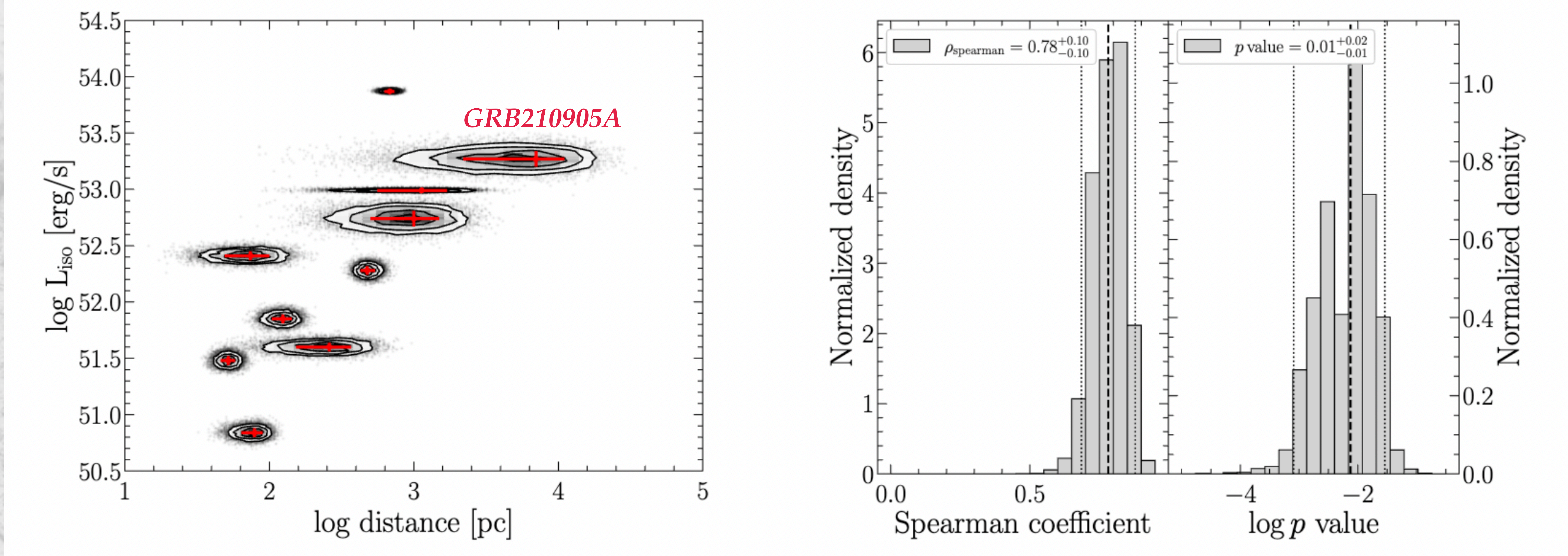

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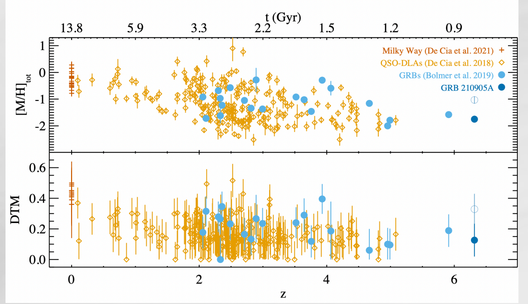
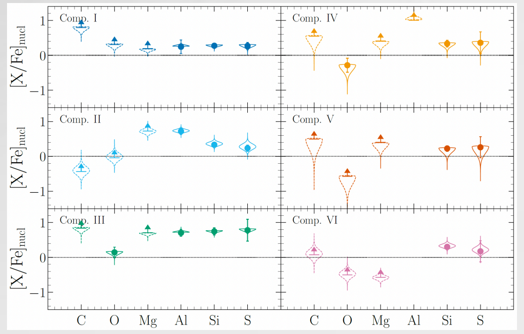
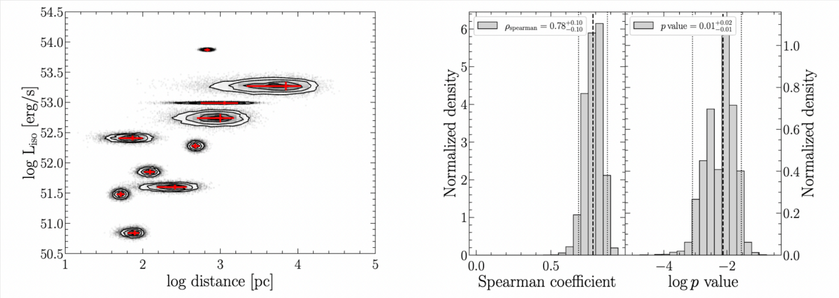
4. Different scenarios can explain the kinematics of this complex system (Galaxies merger, more clumps, more galaxies…)







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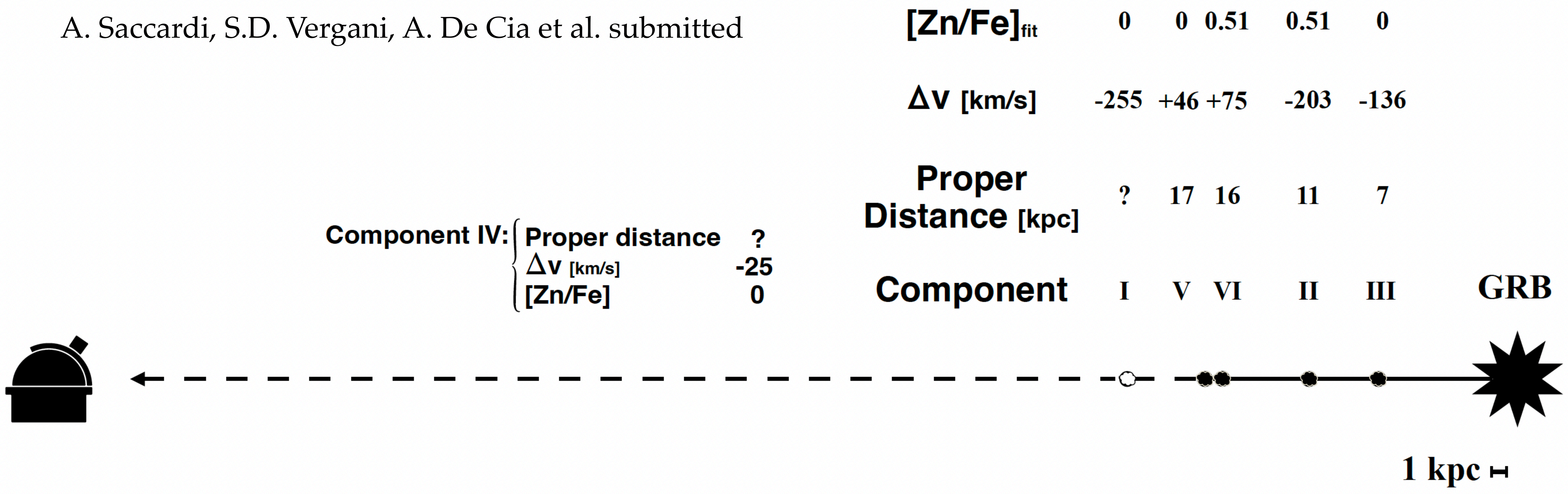
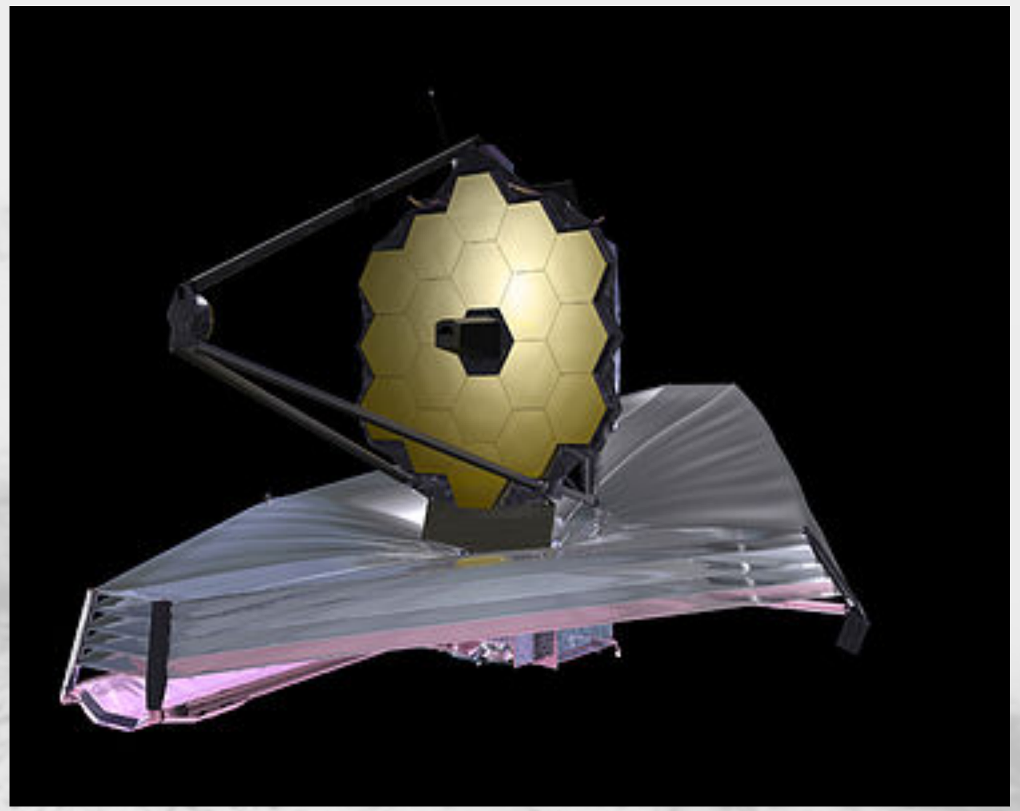


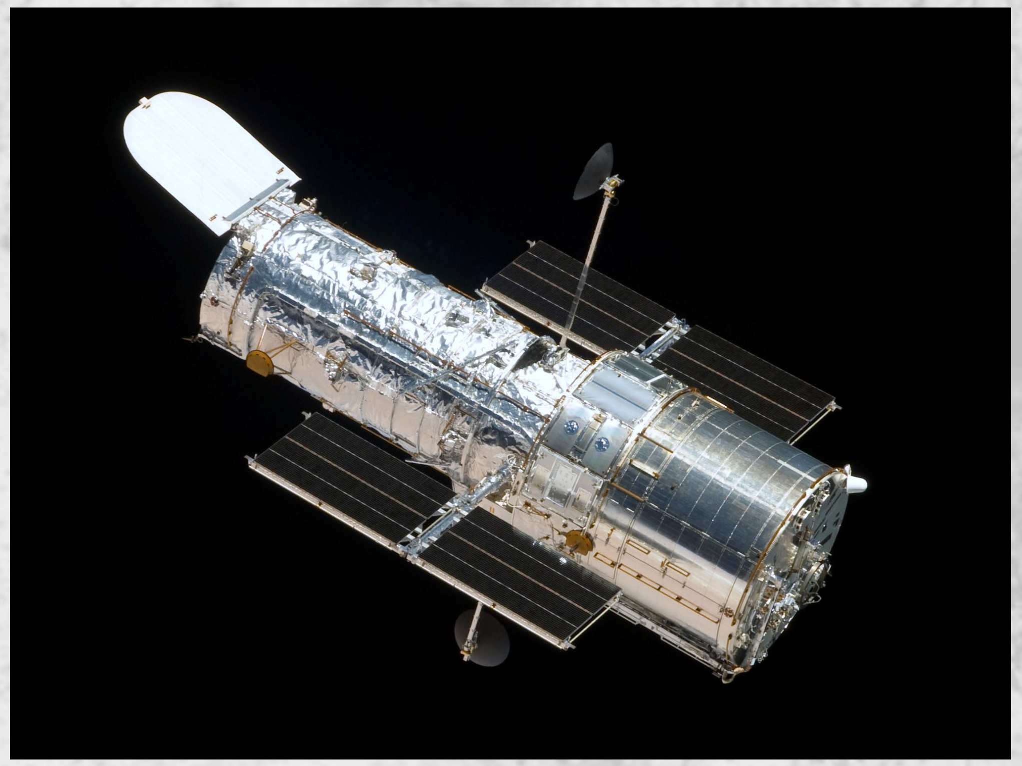
FUTURE PERSPECTIVES

Credits: NASA

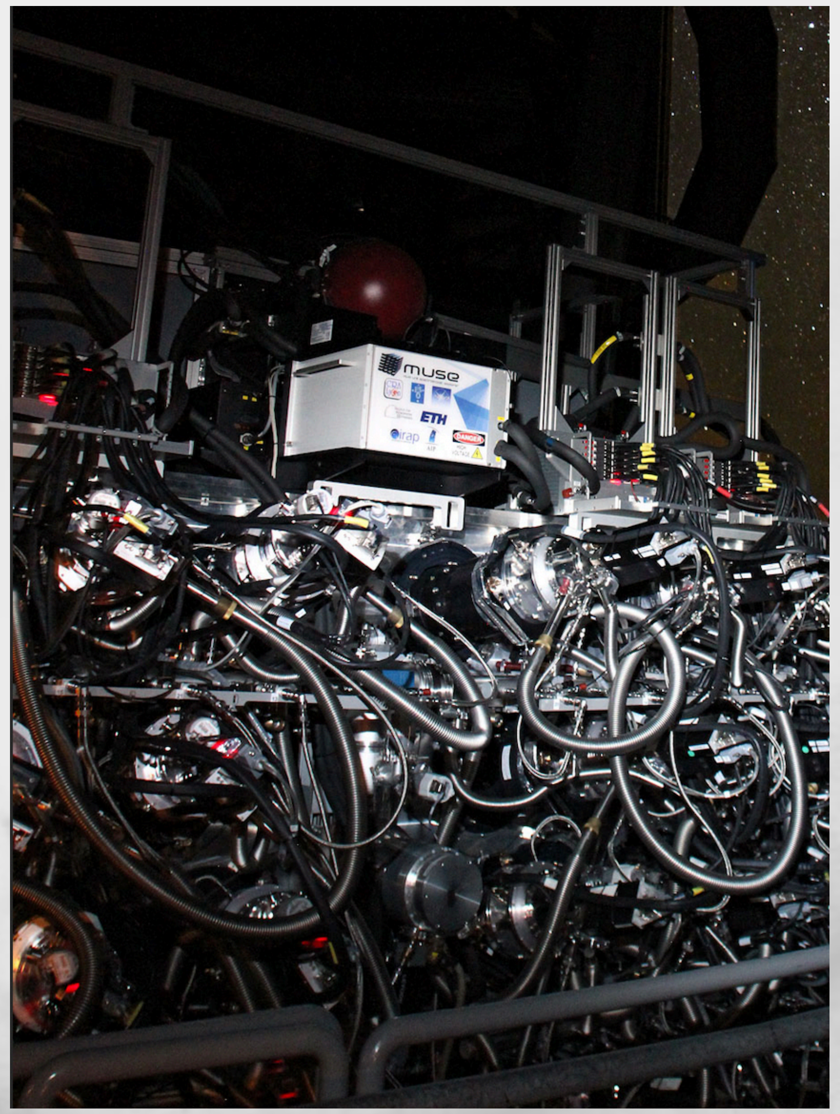


JWST

Credits: NASA



HST



VLT/MUSE

Credits: ESO

The properties of the neutral / warm gas (absorption lines)

+

The continuum and ionized gas (emission lines)

FUTURE PERSPECTIVES

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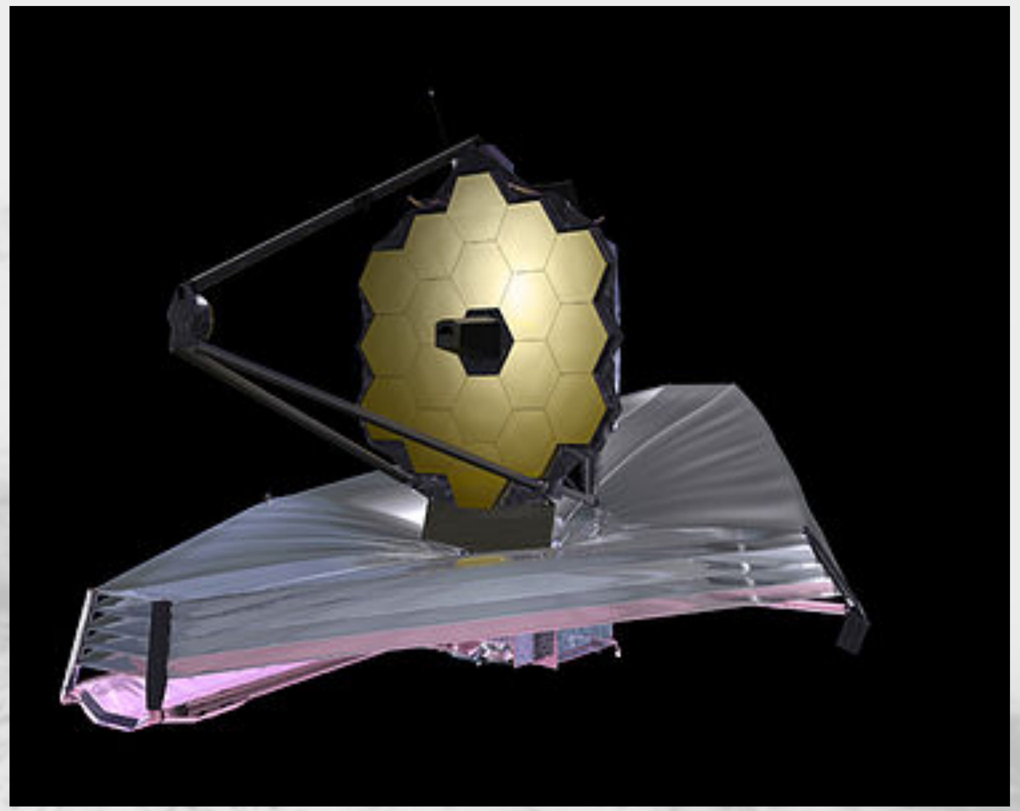

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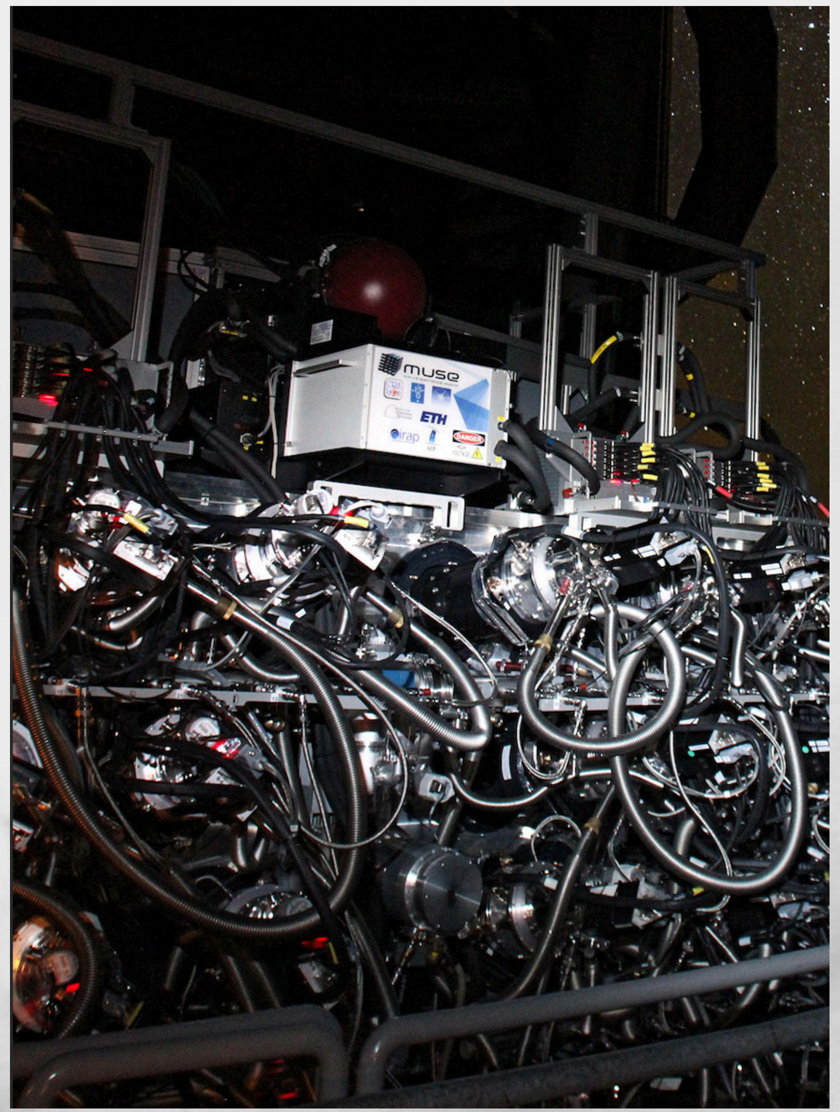

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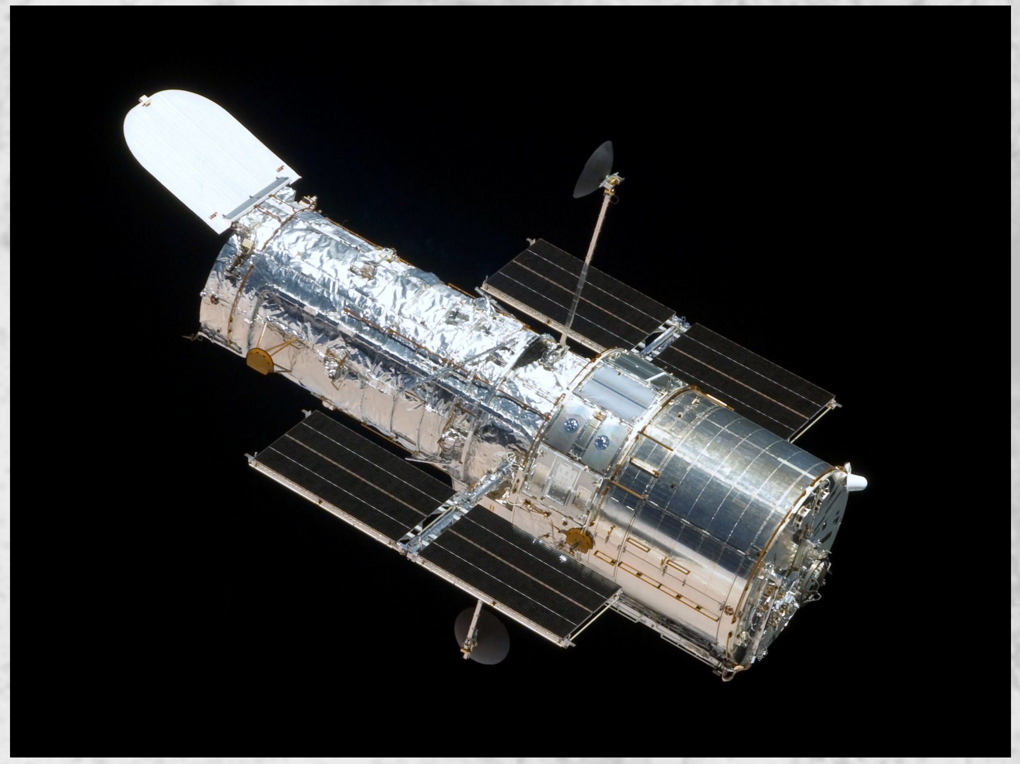


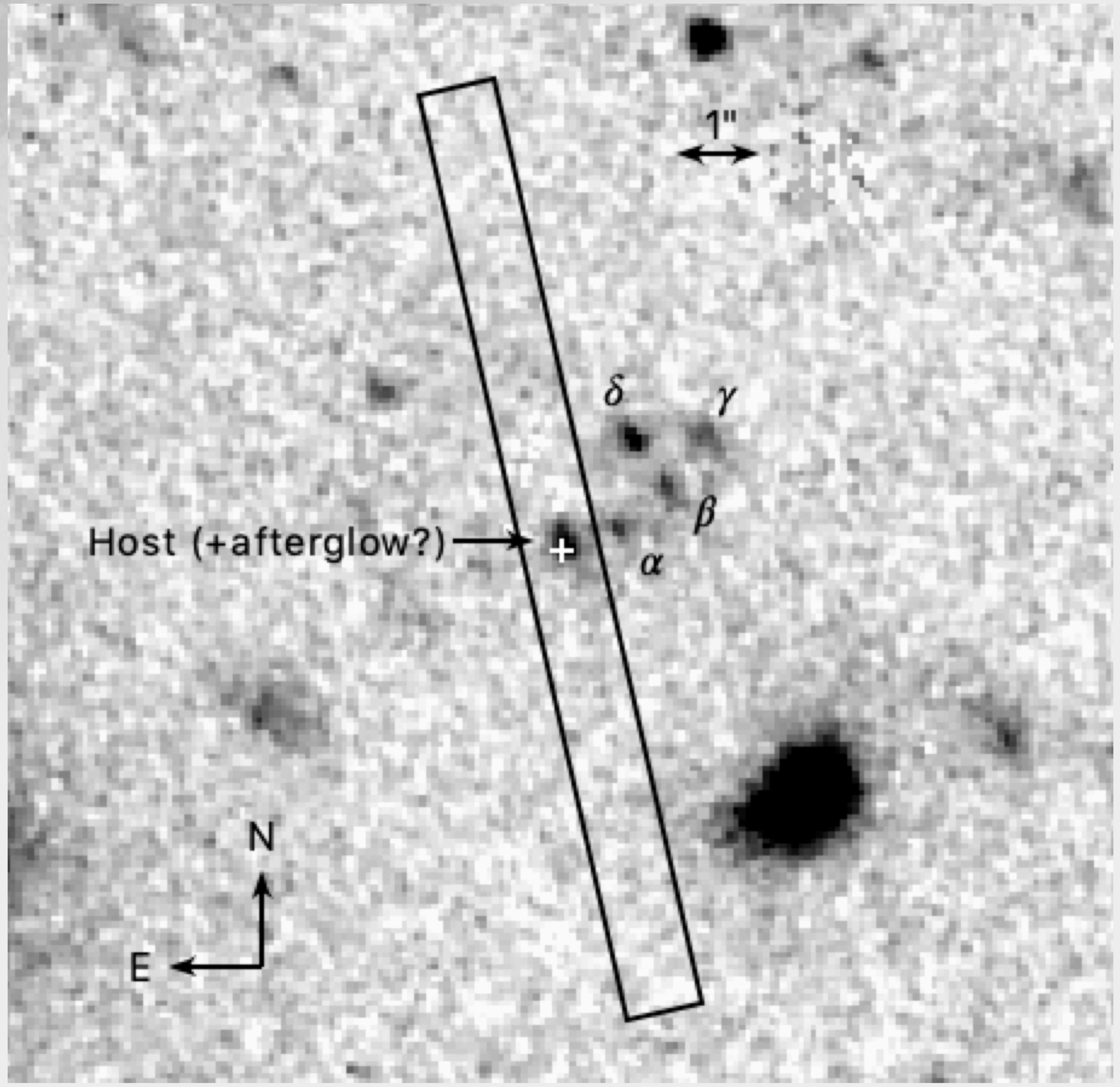
HST

OBSERVED!

The properties of the neutral / warm gas (absorption lines) + **The continuum and ionized gas (emission lines)**

HST/F140W Image

- Complex System



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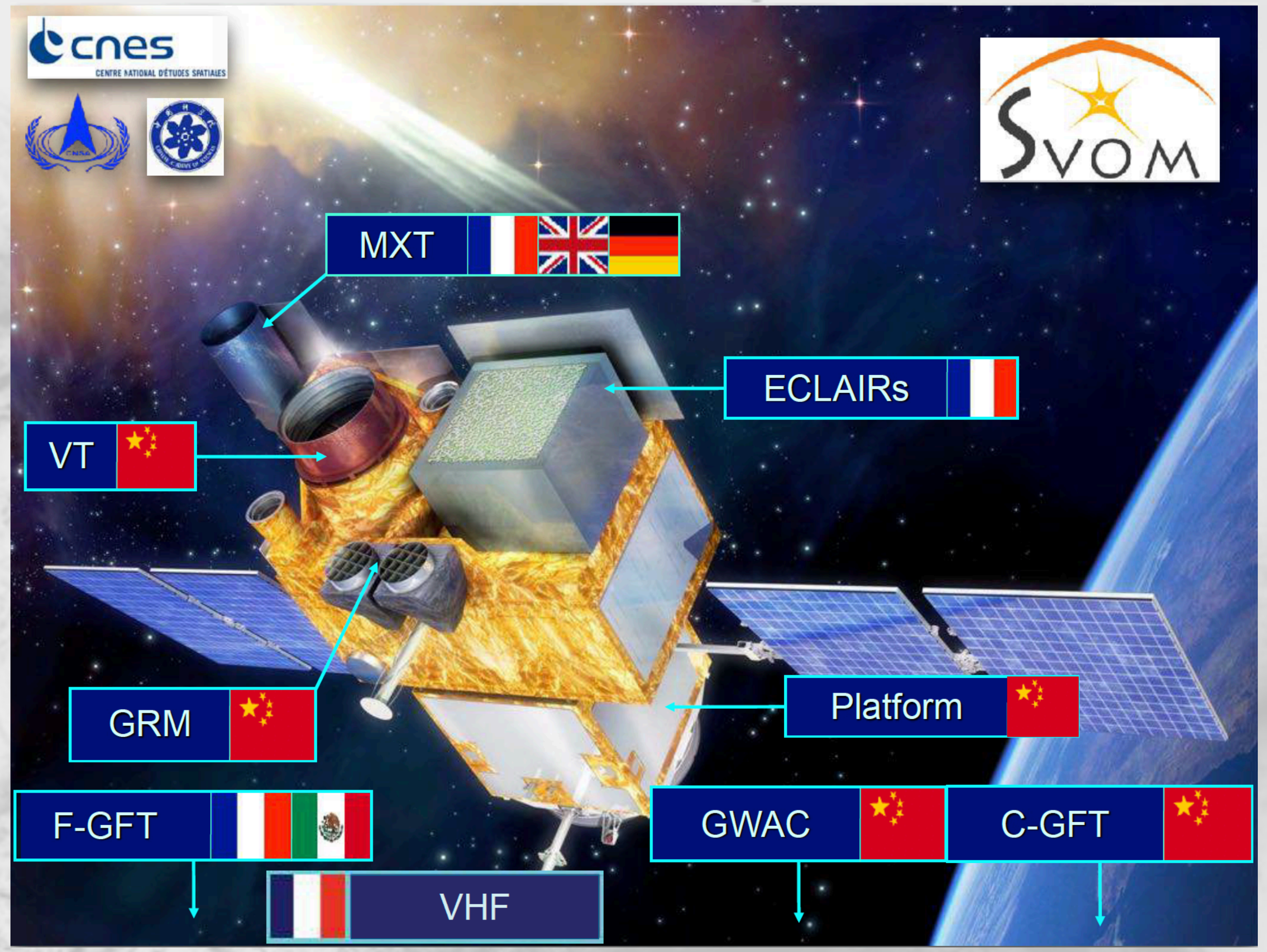
FUTURE OBSERVING FACILITIES

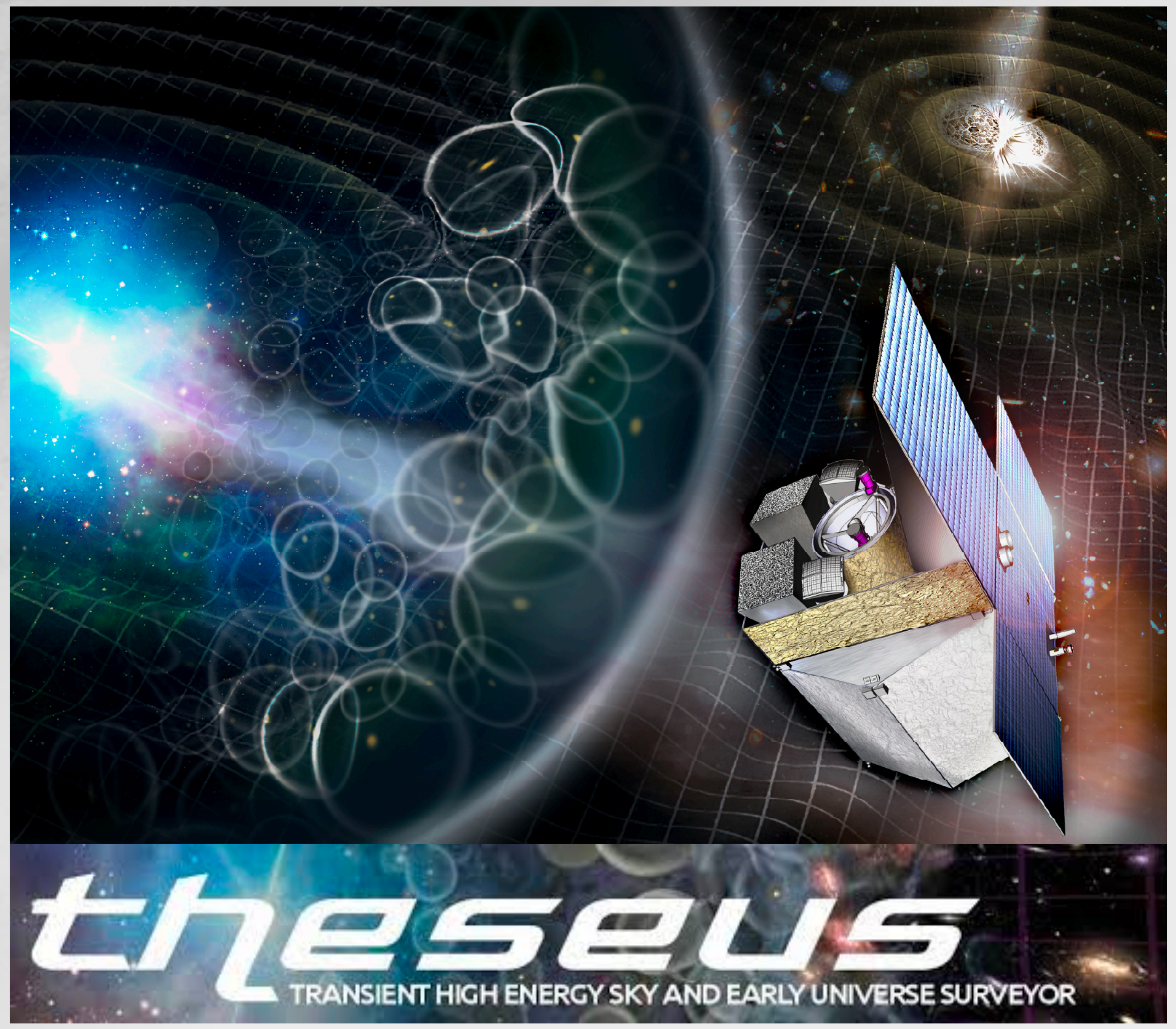
SVOM



https://www.svom.eu/

See Maria Grazia Bernardini's Talk!

THESEUS



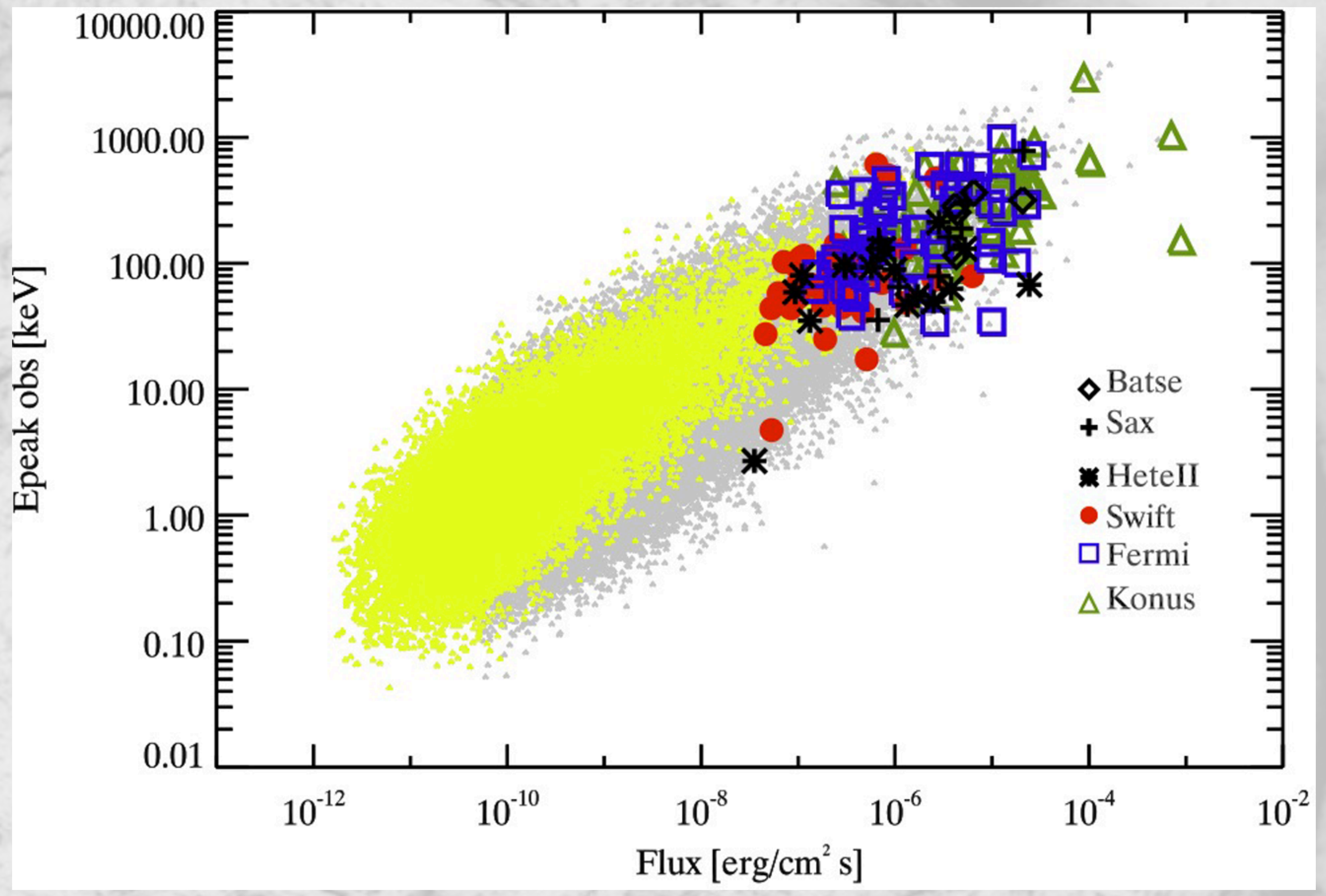
http://www.isdc.unige.ch/theseus

See Giulia Stratta's Talk!

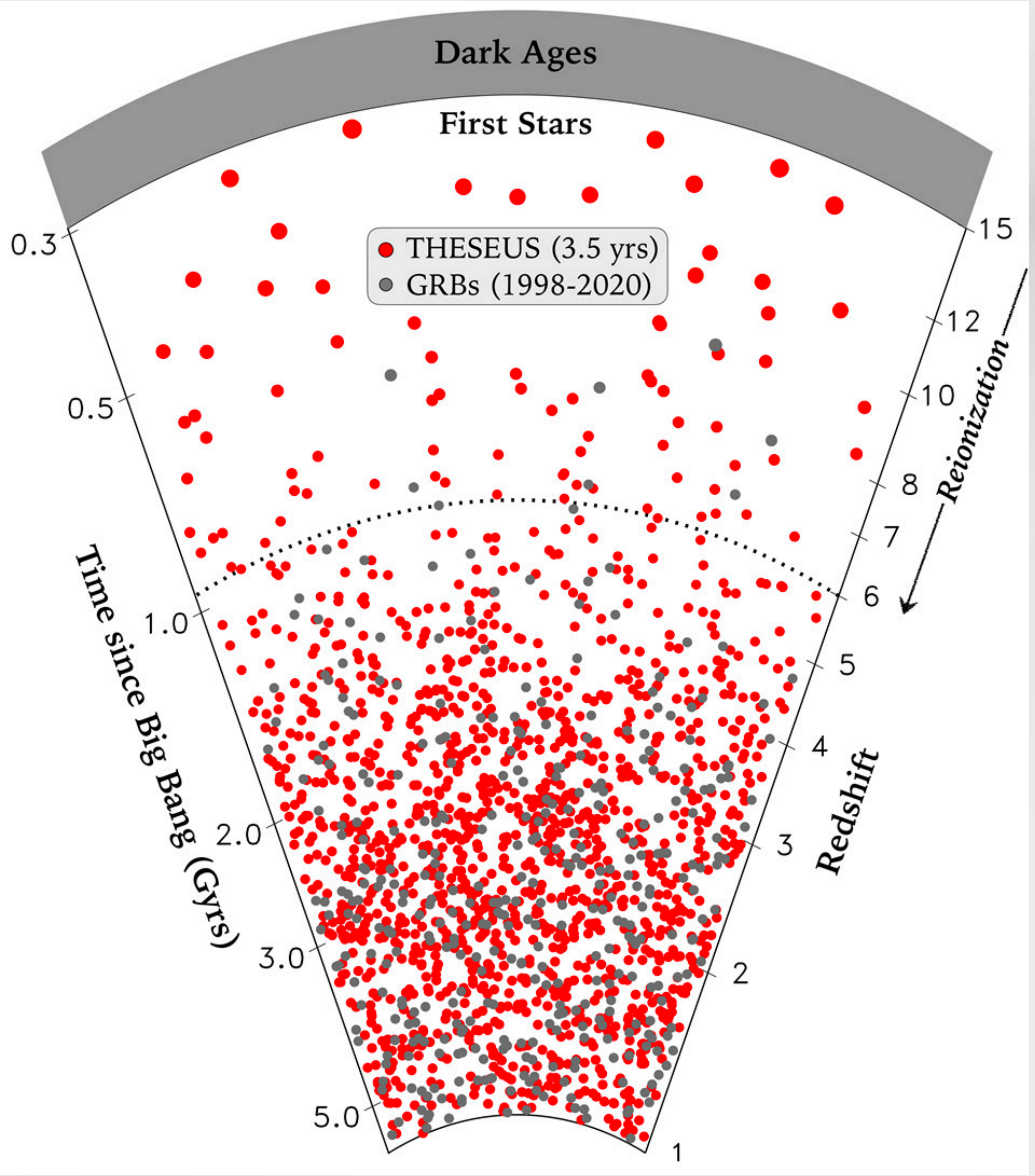
FUTURE OBSERVING FACILITIES

Payload:

-Soft X-ray Imager
(SXI, 0.3 – 5 keV)
-X-Gamma rays Imaging Spectrometer
(XGIS, 2 keV – 10 MeV)
-InfraRed Telescope
(IRT, 0.7 – 1.8 μm)



Ghirlanda+2015



Theseus YB

VLT

ELT

THANKS FOR YOUR ATTENTION

Speaker
ANDREA SACCARDI
Observatoire de Paris - GEPI
Supervisor: S.D. Vergani

V Congresso Nazionale GRB - Trieste
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GRBV

Saccardi et al. (submitted)

GRB210905A

$\text{Log } L_{iso} = 53.27 +/- 0.7 \text{ erg s}^{-1}$

$E_X = 4.1 \times 10^{51} \text{ erg}$

Krongold & Prochaska 2013

GRB050730

$\text{Log } L_{iso} = 51.85 +/- 0.4 \text{ erg s}^{-1}$

$E_X = 8.8 \times 10^{52} \text{ erg}$

Using the burst luminosity and the spectral and temporal parameters, we determined a number of ionizing photons ~ 30 times higher than the GRB050730 average value

$$\phi = \frac{E}{h} \frac{\int_{t_0}^{t_1} \int_{\nu_0}^{\nu_1} t^{-\alpha} \upsilon^{-\beta-1}}{\int_{t_0}^{t_1} \int_{\nu_0}^{\nu_1} t^{-\alpha} \upsilon^{-\beta}}$$