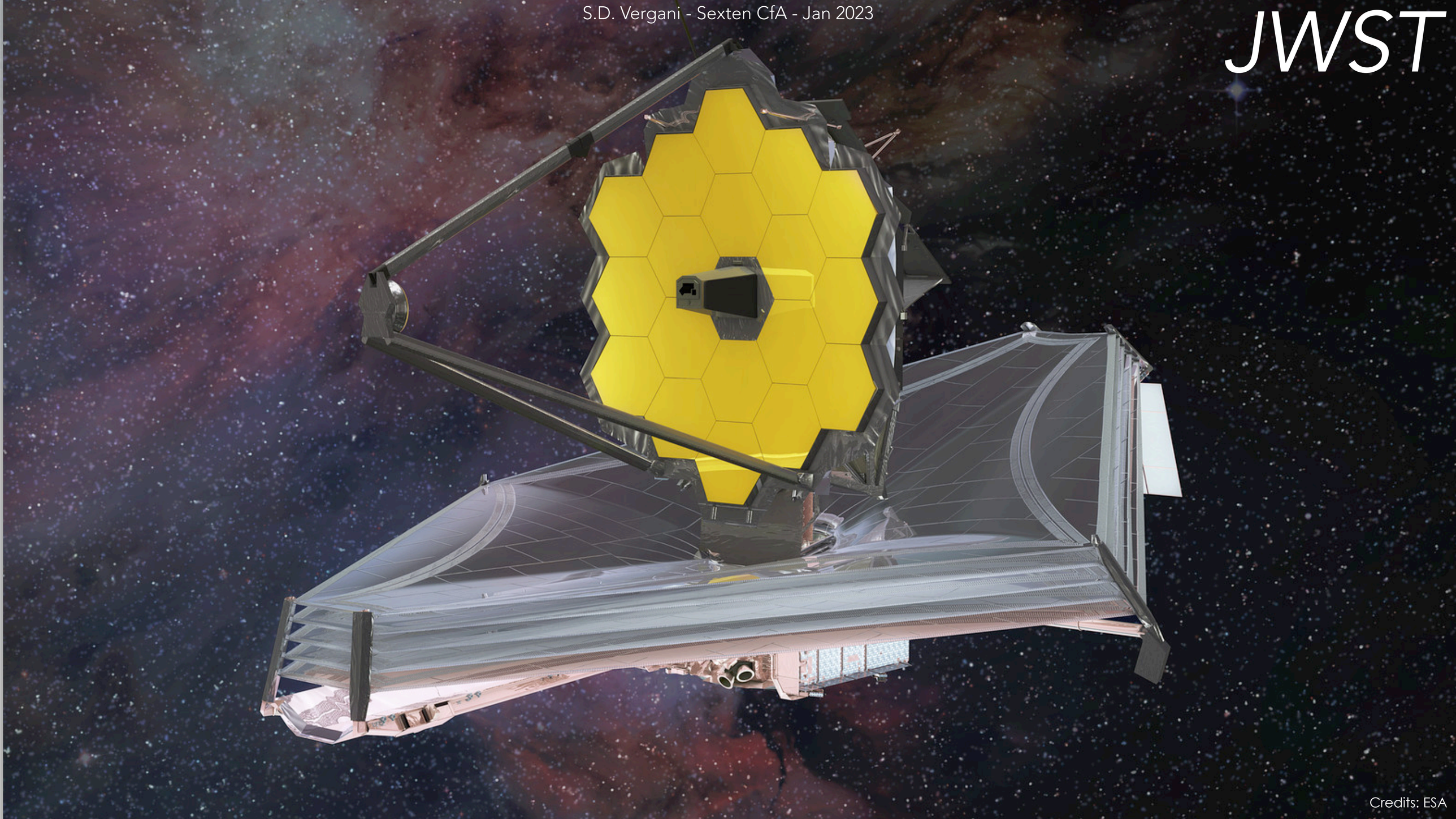
High-z GRBs in the JWST era

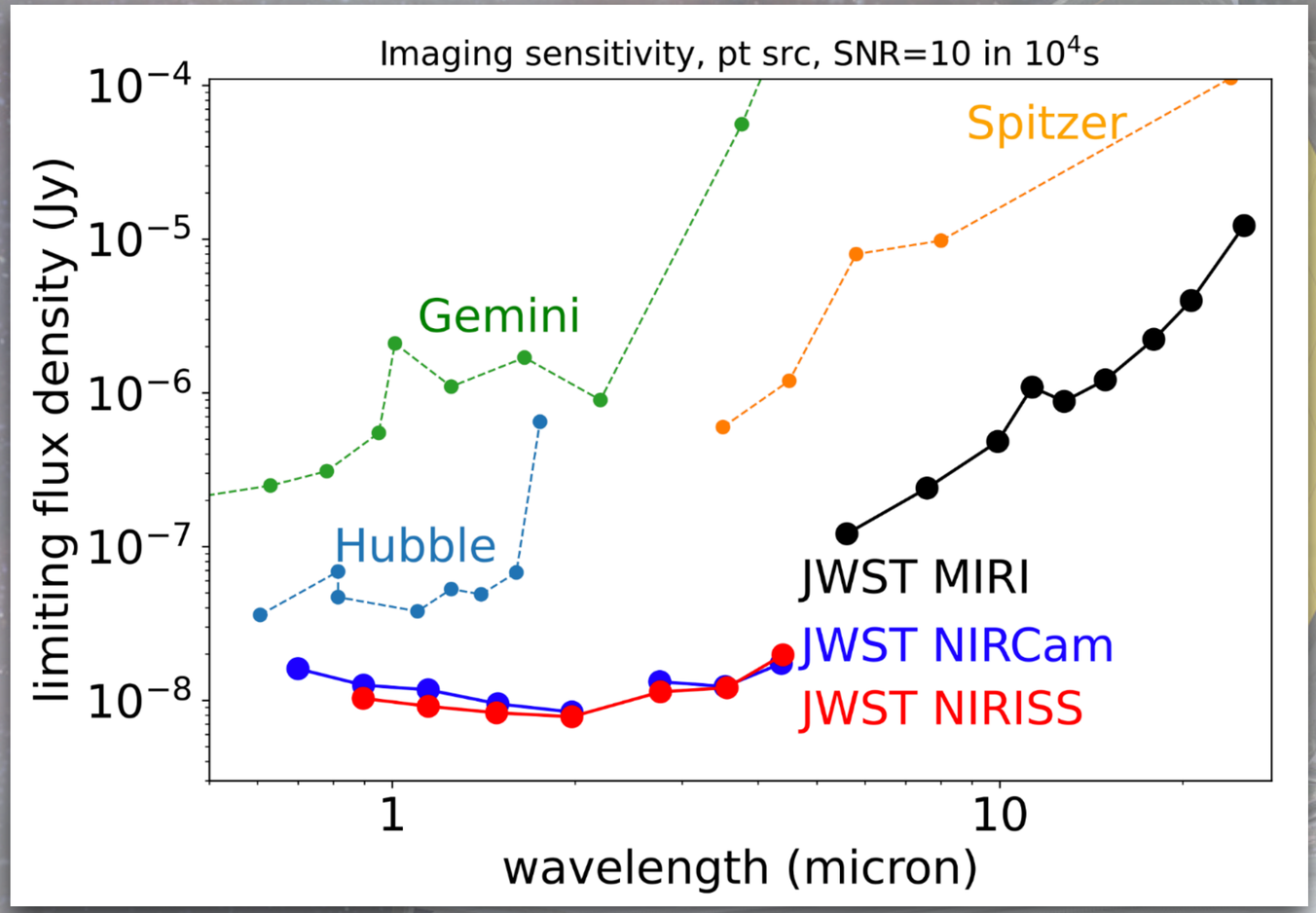
S.D. Vergani

JWST



Credits: ESA

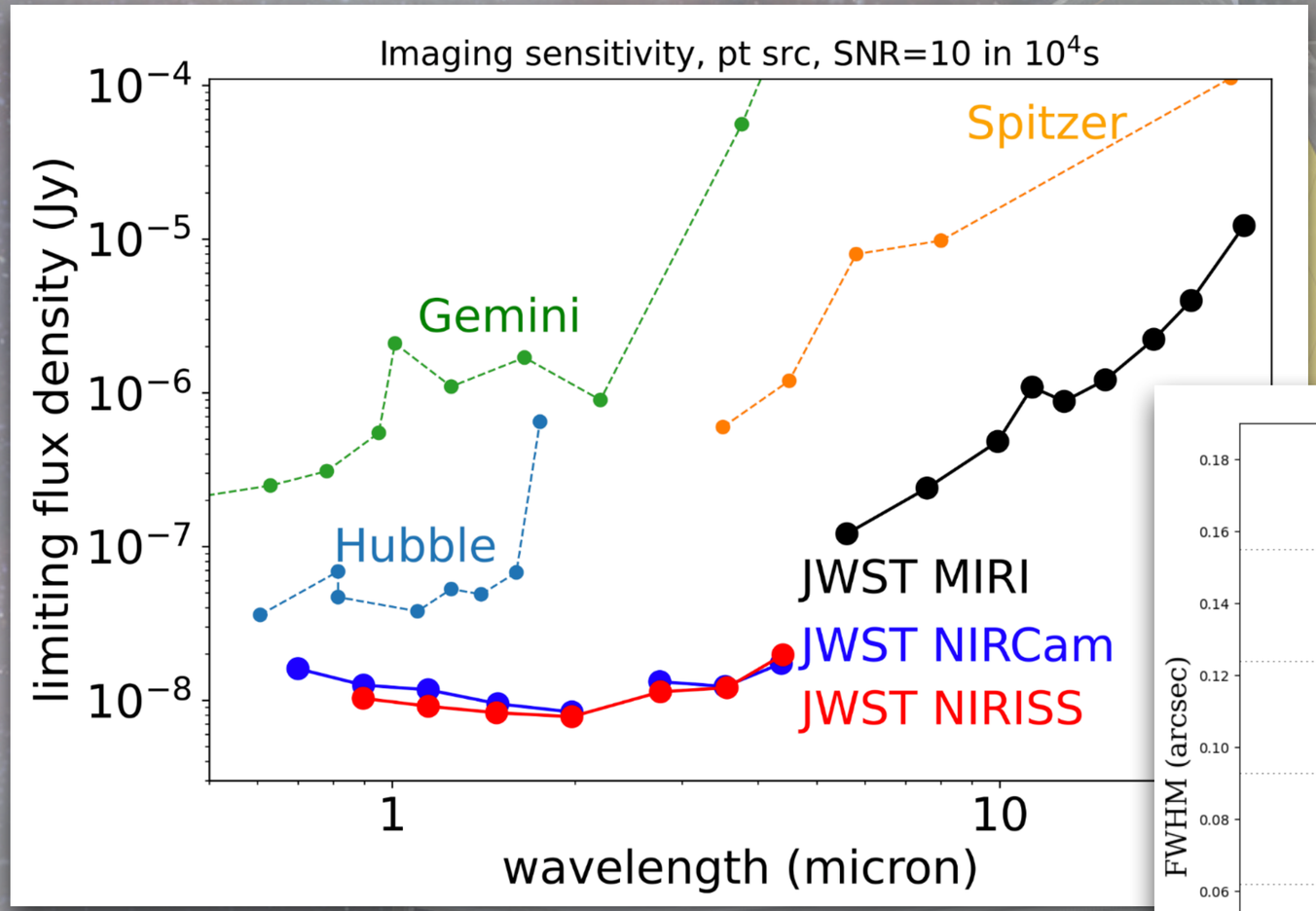
JWST



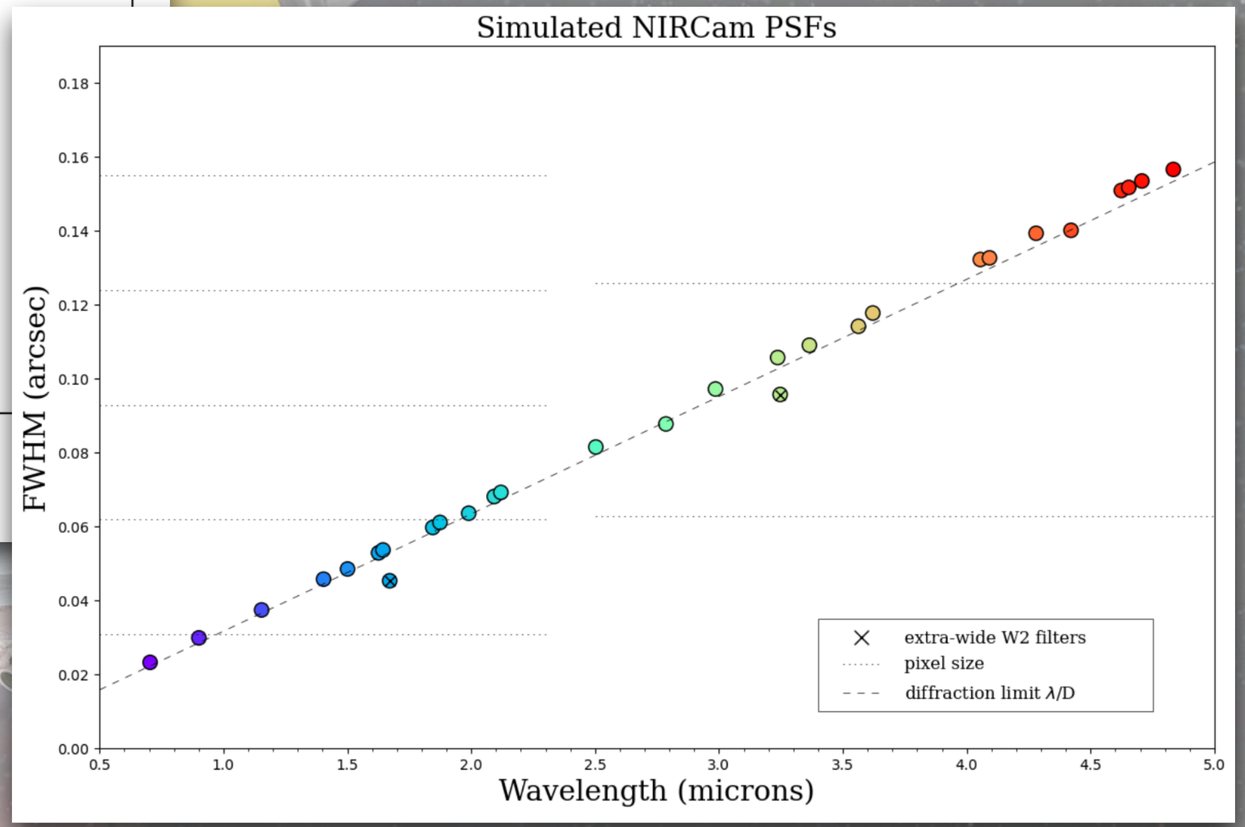
JWST Consortium

Credits: ESA

JWST

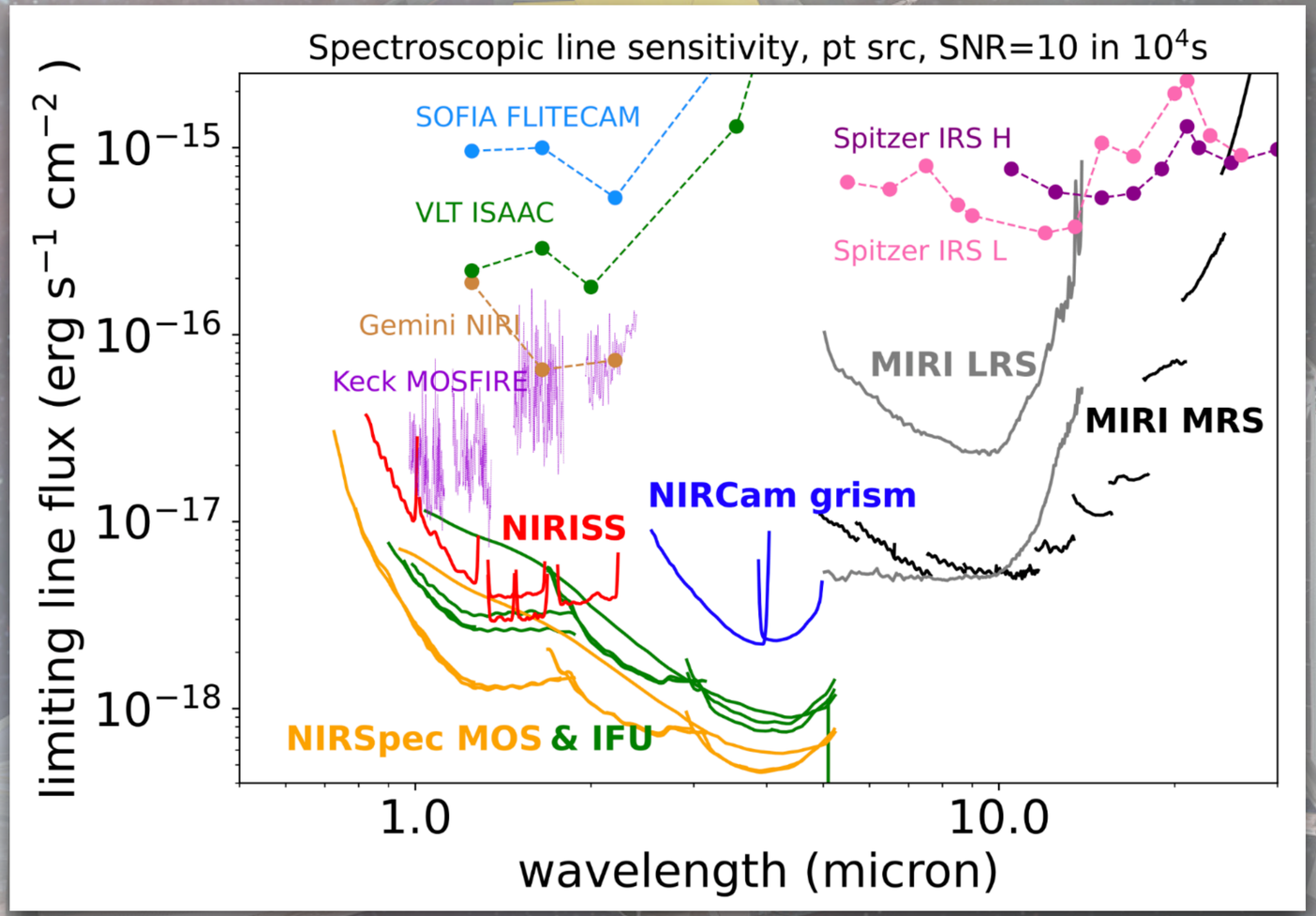


JWST Consortium



Credits: ESA

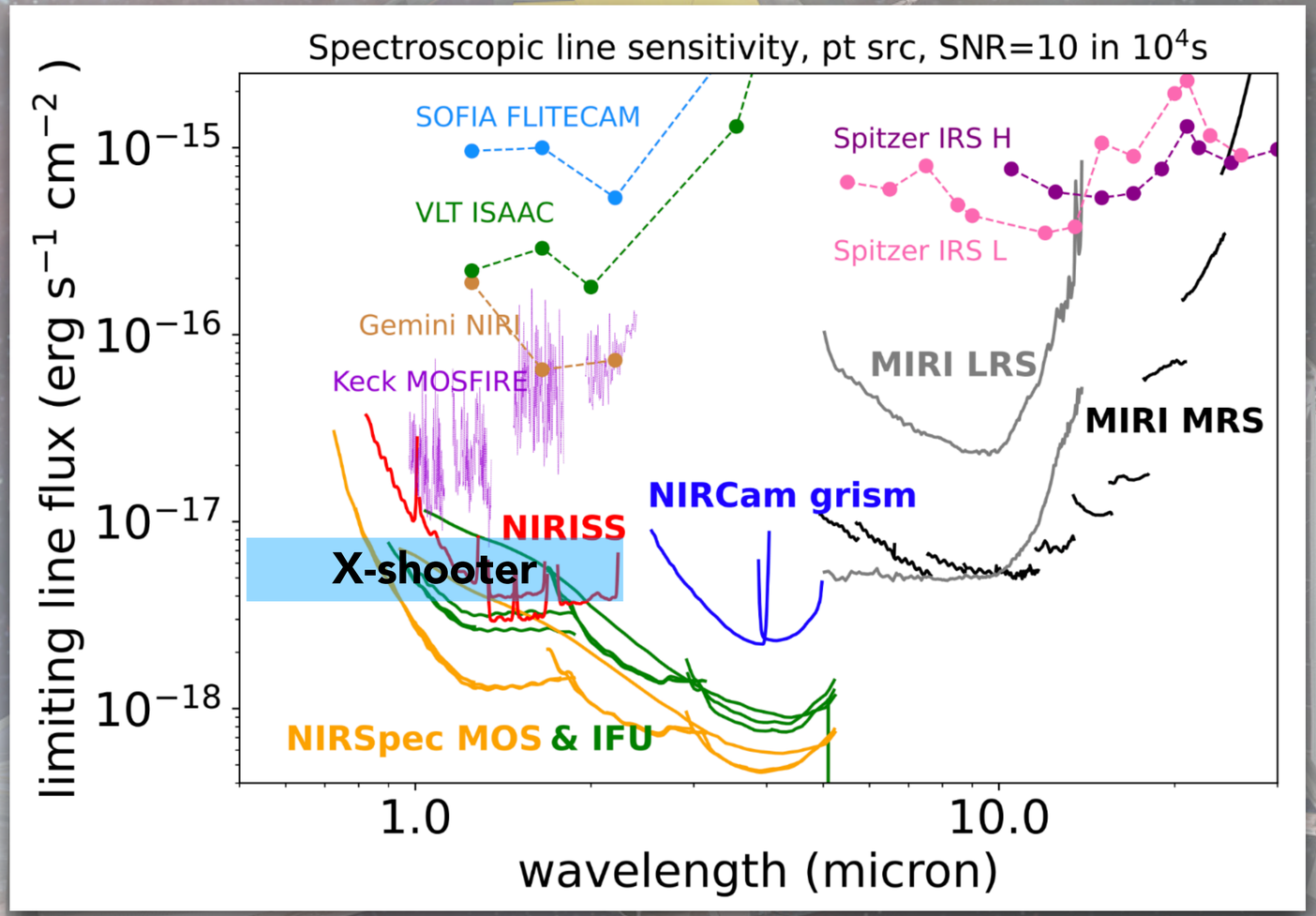
JWST



JWST Consortium

Credits: ESA

JWST

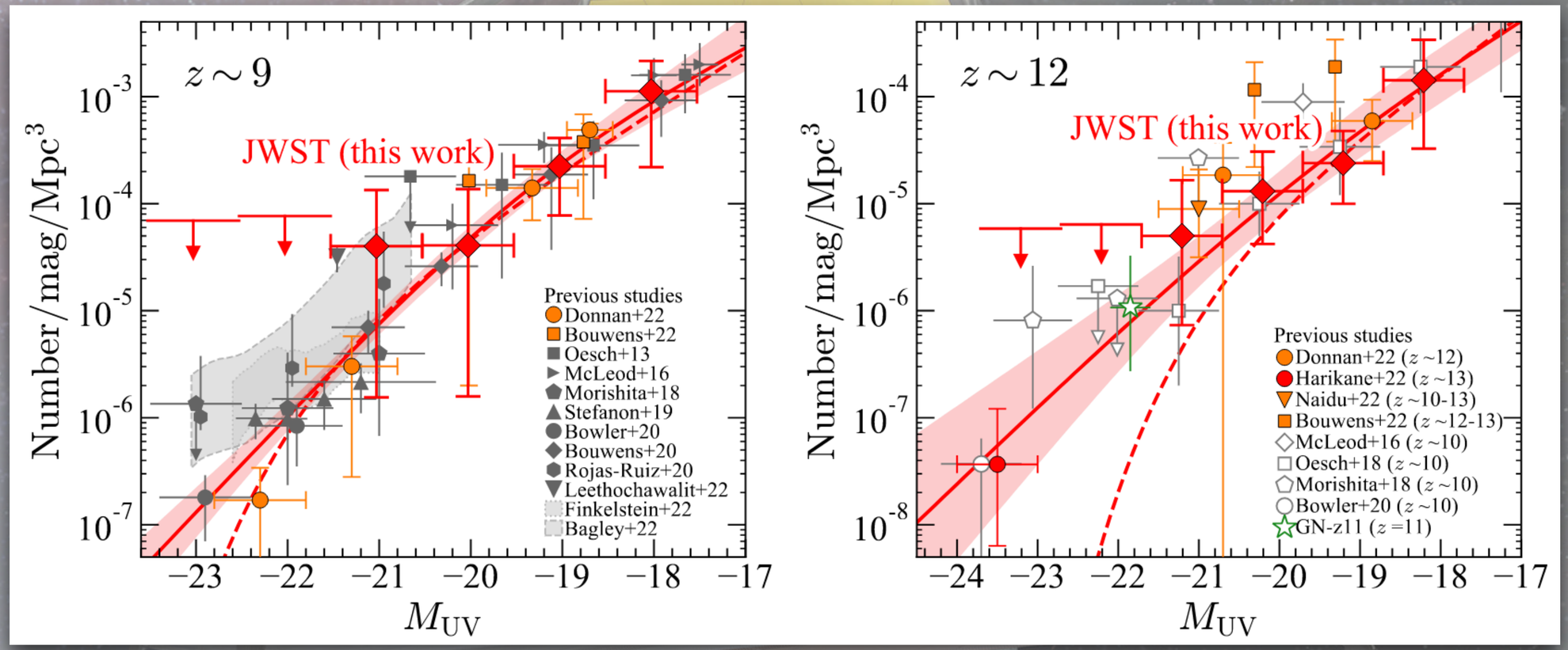


JWST Consortium

Credits: ESA

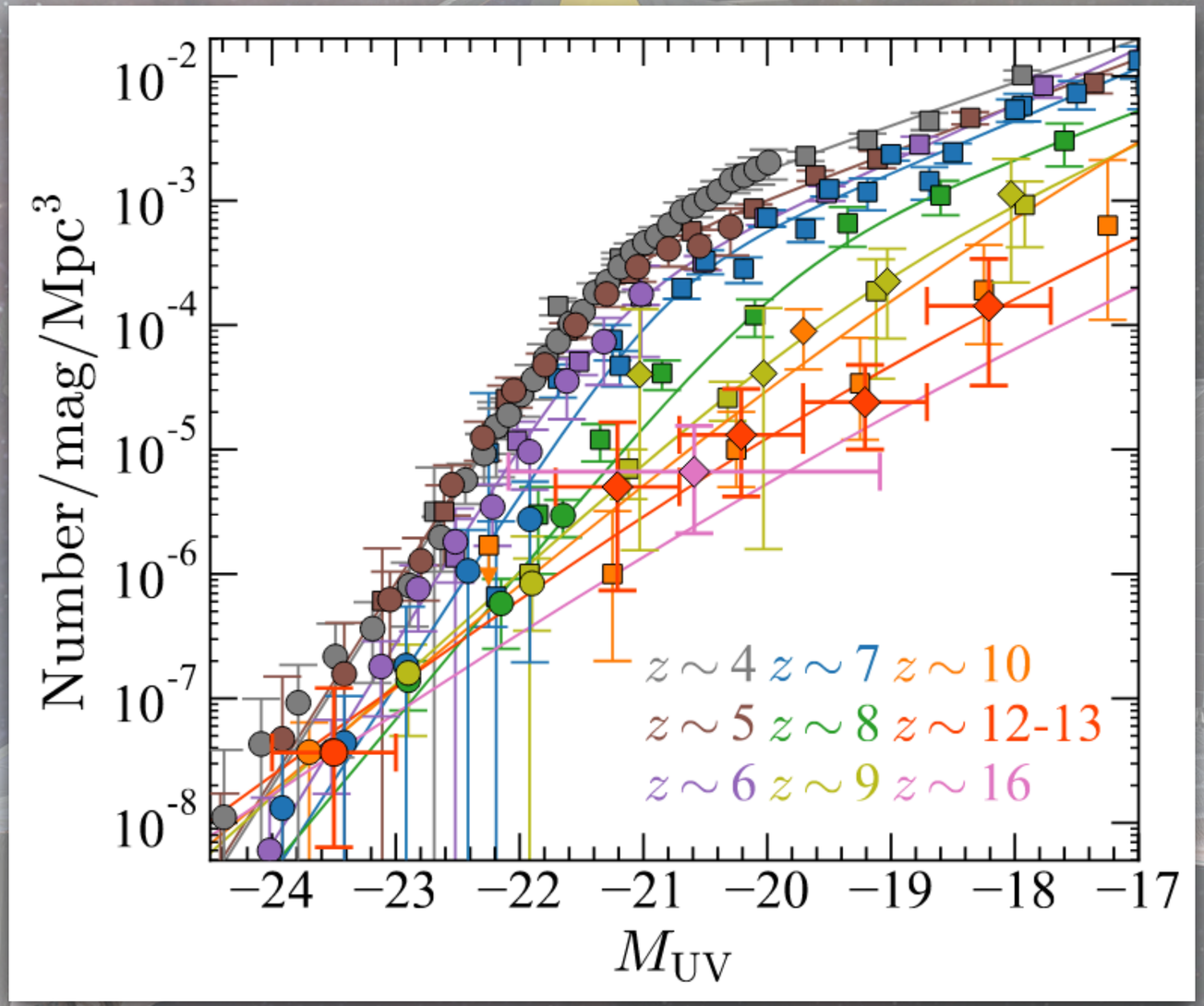
JWST

Harikane+22



Credits: ESA

JWST

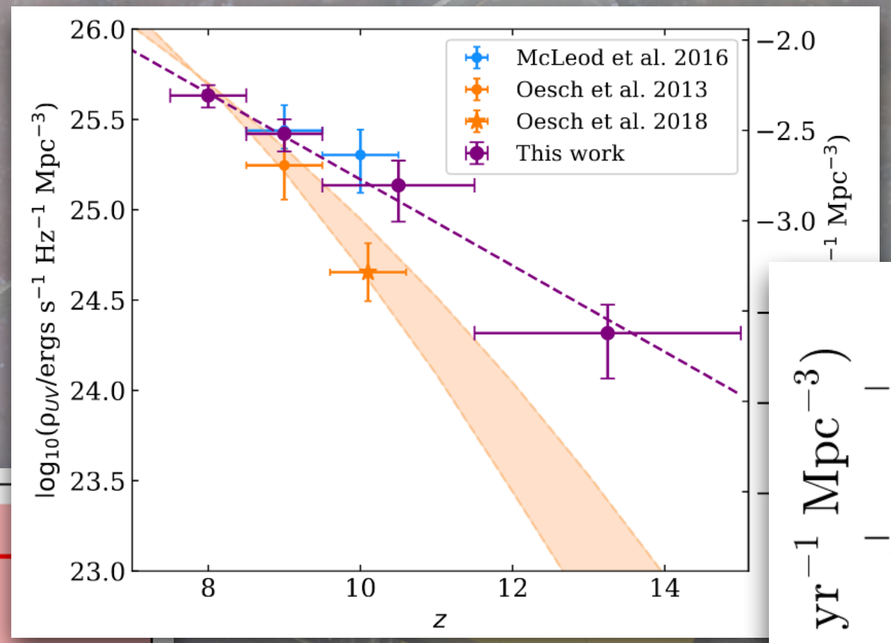


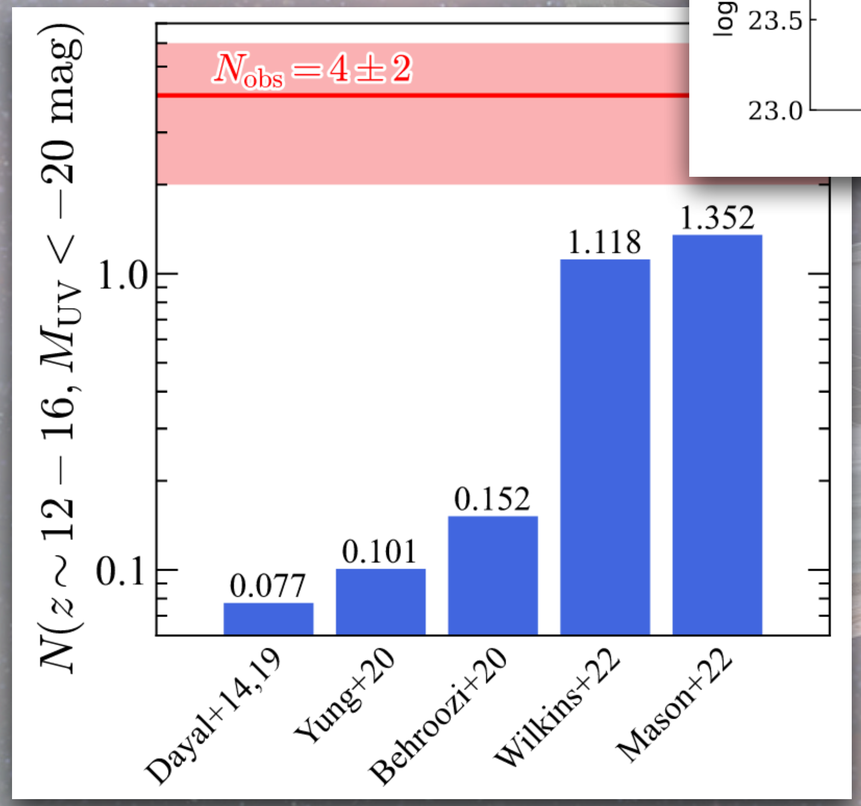
Harikane+22

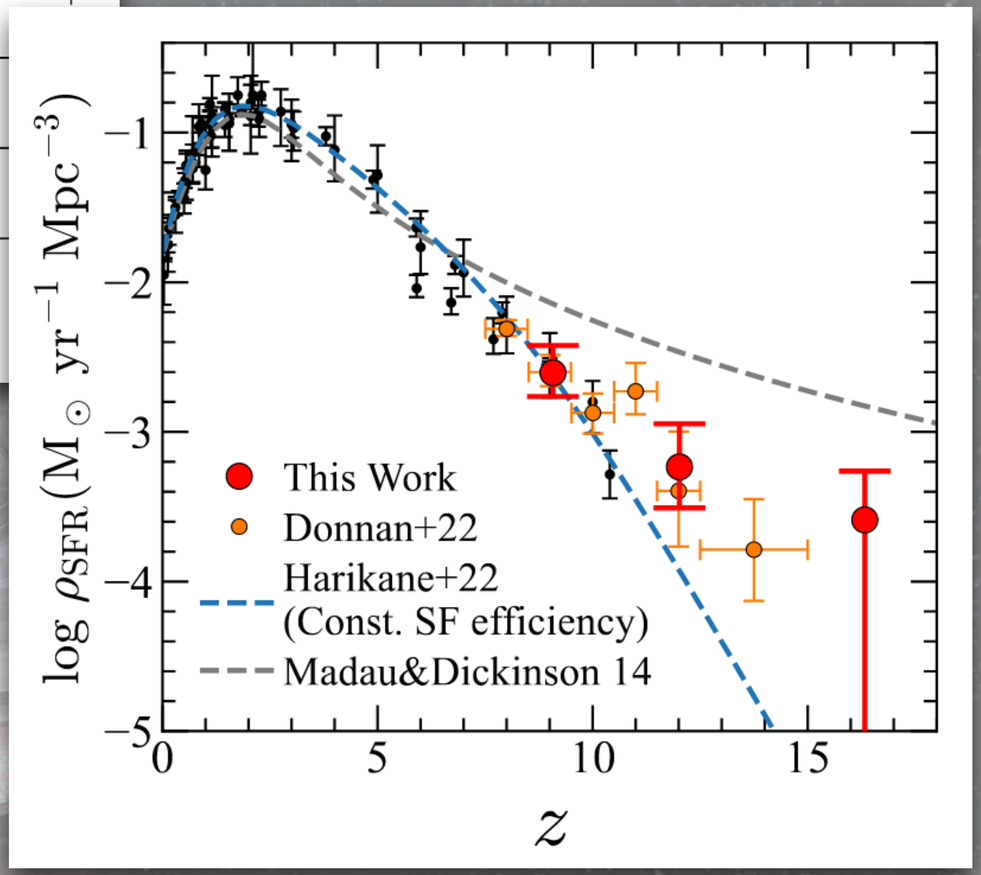
Credits: ESA

JWST

Donnan+22





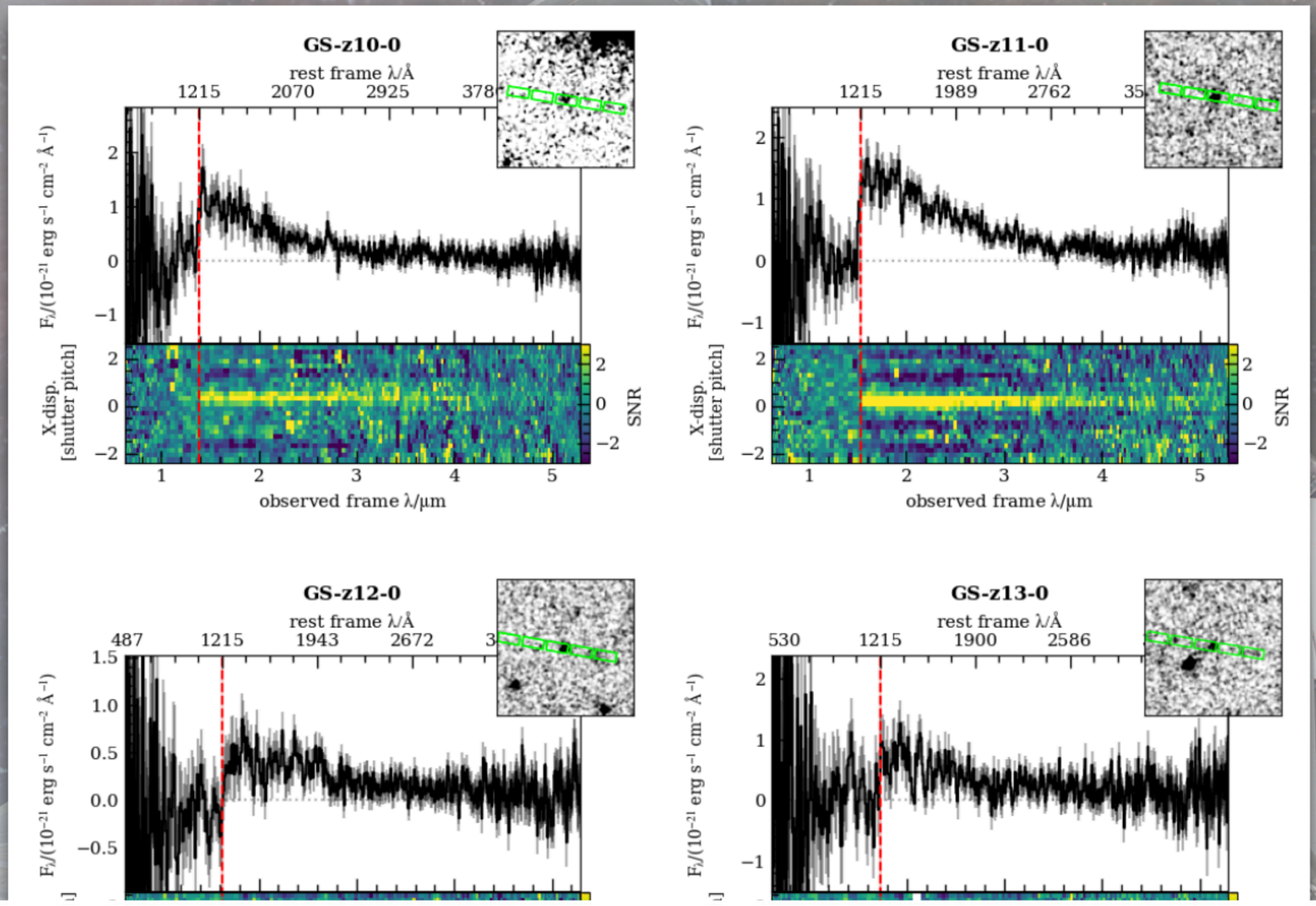


Harikane+22

Credits: ESA

JWST

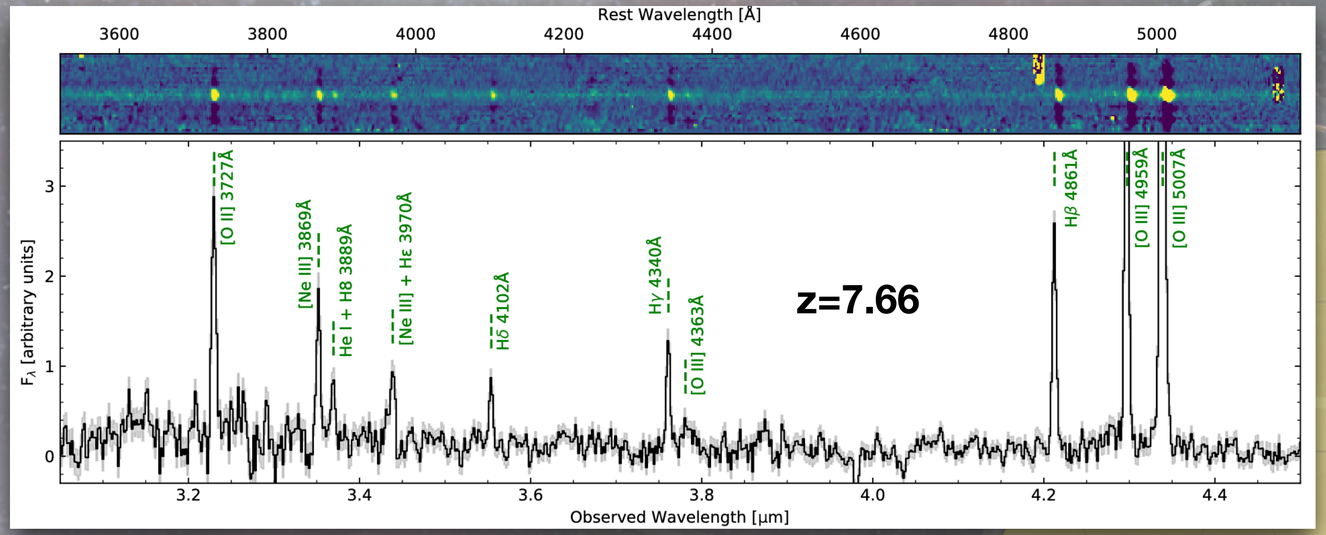
Curtis Lake+22

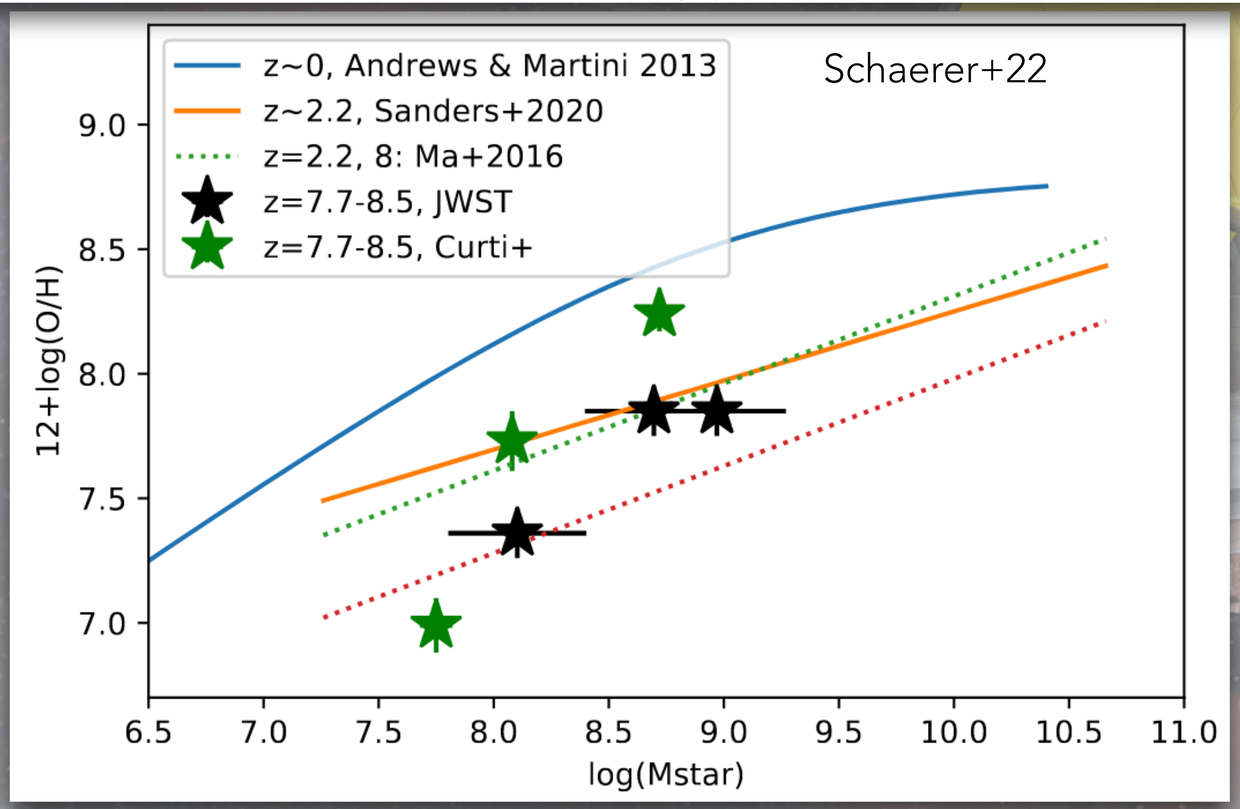


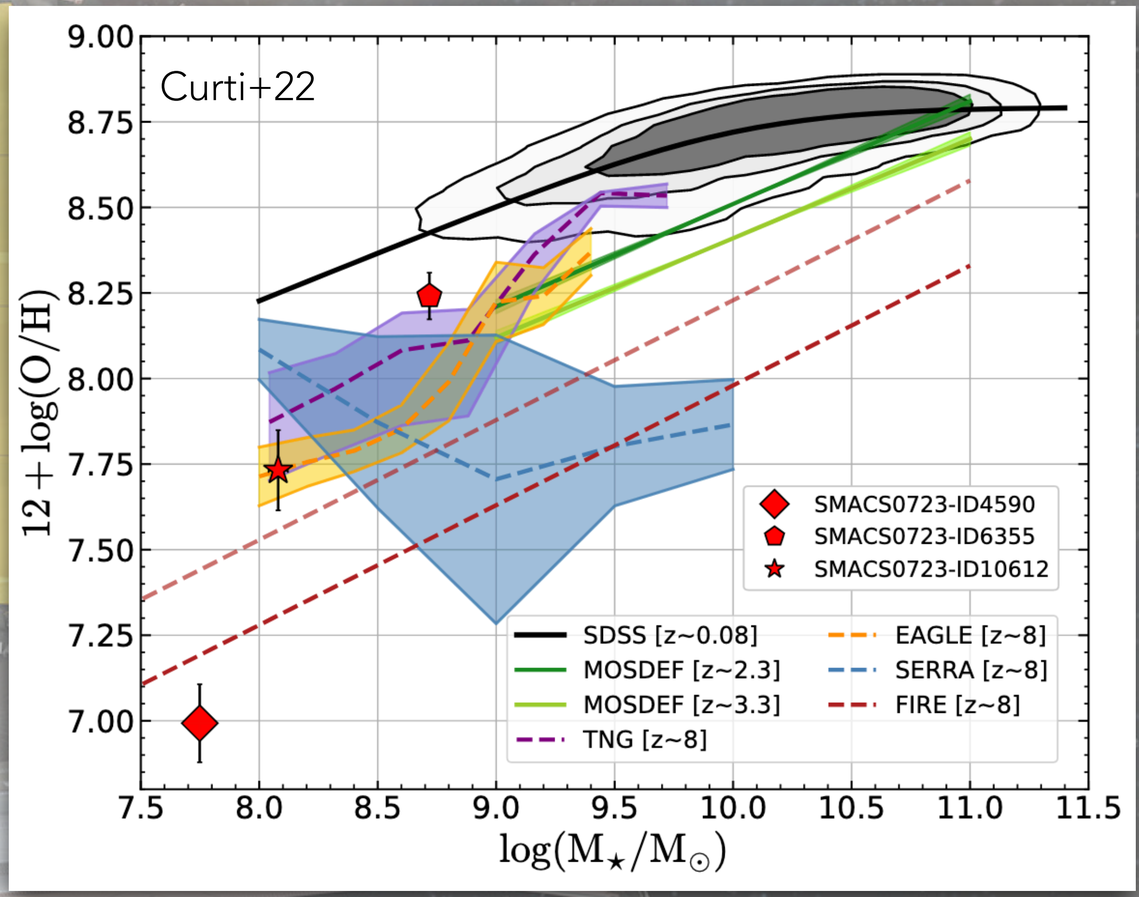
Object ID	Name	R.A. (deg)	Decl. (deg)	z_{phot}	z_{spec}	m_{F200W} (AB mag)	M_{UV} (AB mag)	β_{UV}	$\log_{10} M_\star$ ($M_\odot$)	$\log_{10}$ SFR ($M_\odot/yr$)	$t_\star$ (Myr)
JADES-GS+53.1499-27.7765	JADES-GS-z13-0	53.149880	-27.776500	$12.9^{+0.5}_{-0.4}$	$13.20^{+0.04}_{-0.07}$	29.43±0.14	-18.5±0.2	$-2.44^{+0.15}_{-0.16}$	$7.8^{+0.4}_{-0.5}$	$0.0^{+0.3}_{-0.3}$	16^{+43}_{-13}
JADES-GS+53.1663-27.8216	JADES-GS-z12-0	53.166338	-27.821555	$13.0^{+0.5}_{-0.5}$	$12.63^{+0.24}_{-0.08}$	28.99±0.10	-18.8±0.1	$-2.18^{+0.13}_{-0.15}$	$8.4^{+0.4}_{-0.7}$	$0.1^{+0.4}_{-0.5}$	50^{+60}_{-44}
JADES-GS+53.1648-27.7746	JADES-GS-z11-0	53.164763	-27.774626	$11.7^{+0.5}_{-0.4}$	$11.58^{+0.05}_{-0.05}$	28.38±0.12	-19.3±0.1	$-2.06^{+0.12}_{-0.09}$	$8.9^{+0.2}_{-0.4}$	$0.3^{+0.4}_{-1.0}$	71^{+55}_{-45}
JADES-GS+53.1588-27.7735	JADES-GS-z10-0	53.158836	-27.773492	$10.8^{+0.3}_{-0.3}$	$10.38^{+0.07}_{-0.06}$	29.05±0.10	-18.4±0.1	$-2.42^{+0.09}_{-0.10}$	$7.9^{+0.3}_{-0.5}$	$0.0^{+0.2}_{-0.3}$	31^{+50}_{-21}

Credits: ESA

JWST



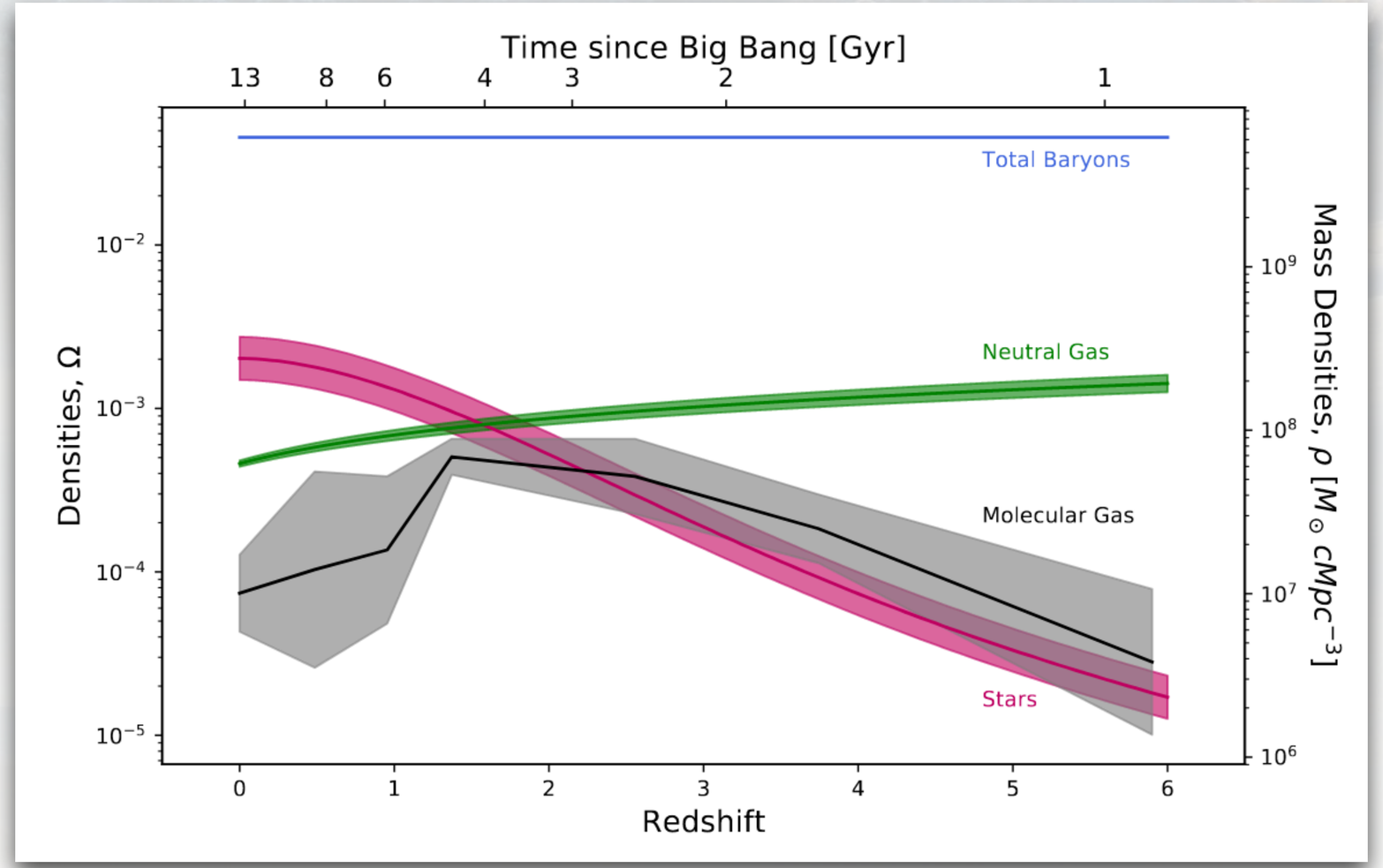




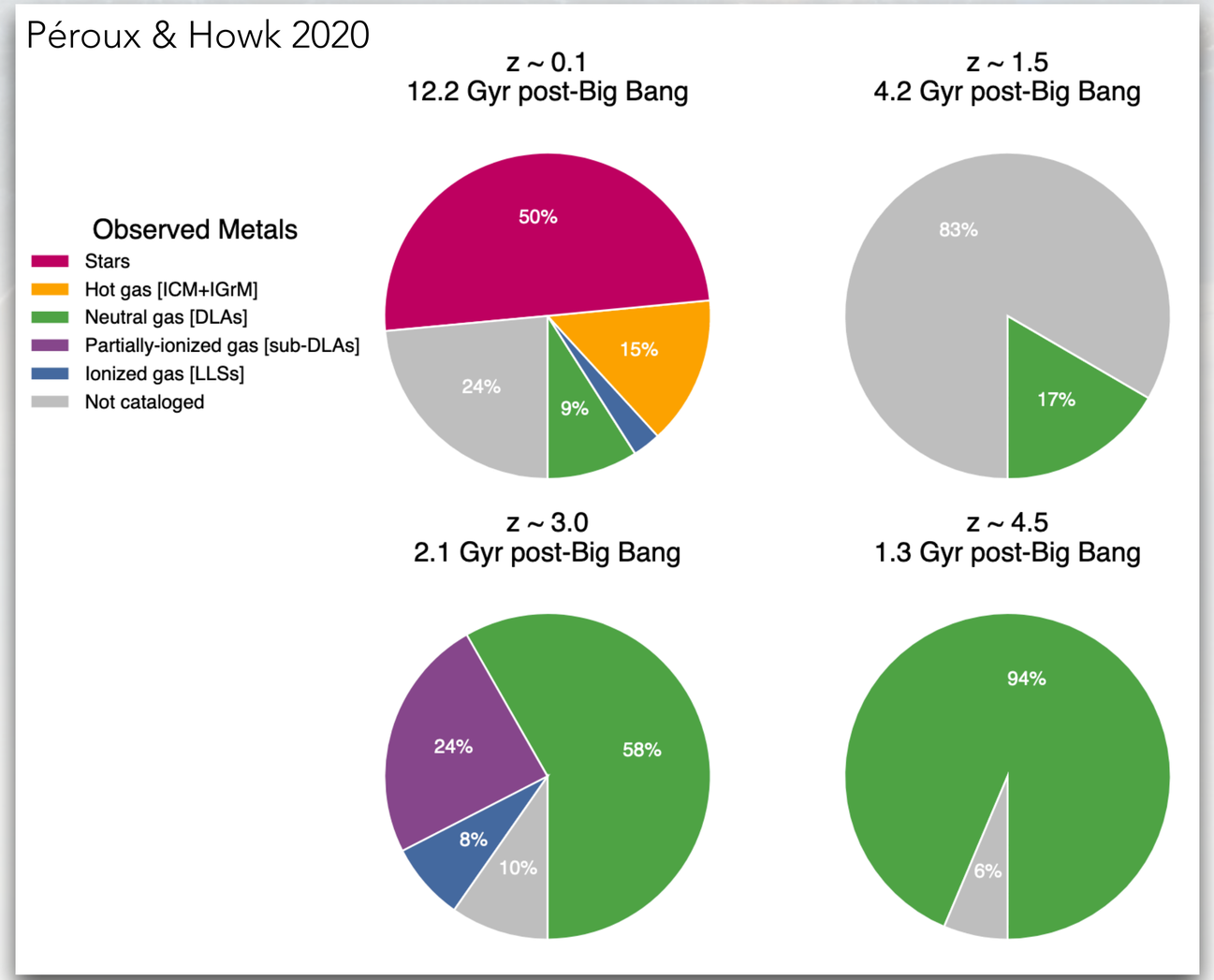
Credits: ESA

Neutral gas

Péroux & Howk 2020



Neutral gas

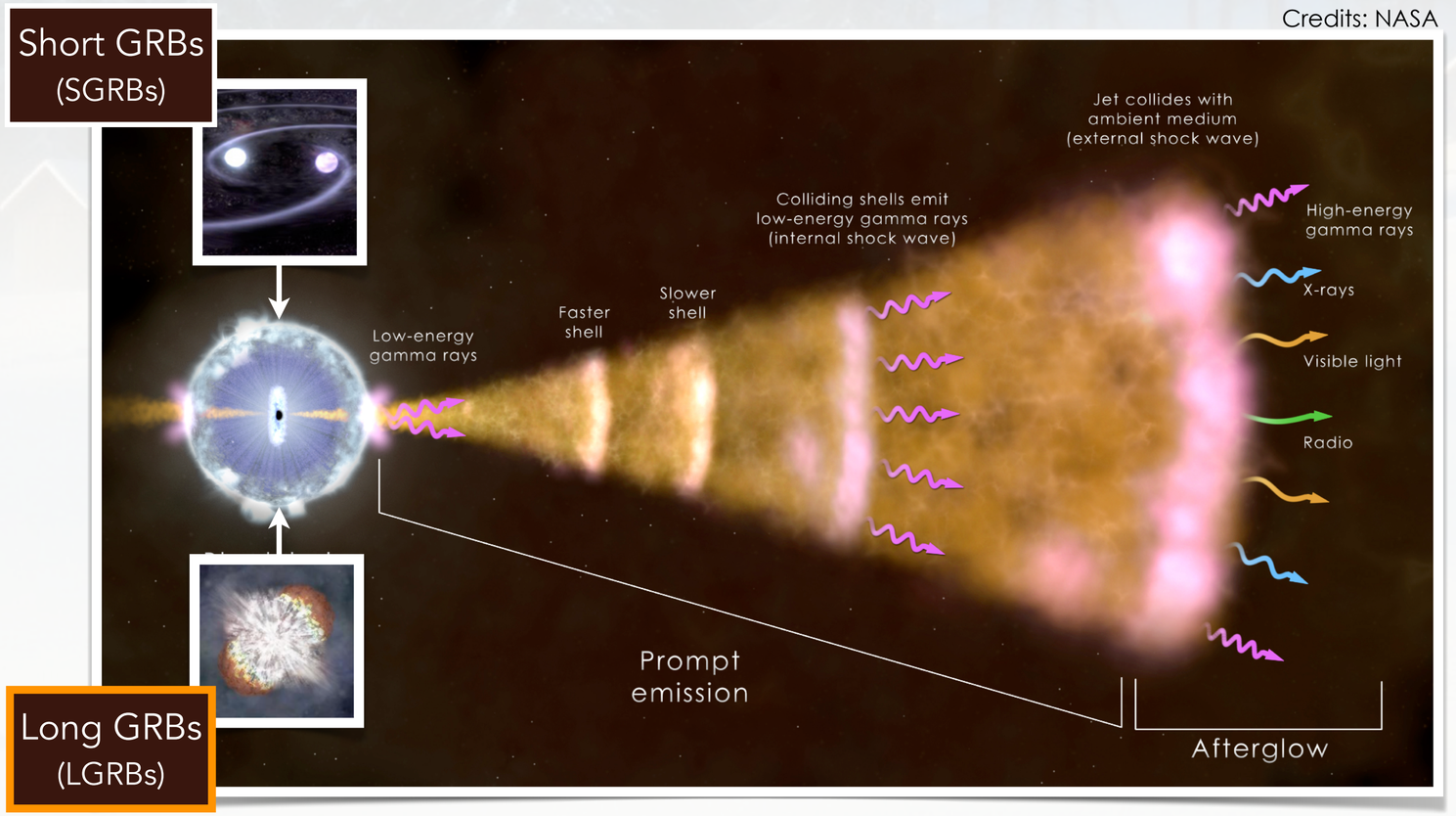

Péroux & Howk 2020
Observed Metals
Stars
Hot gas [ICM+IGrM]
Neutral gas [DLAs]
Partially-ionized gas [sub-DLAs]
Ionized gas [LLSs]
Not cataloged
z ~ 0.1
12.2 Gyr post-Big Bang
50%
15%
9%
24%
z ~ 1.5
4.2 Gyr post-Big Bang
83%
17%
z ~ 3.0
2.1 Gyr post-Big Bang
58%
24%
8%
10%
z ~ 4.5
1.3 Gyr post-Big Bang
94%
6%

GRBs

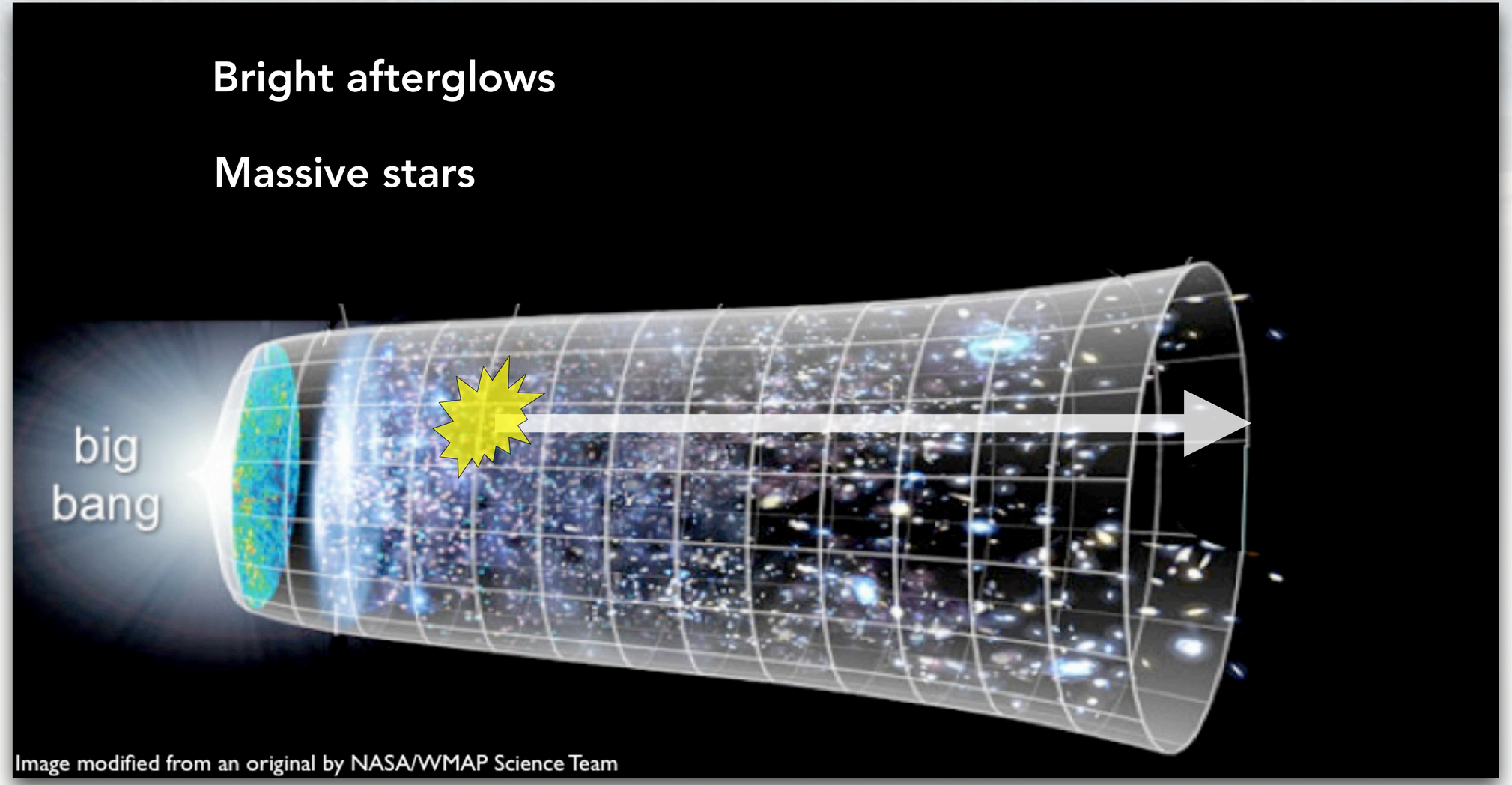
Ultra-relativistic jests associated with the formation of stellar black-holes (and magnetars?)

Merger of compact objects

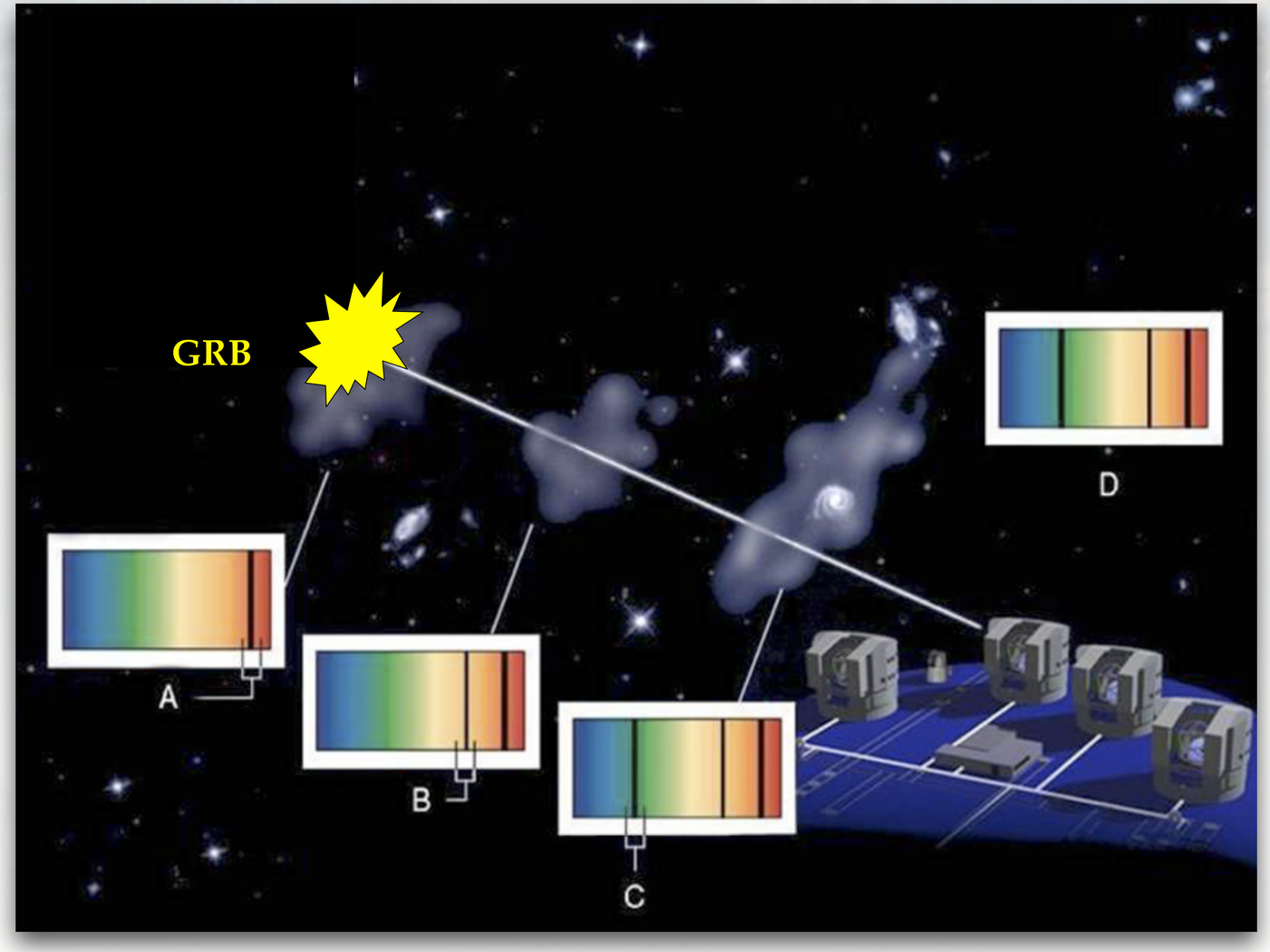
Explosion of massive stars



Long GRBs as tools to probe galaxies

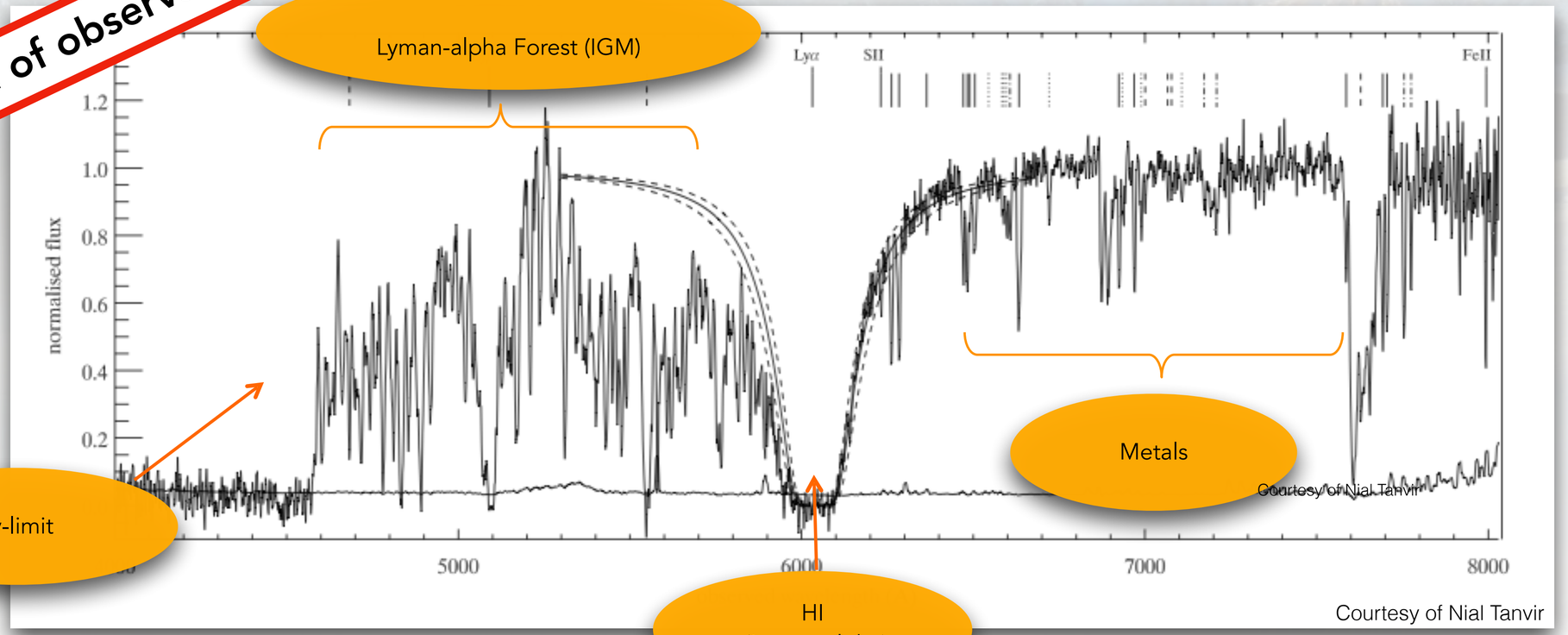


Long GRBs as tools to probe galaxies



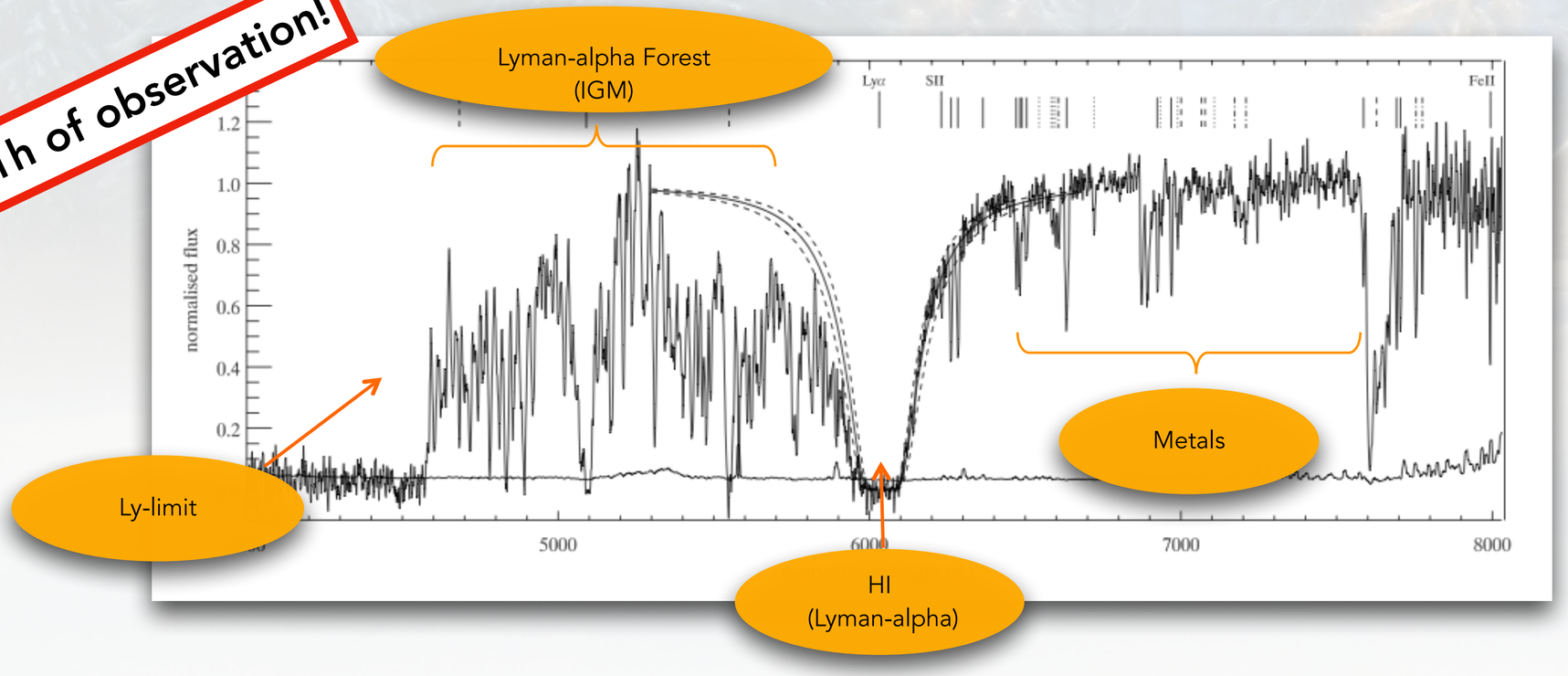
Long GRBs as tools to probe galaxies

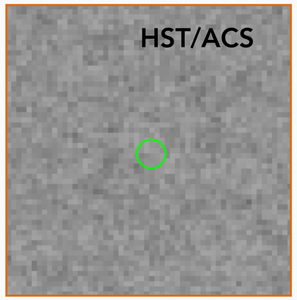
~1h of observation!



Long GRBs as tools to probe galaxies

~1h of observation!



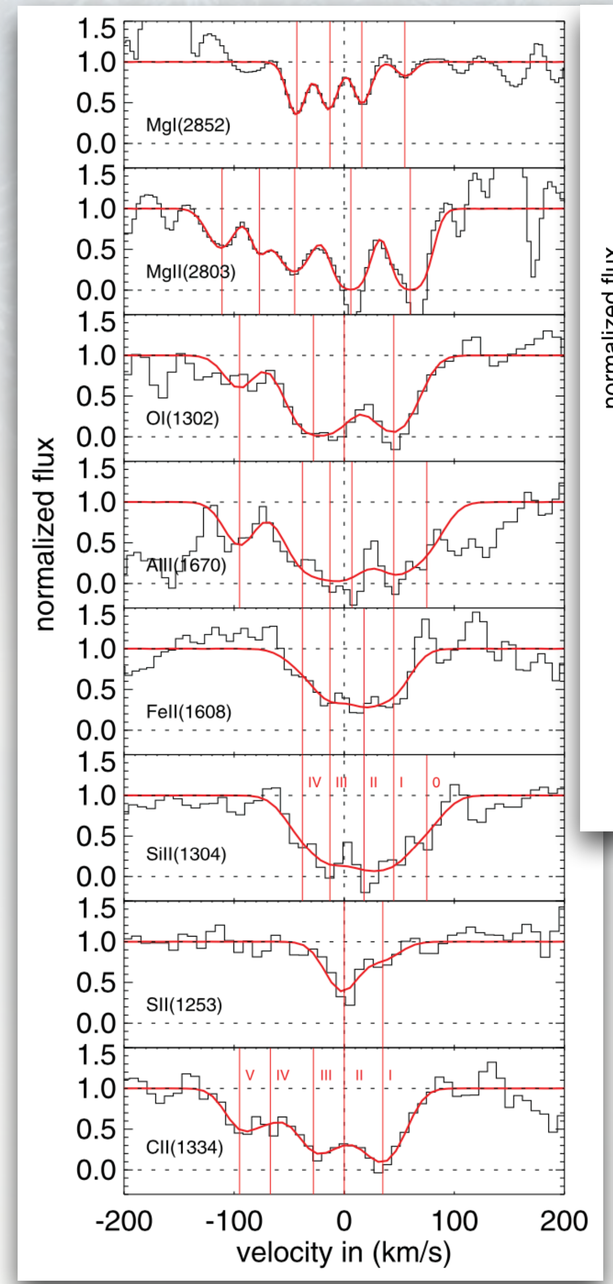


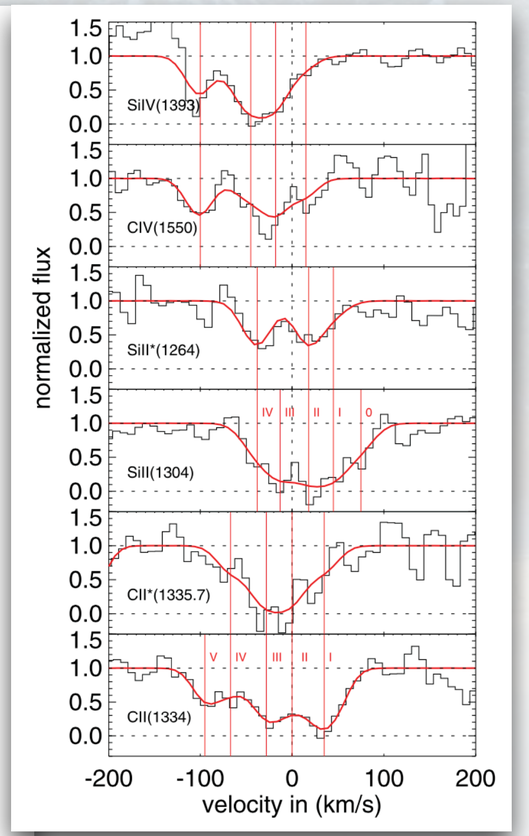
z=3.97

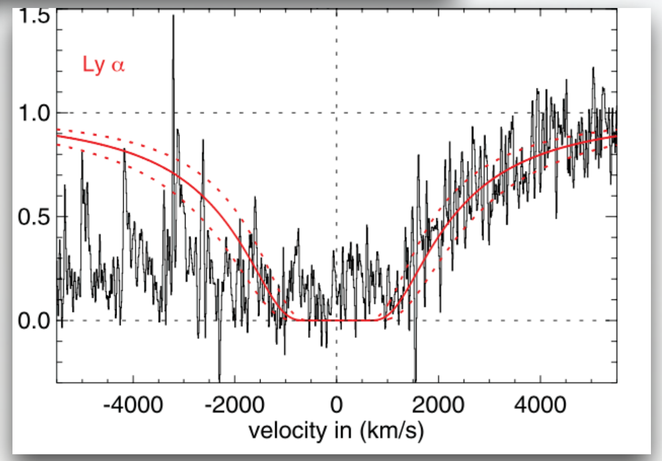
R>28.5

Chen+ 2005; Starling+2005

GRB100219A Thöne et al. 2013







Neutral hydrogen absorption

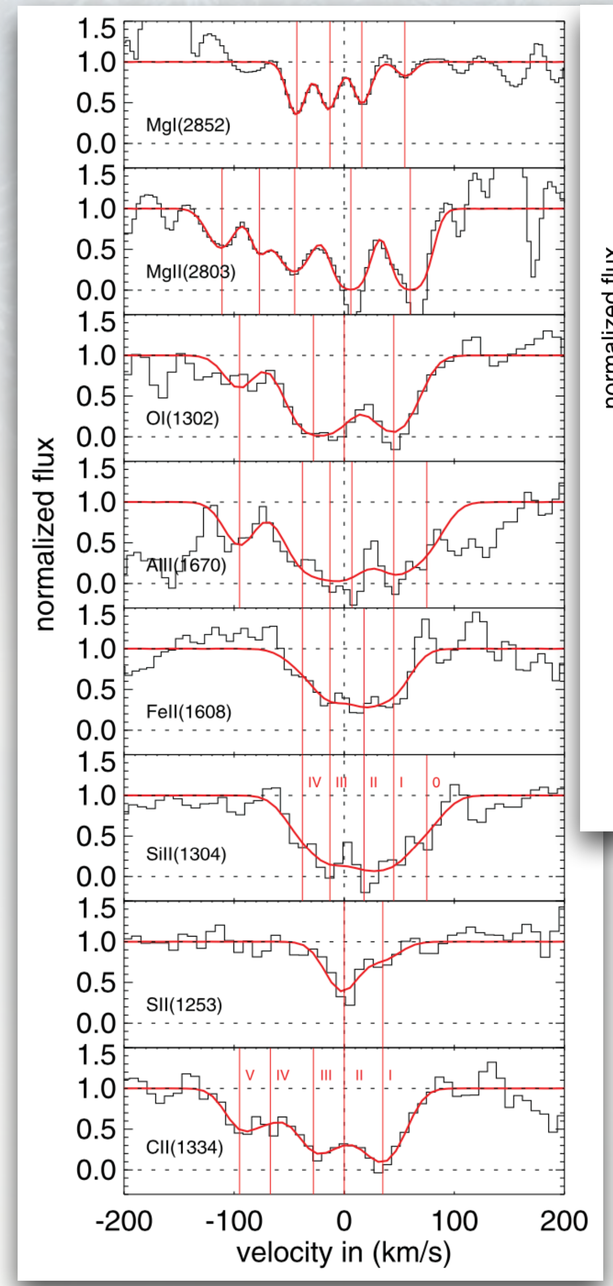
Low-ionization absorption lines

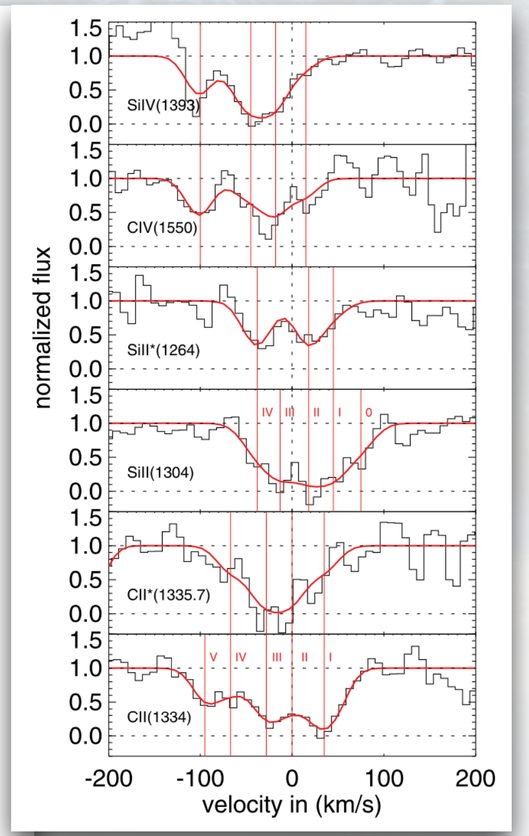
High-ionization absorption lines

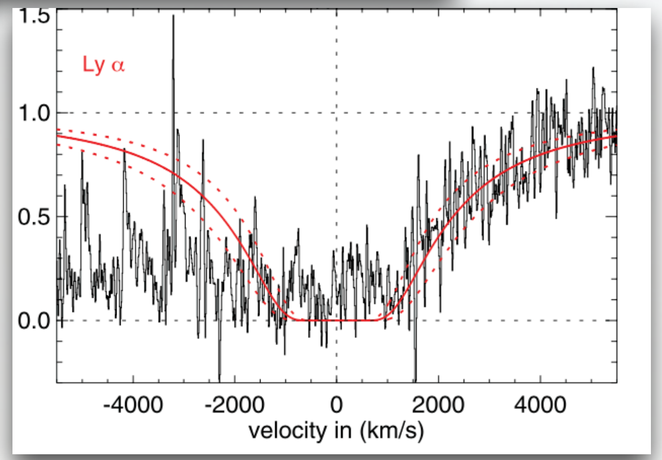
Fine-structure absorption lines

GRB100219A

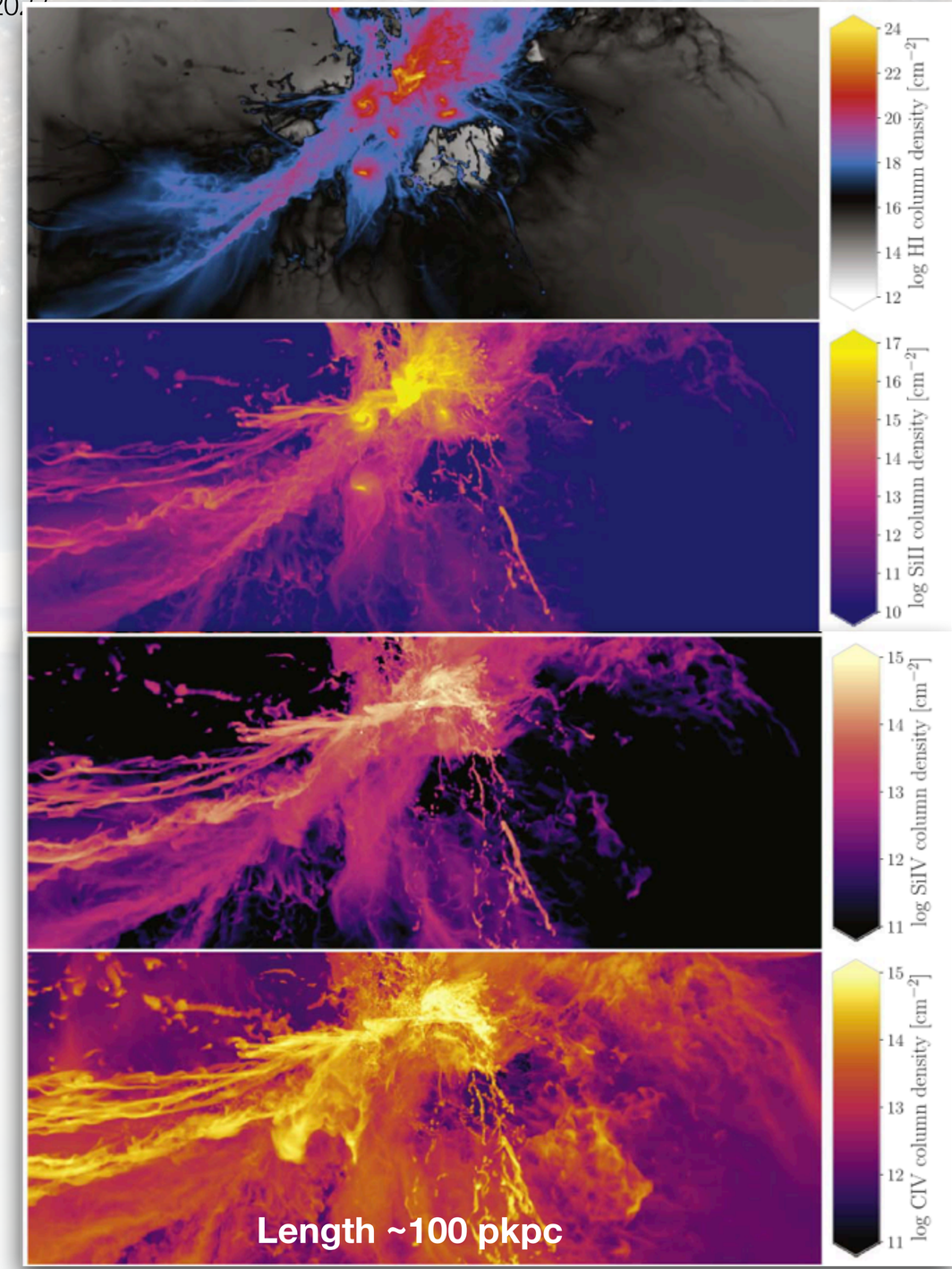
Thöne et al. 2013



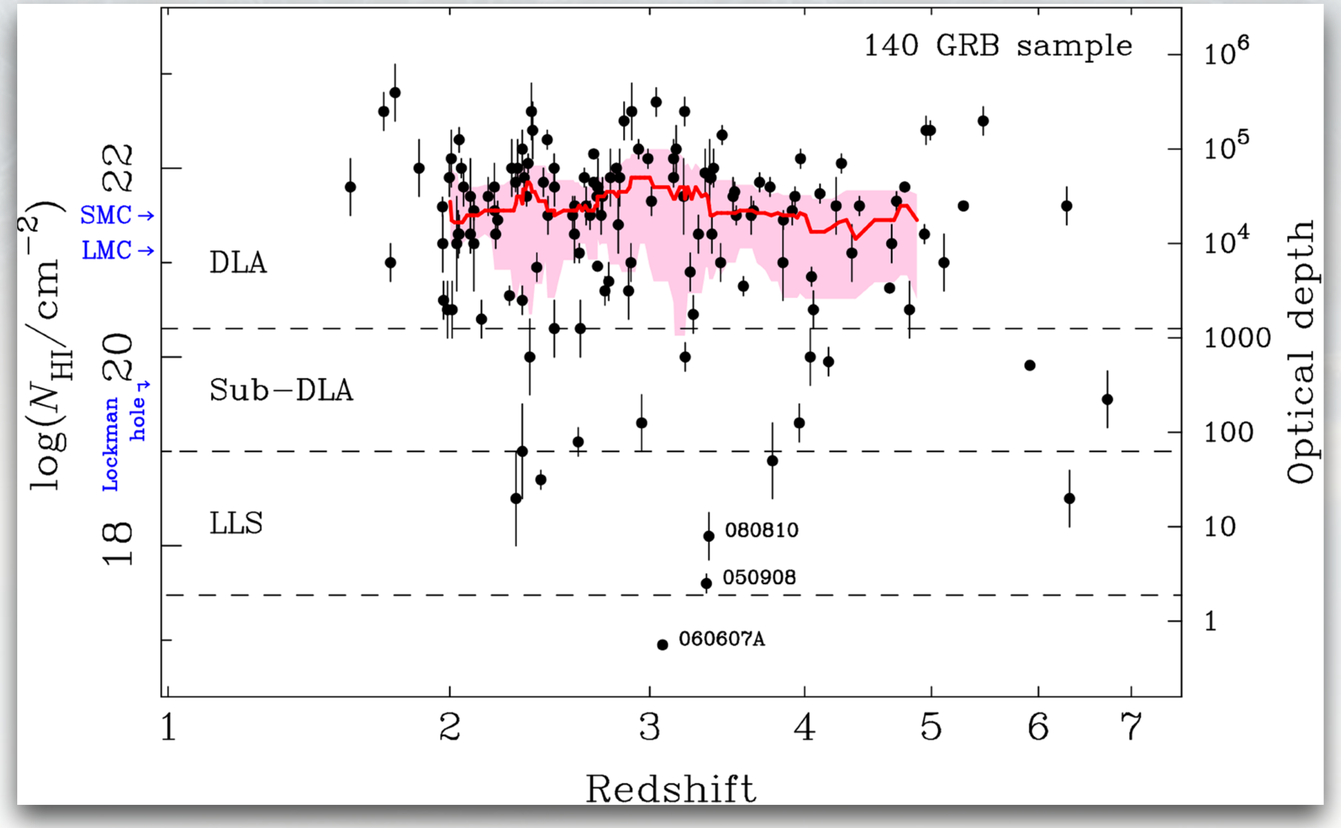




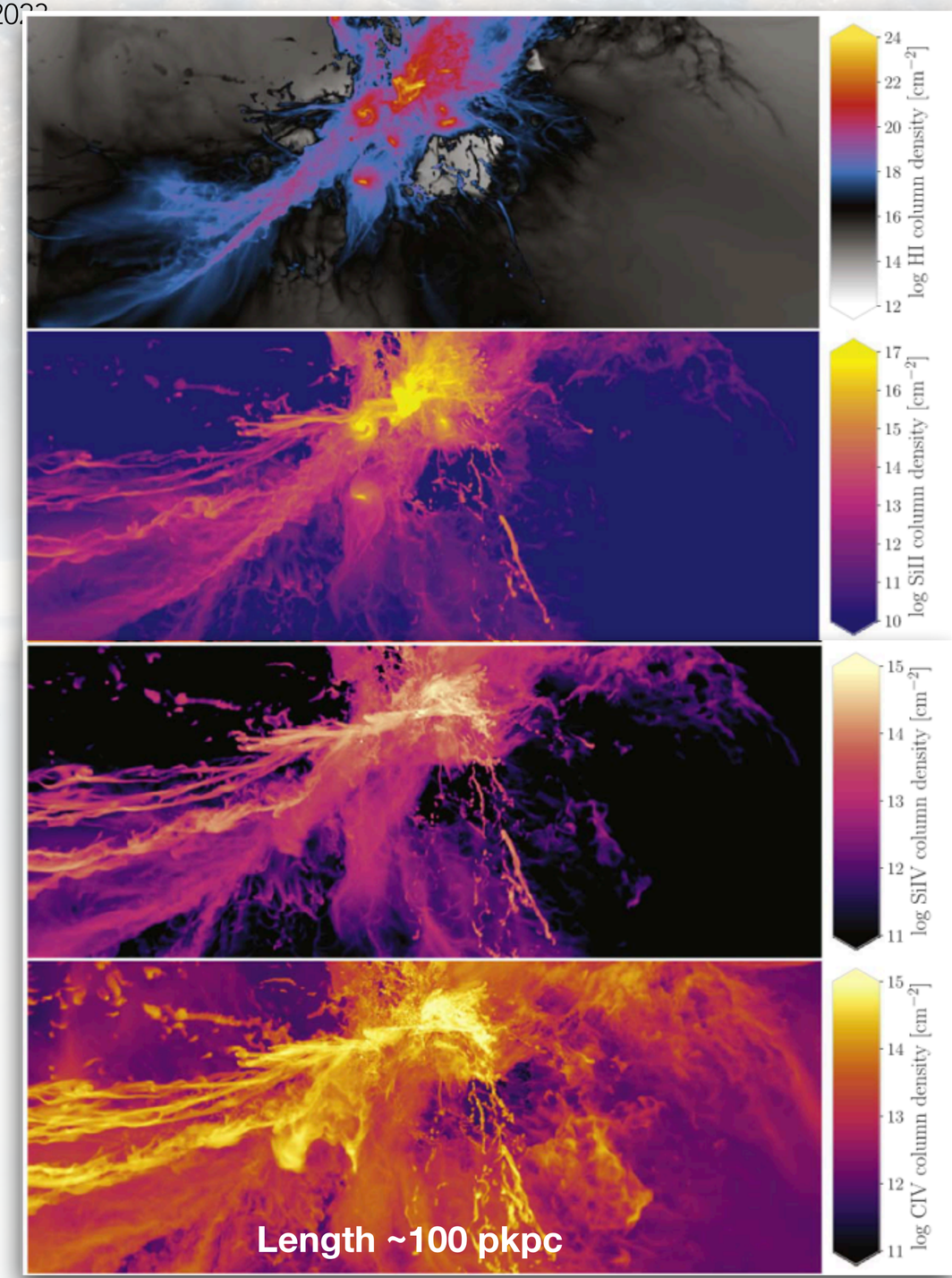
Peeples+19 **z=2.5**



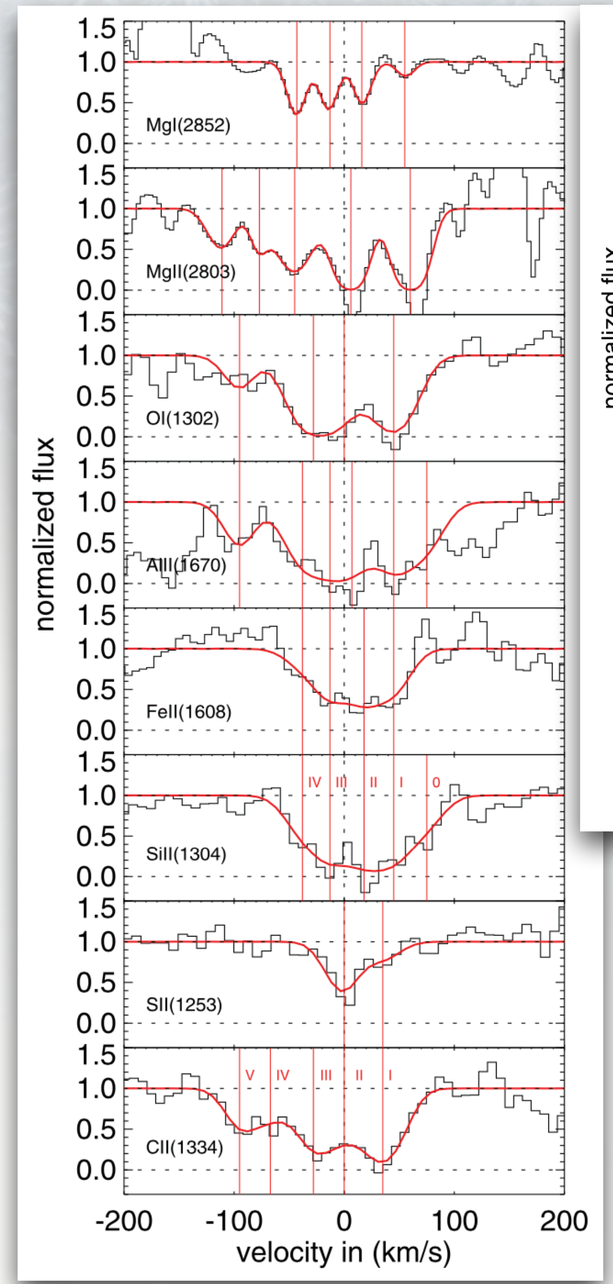
Tanvir+19

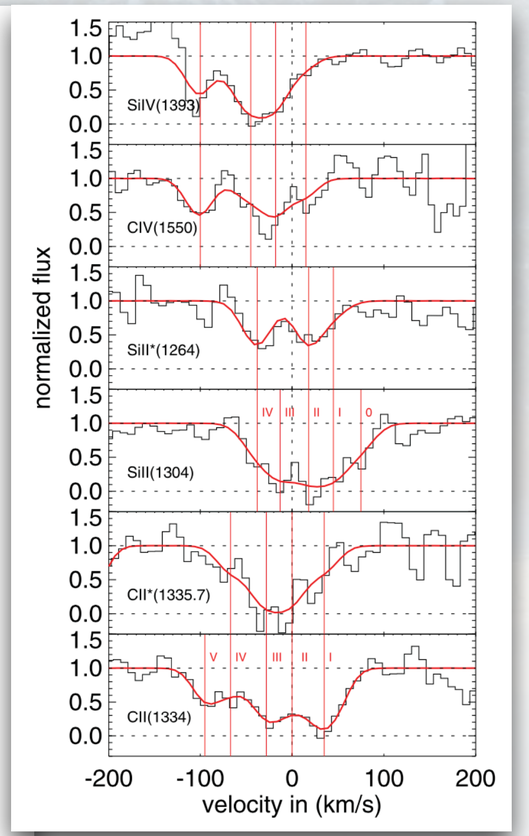


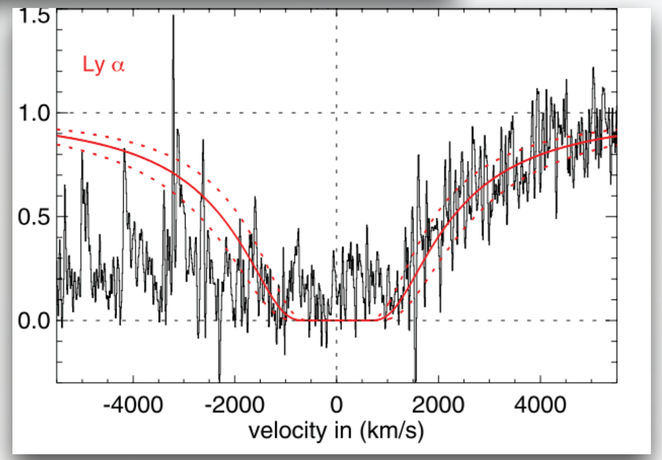
Peeples+19 **z=2.5**



GRB100219A Thöne et al. 2013







Neutral hydrogen absorption

Low-ionization absorption lines

High-ionization absorption lines

Fine-structure absorption lines

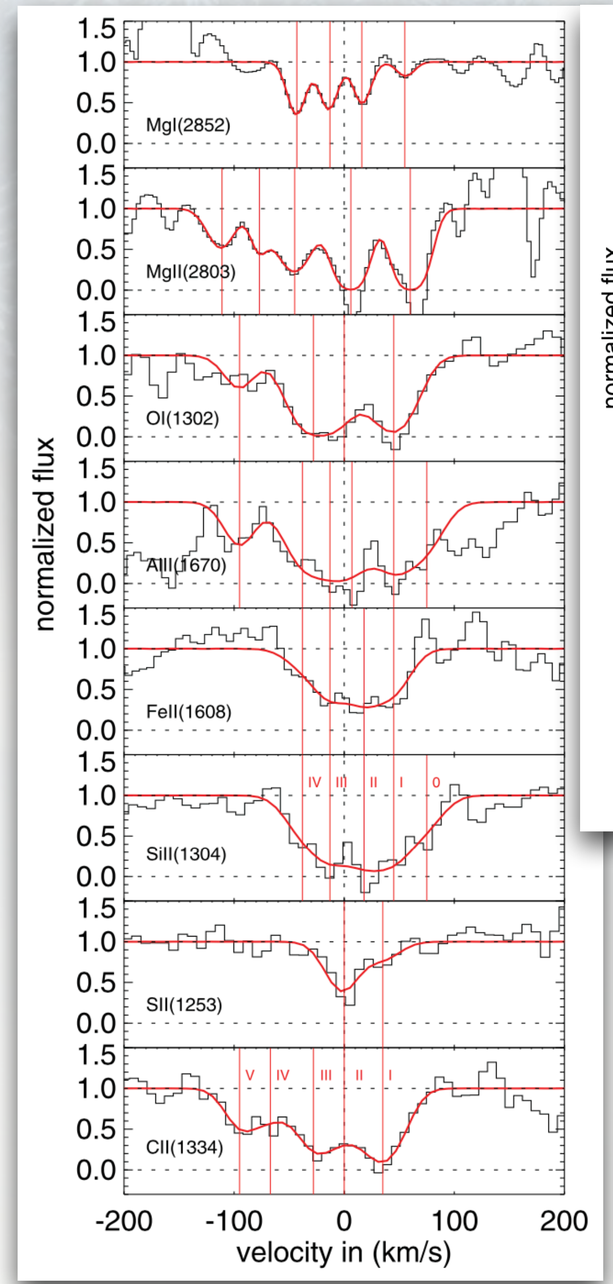
Gas kinematic

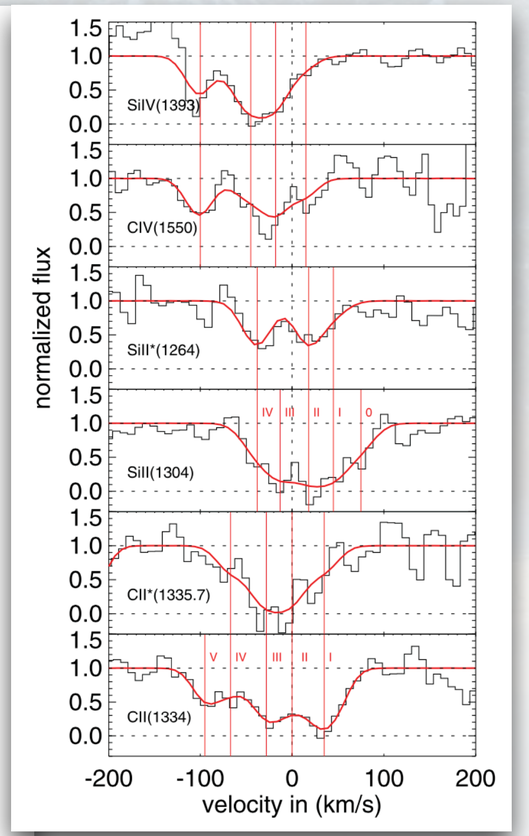
Metallicity, abundances

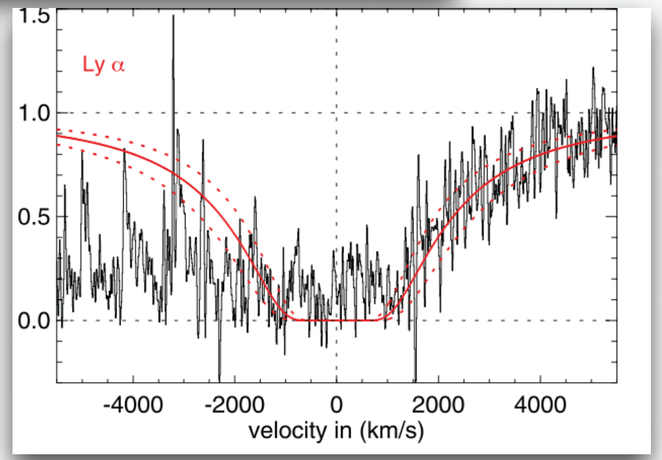
Dust depletion, dust to metal ratio

Gas distance from GRB

GRB100219A Thöne et al. 2013







Column density (N_{HI})

Column density (N_X)

Neutral hydrogen absorption

Low-ionization absorption lines

High-ionization absorption lines

Fine-structure absorption lines

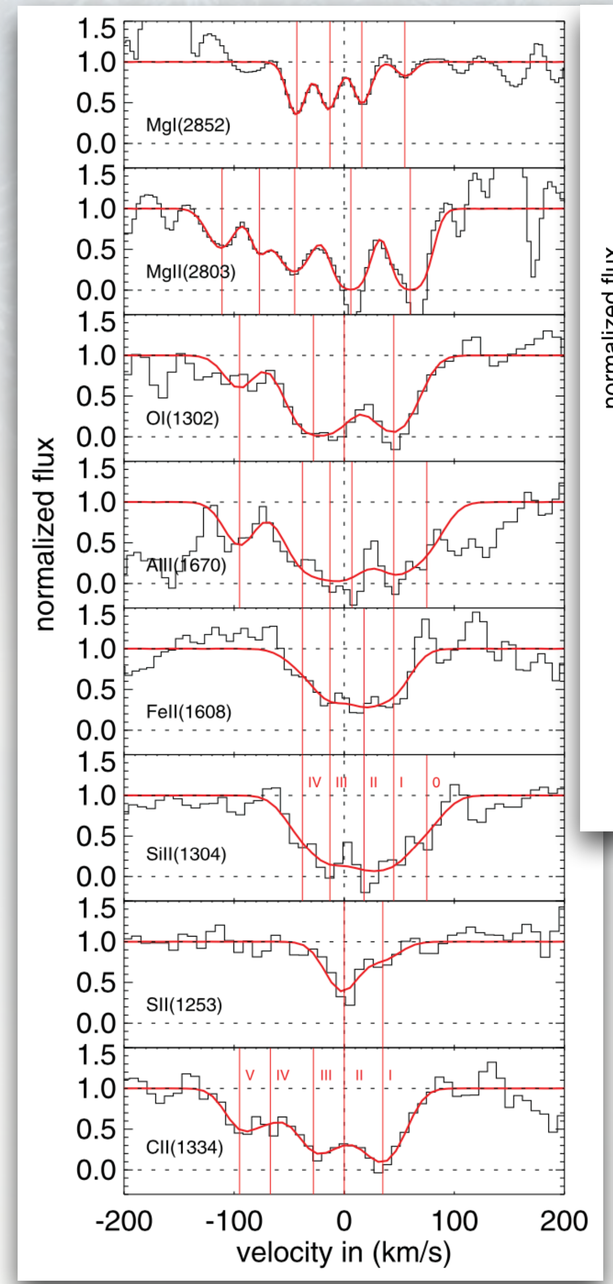
Gas kinematic

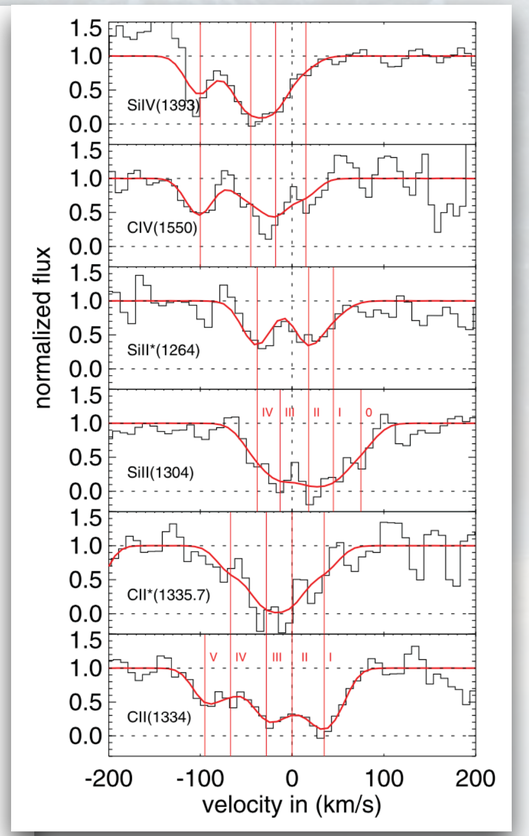
Metallicity, abundances

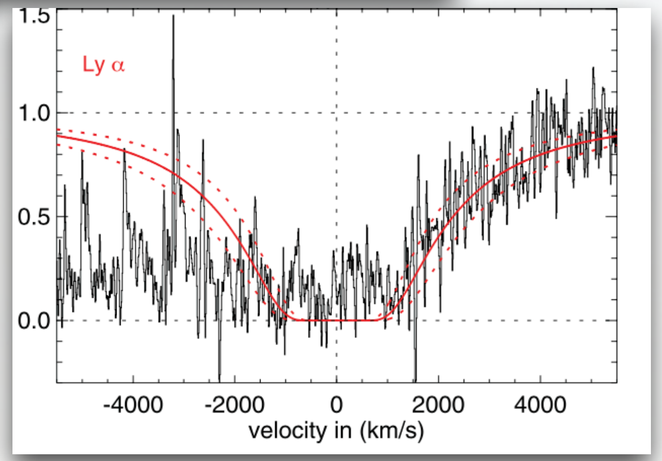
Dust depletion, dust to metal ratio

Gas distance from GRB

GRB100219A Thöne et al. 2013







Neutral hydrogen absorption

Low-ionization absorption lines

High-ionization absorption lines

Fine-structure absorption lines

Gas kinematic

Metallicity, abundances

Dust depletion, dust to metal ratio

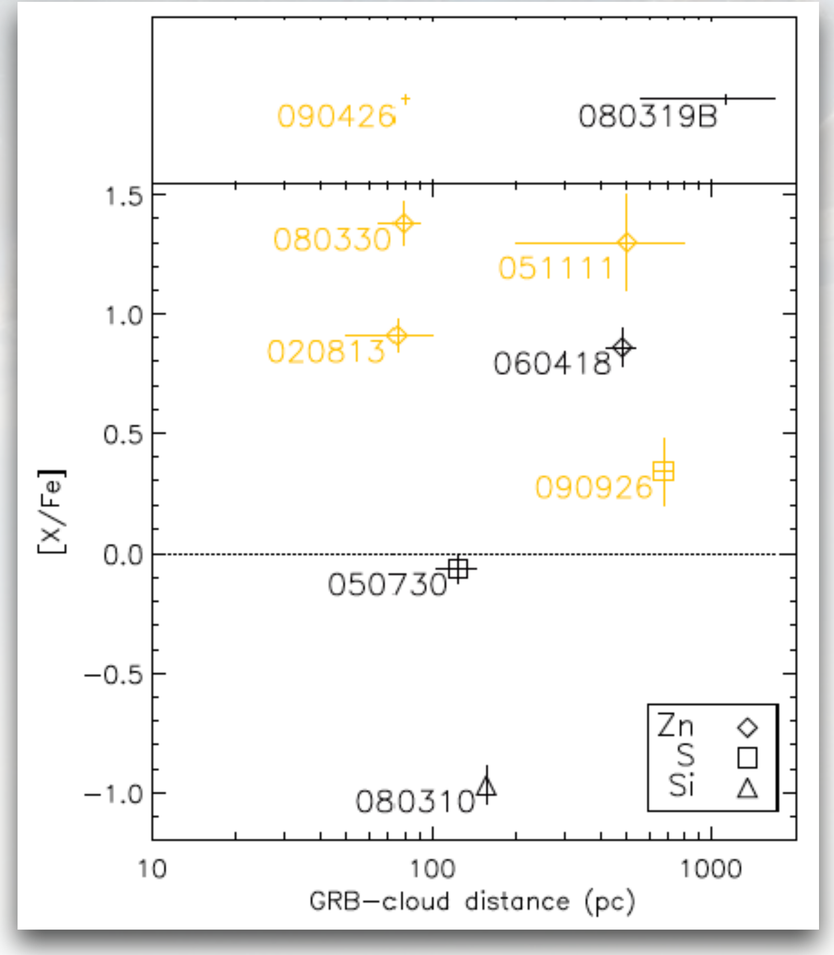
Gas distance from GRB

We are probing the star-forming regions
(but not the closest environment)

Probing the ISM gas in detail
up to the highest redshift!

Effect of the GRB
On its environment

Vreeswijk+12

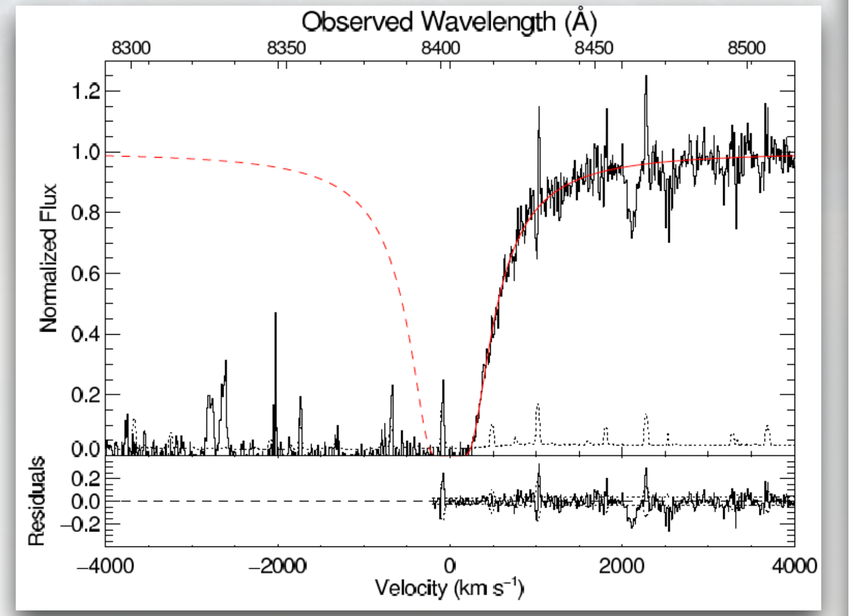


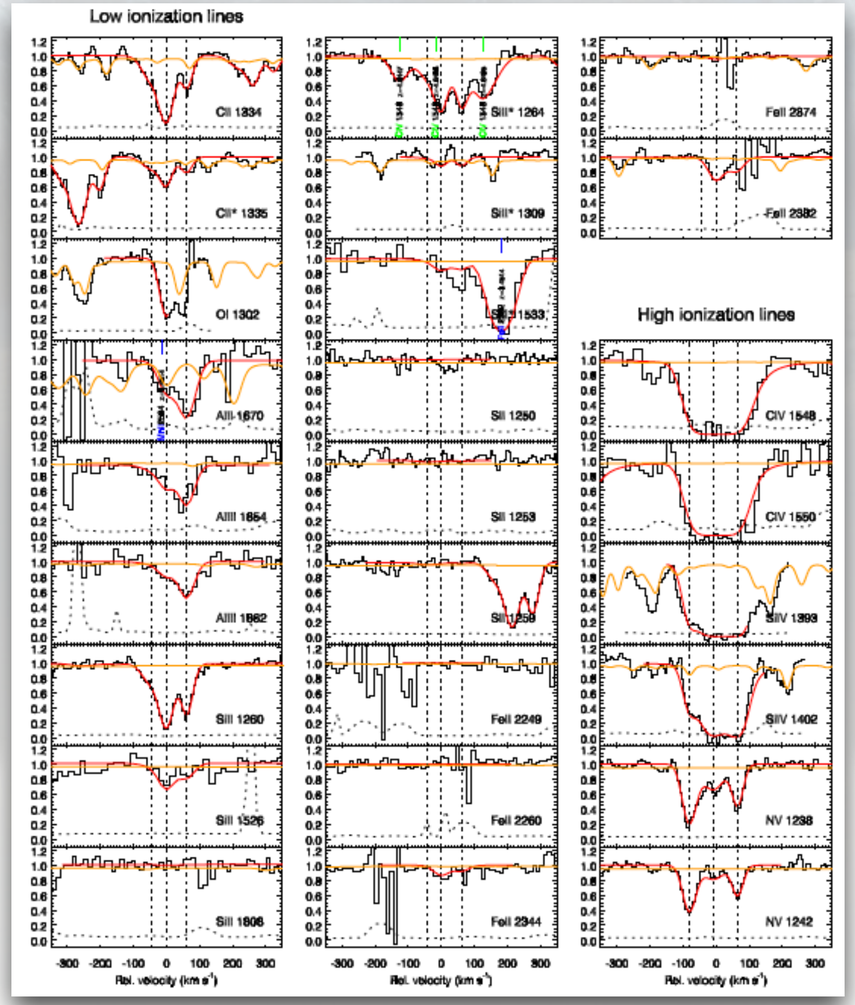
Long GRBs as tools to probe galaxies

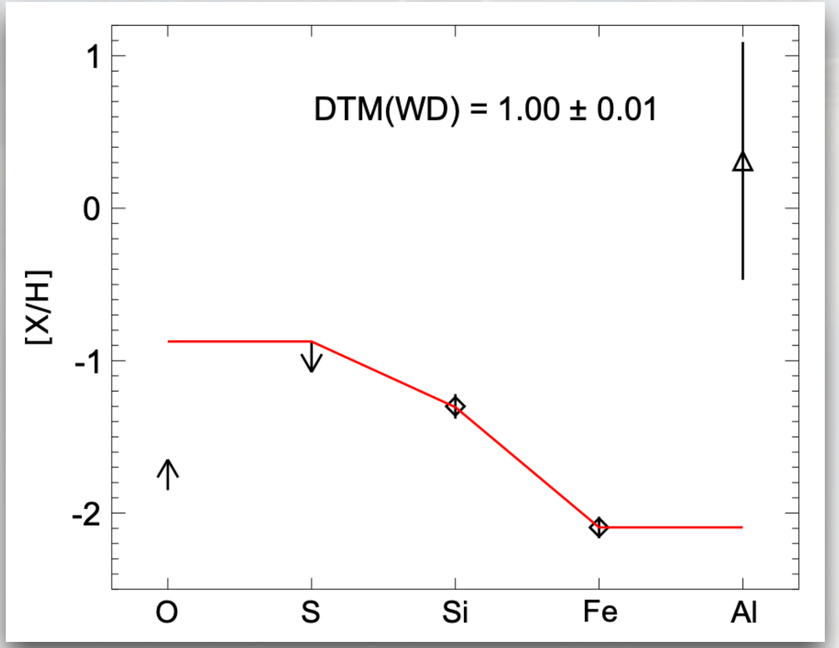
VLT/X-shooter

GRB130606A, z=5.9

Hartoog et al. 2015







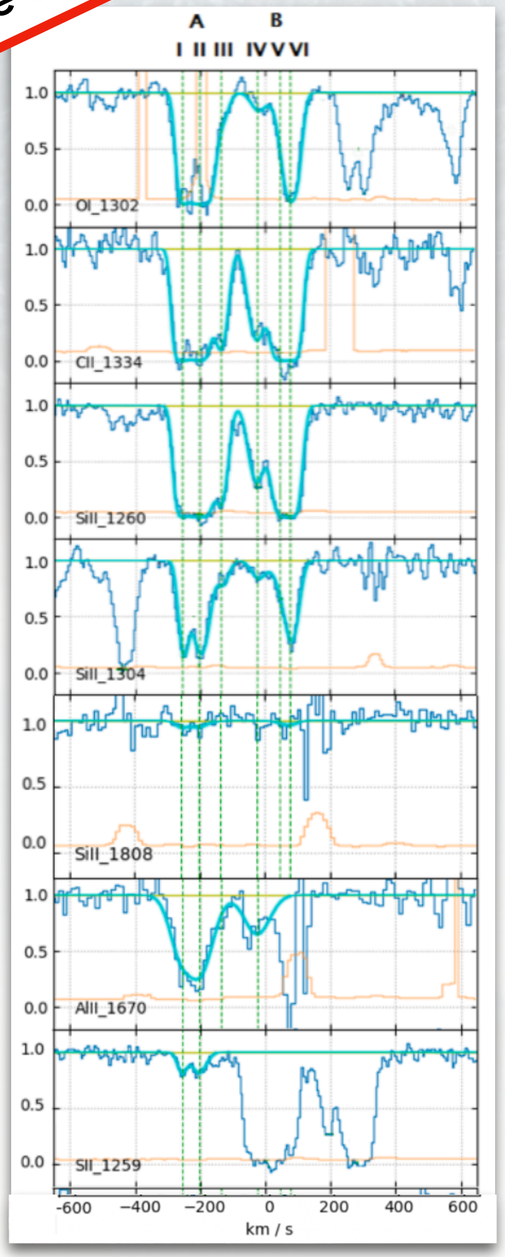
Aluminium overabundance

See Saccardi's talk

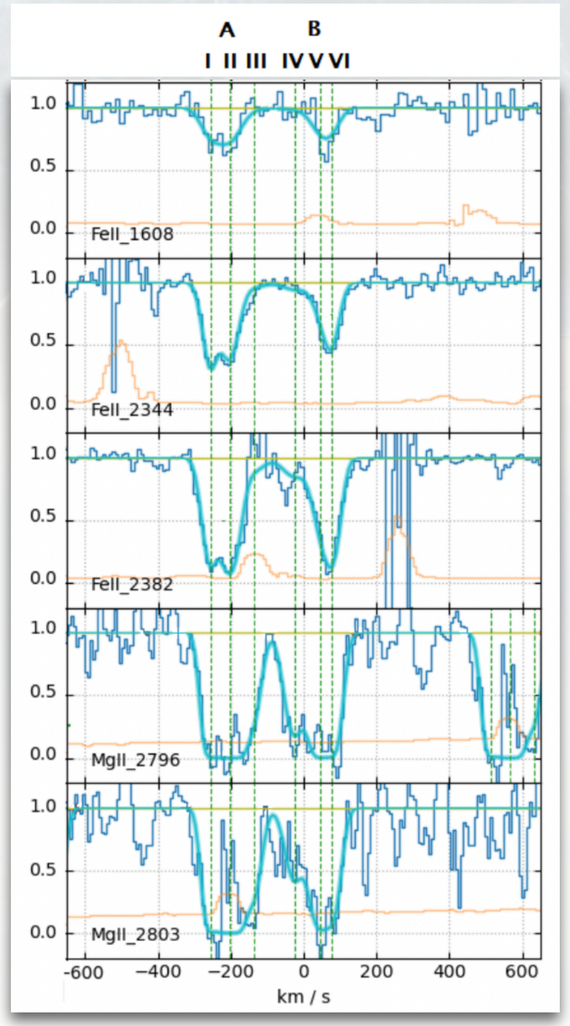
GRB210905A @ z=6.3 : VLT/X-Shooter

Saccardi et al. 2023 in press

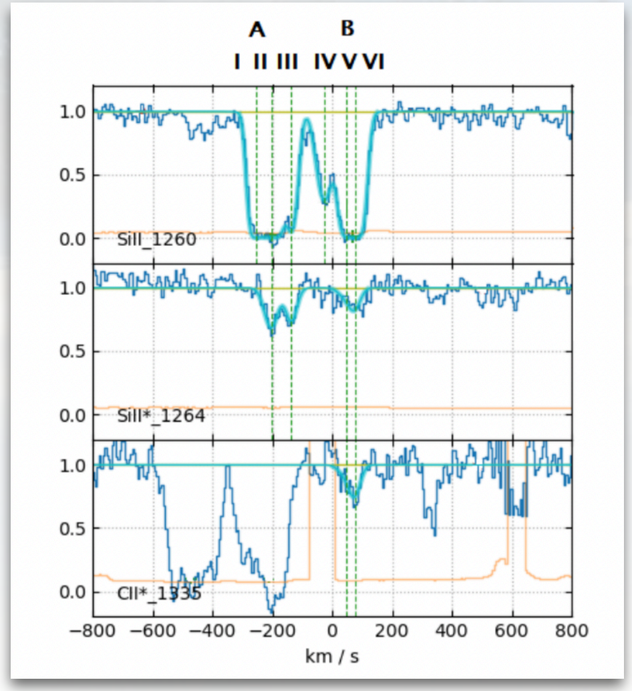
See also Rossi et al. 2022



Low-ionization lines



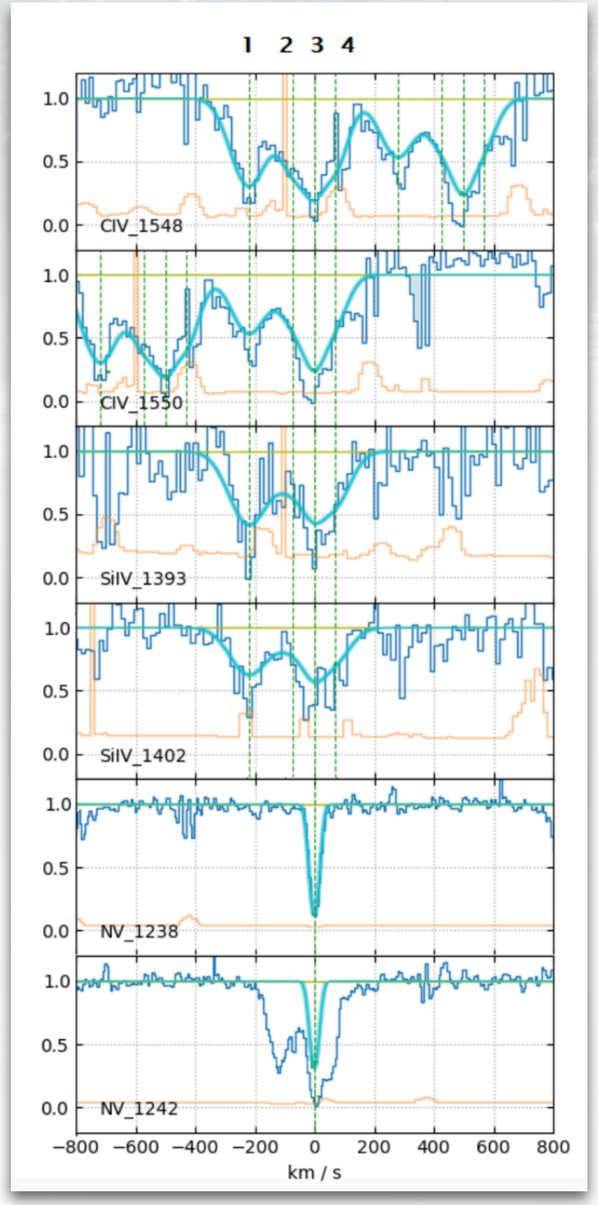
Fine-structure lines



+ HI DLA

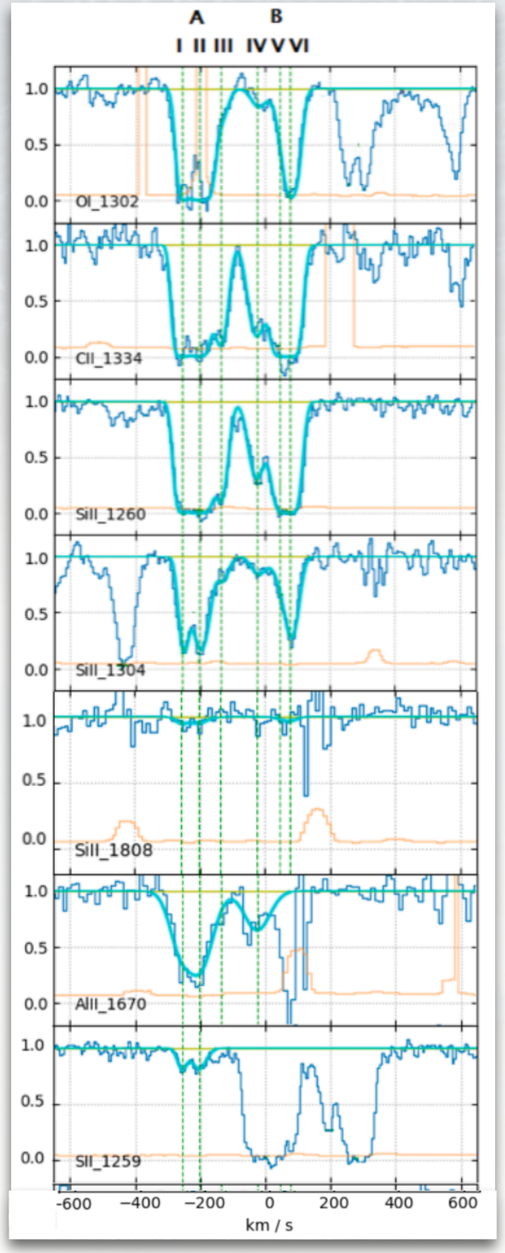
Log(N(HI)/cm^{-2}) = 21.1

High-ionization lines

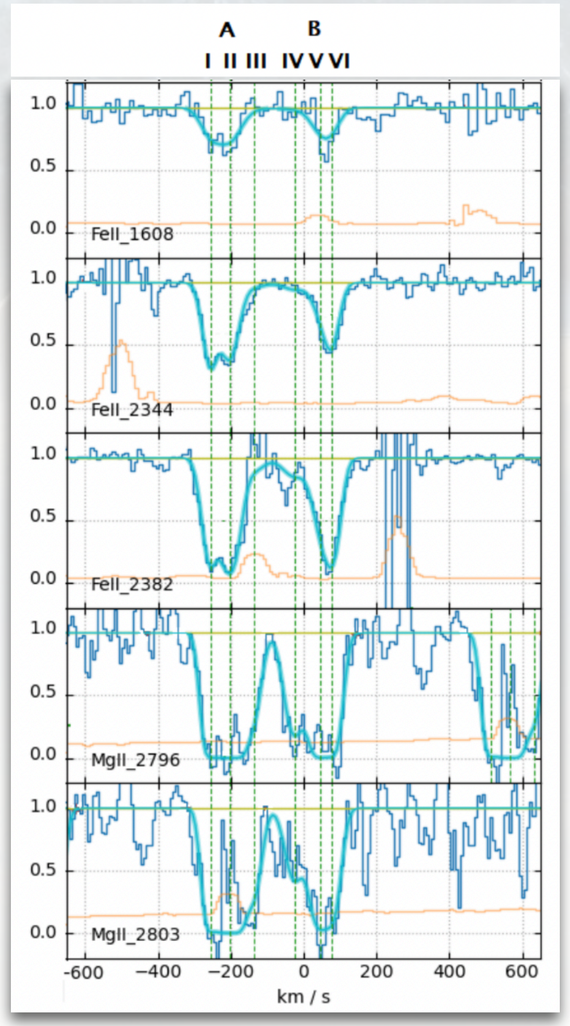


GRB210905A @ z=6.3 : VLT/X-Shooter

Saccardi et al. 2023 in press



Low-ionization lines



[Si/H] = –1.71 ± 0.11

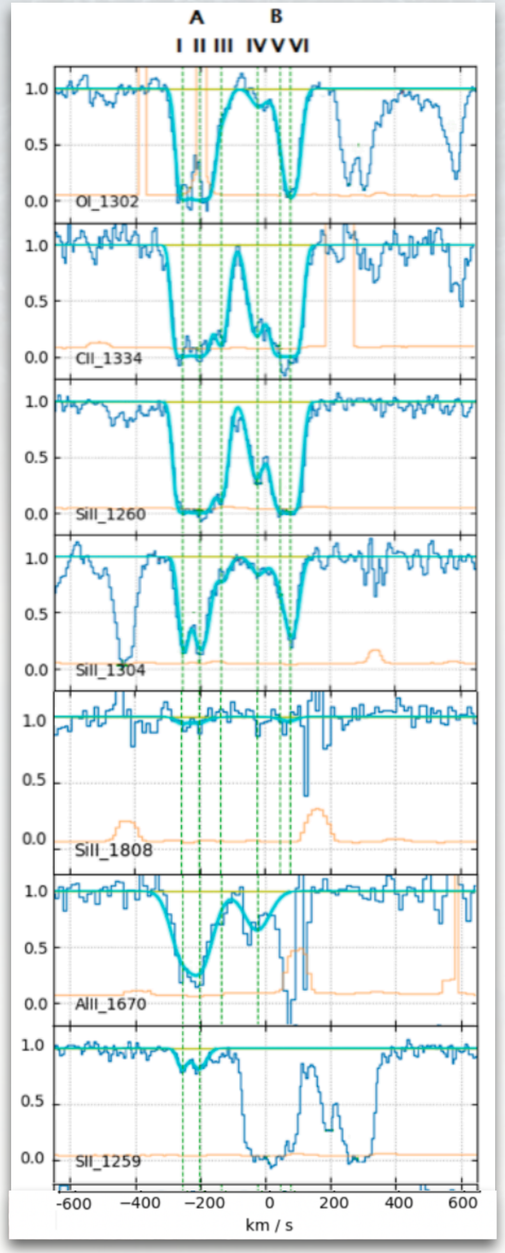
[Fe/H] = –2.17 ± 0.11

+ HI DLA

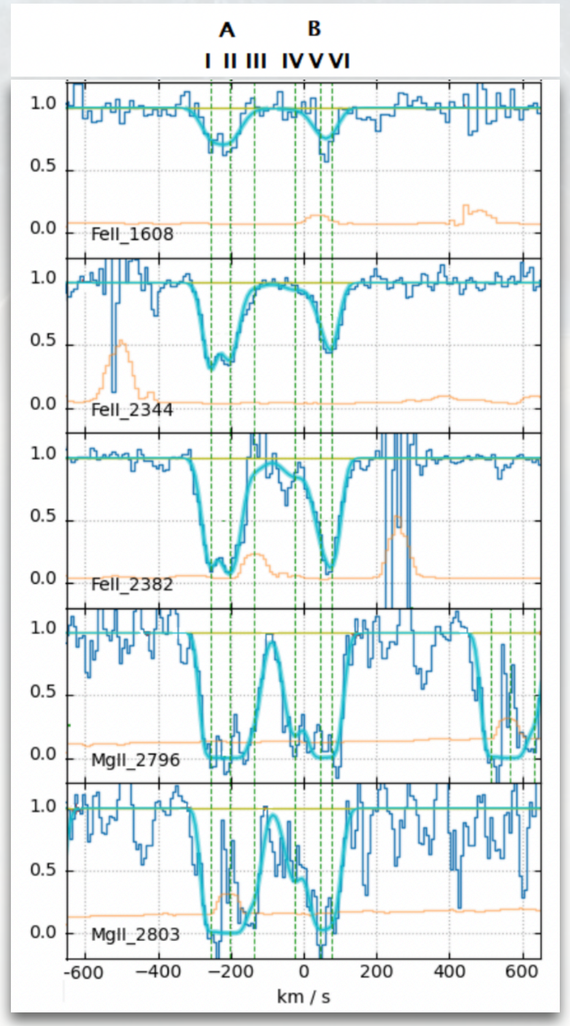
Log(N(HI)/cm^{-2}) = 21.1

GRB210905A @ z=6.3 : VLT/X-Shooter

Saccardi et al. 2023 in press



Low-ionization lines



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

Dust corrected metallicity

$[M/H]_{tot} = -1.72 \pm 0.13$

Dust depletion

$[Zn/Fe]_{fit} = 0.33 \pm 0.09$

Dust-to-metal mass ratio

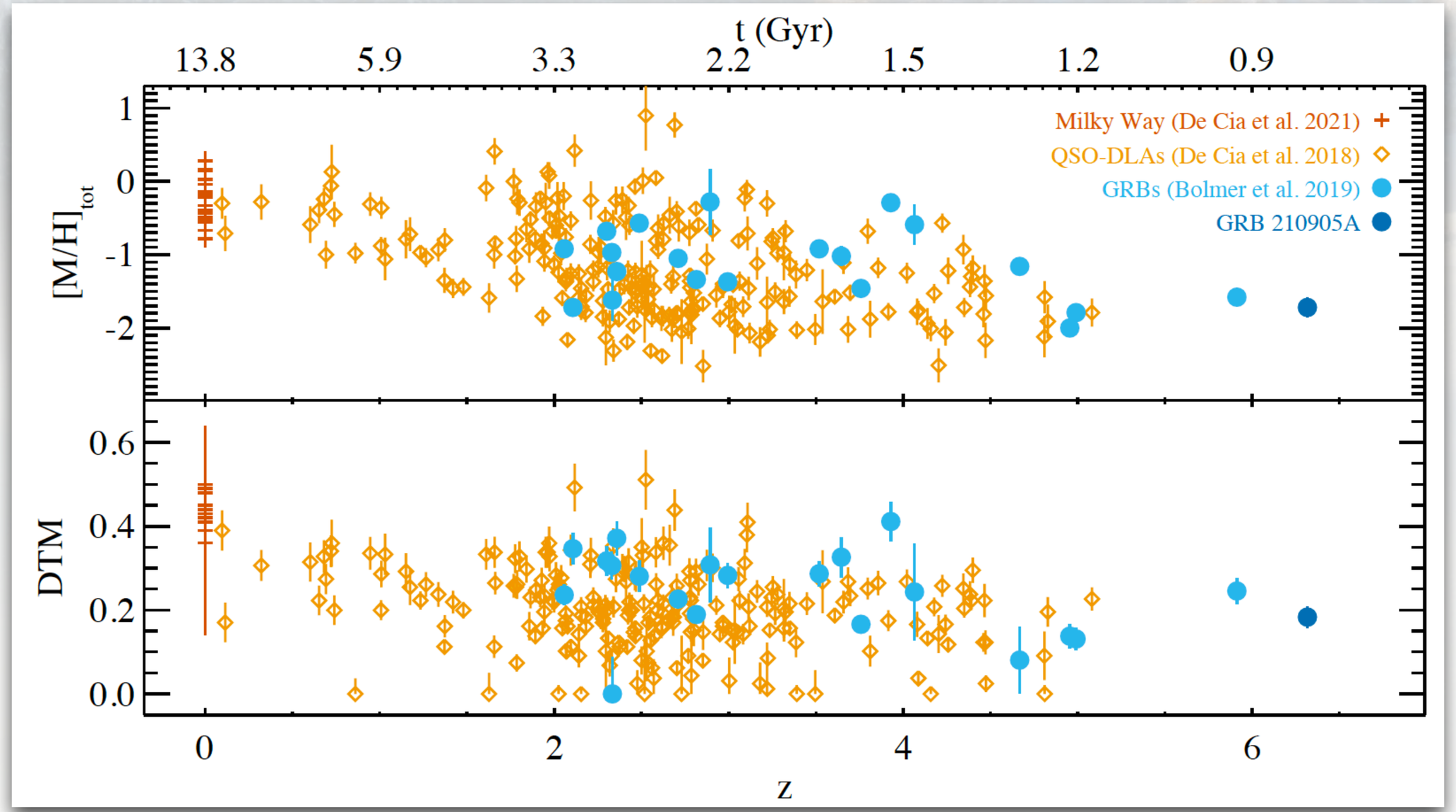
$DTM = 0.18 \pm 0.03$

+ HI DLA

$Log(N(HI)/cm^{-2}) = 21.1$

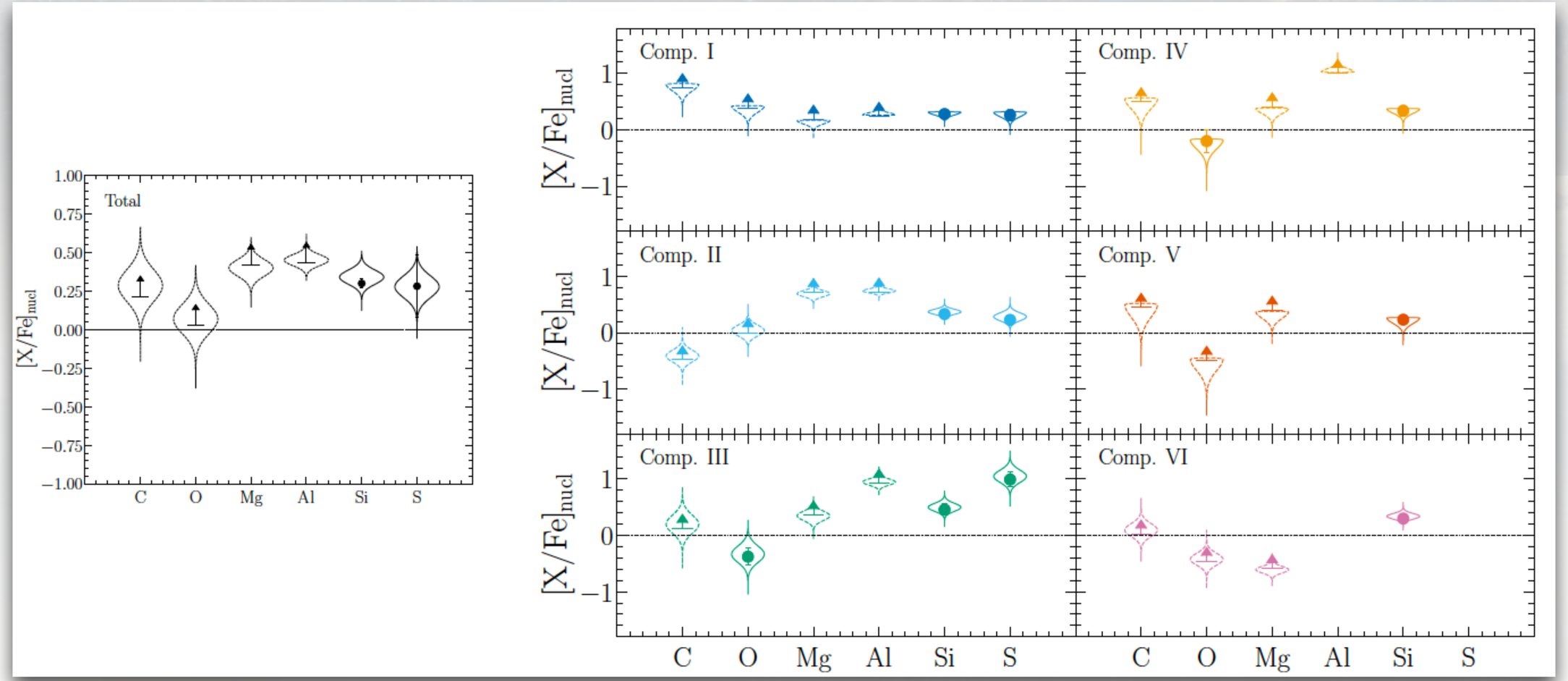
GRB210905A @ z=6.3 : VLT/X-Shooter

Saccardi et al. 2023 in press



GRB210905A @ z=6.3 : VLT/X-Shooter

Saccardi et al. 2023 in press



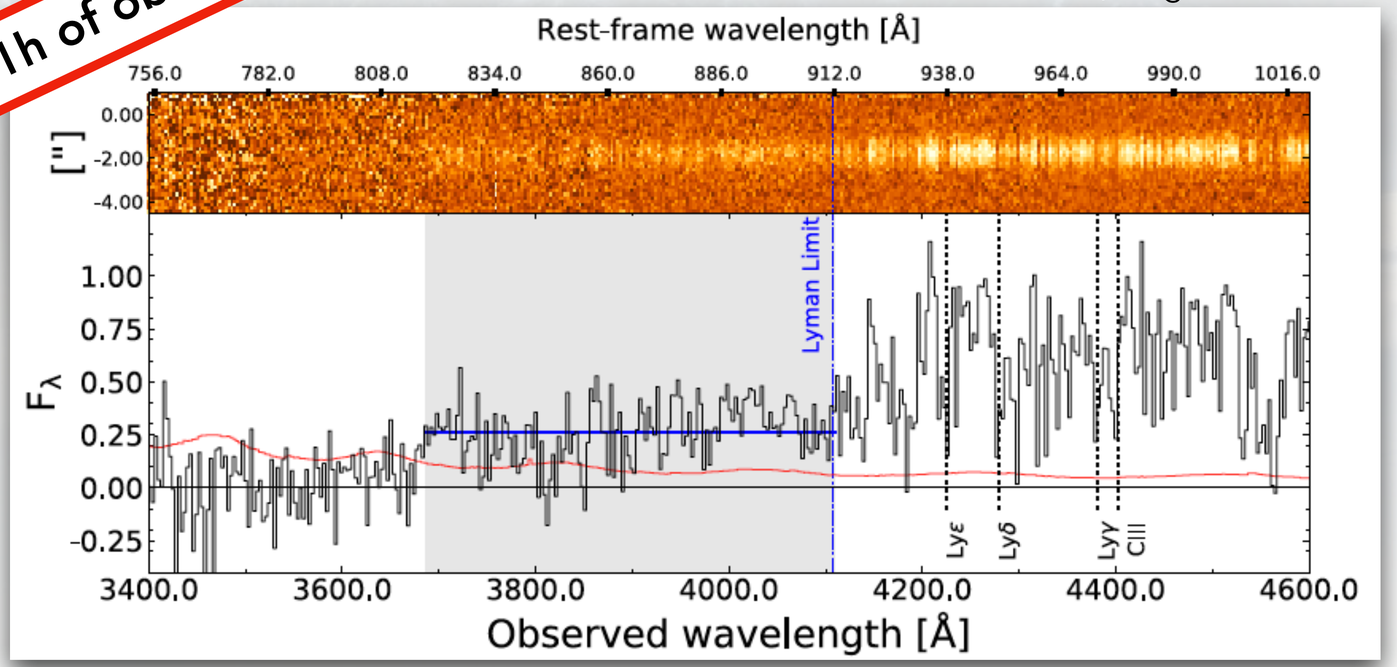
Long GRBs as tools to probe galaxies :

Lyman-continuum studies

<1h of observation!

GRB191004B, z=3.5

Vielfaure, Vergani et al. 2020



$$f_{\rm esc} = \exp[-\tau_{\rm LL}(\lambda)]$$

$$\tau_{\rm LL}(\lambda) \approx \frac{N_{\rm HI}}{10^{17.2}\,{\rm cm}^{-2}} \left(\frac{\lambda}{\lambda_{\rm LL}}\right)^3$$

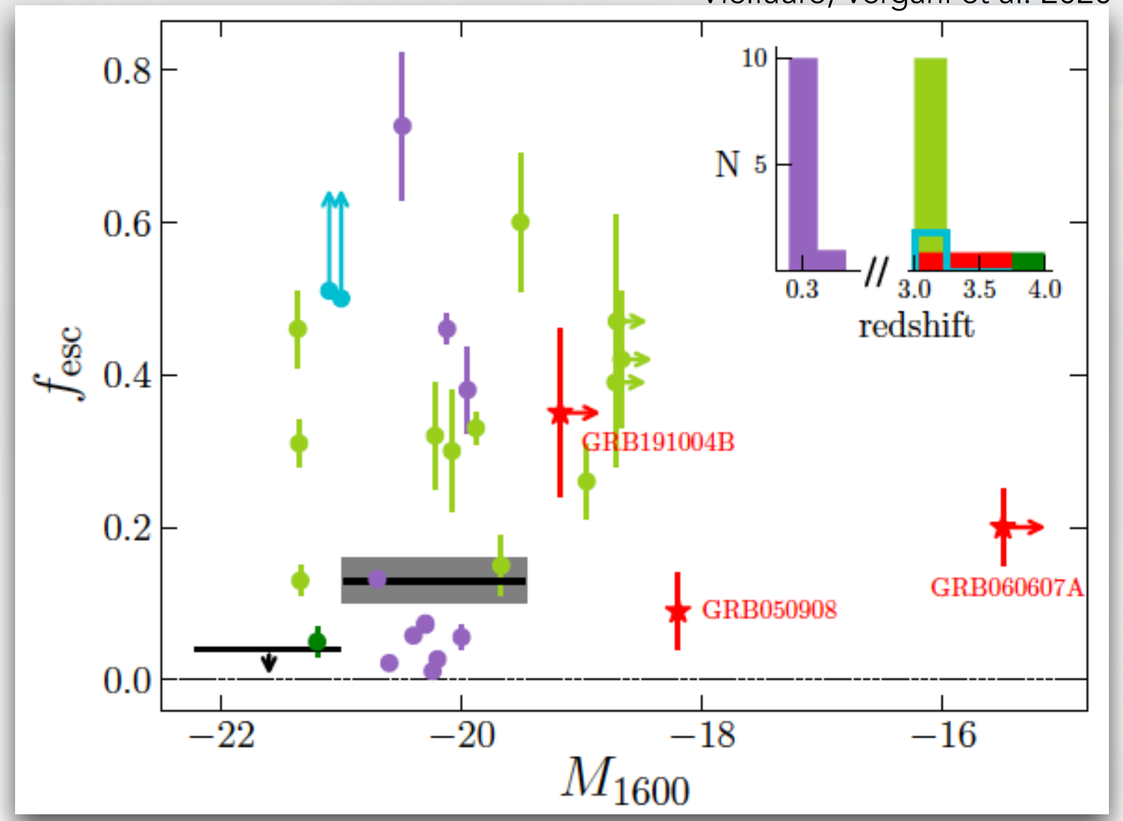
$$f_{\rm esc,\,rel} = \frac{(f_{1500}/f_{900})^{\rm int}}{(f_{1500}/f_{900})^{\rm obs}\, T_{900}^{\rm IGM}}$$

Long GRBs as tools to probe galaxies :

Lyman-continuum studies

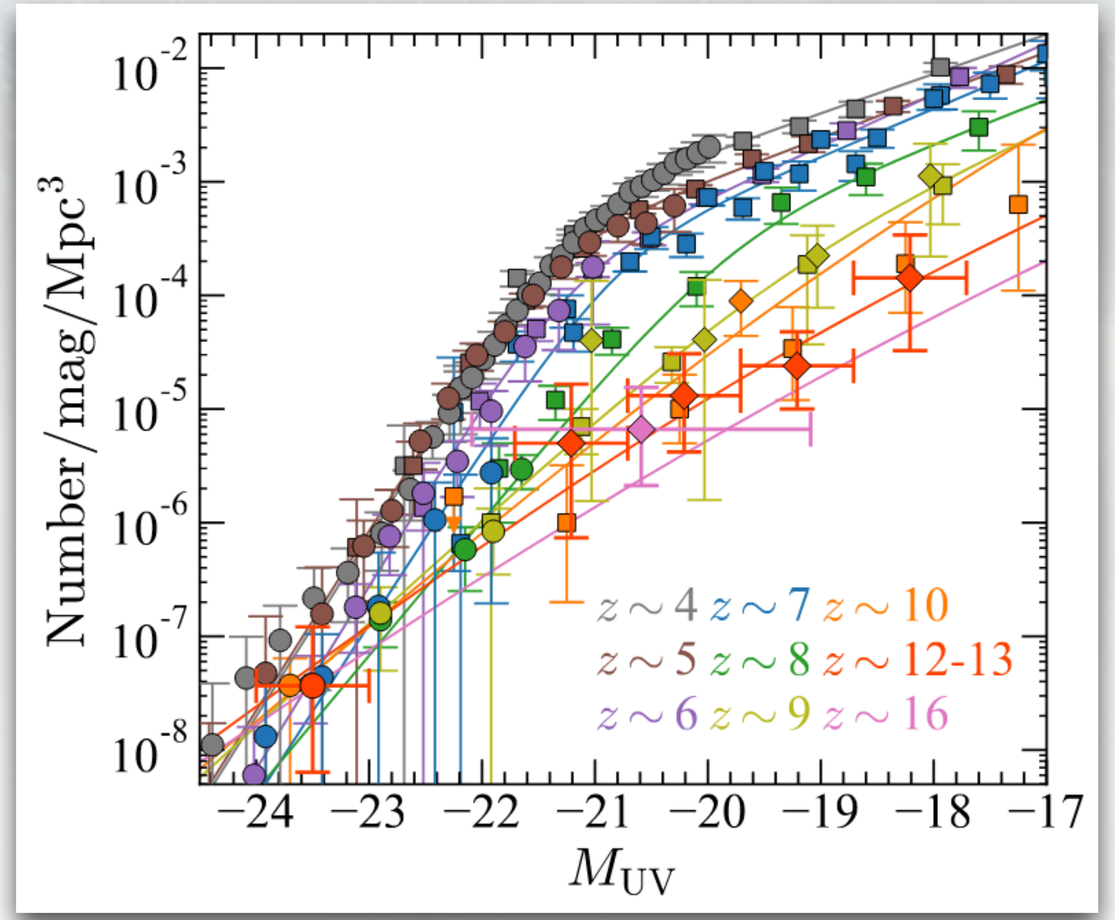
Lyman-continuum photons escaping from extremely faint galaxies
Bulk of the population at reionization!

Vielfaure, Vergani et al. 2020

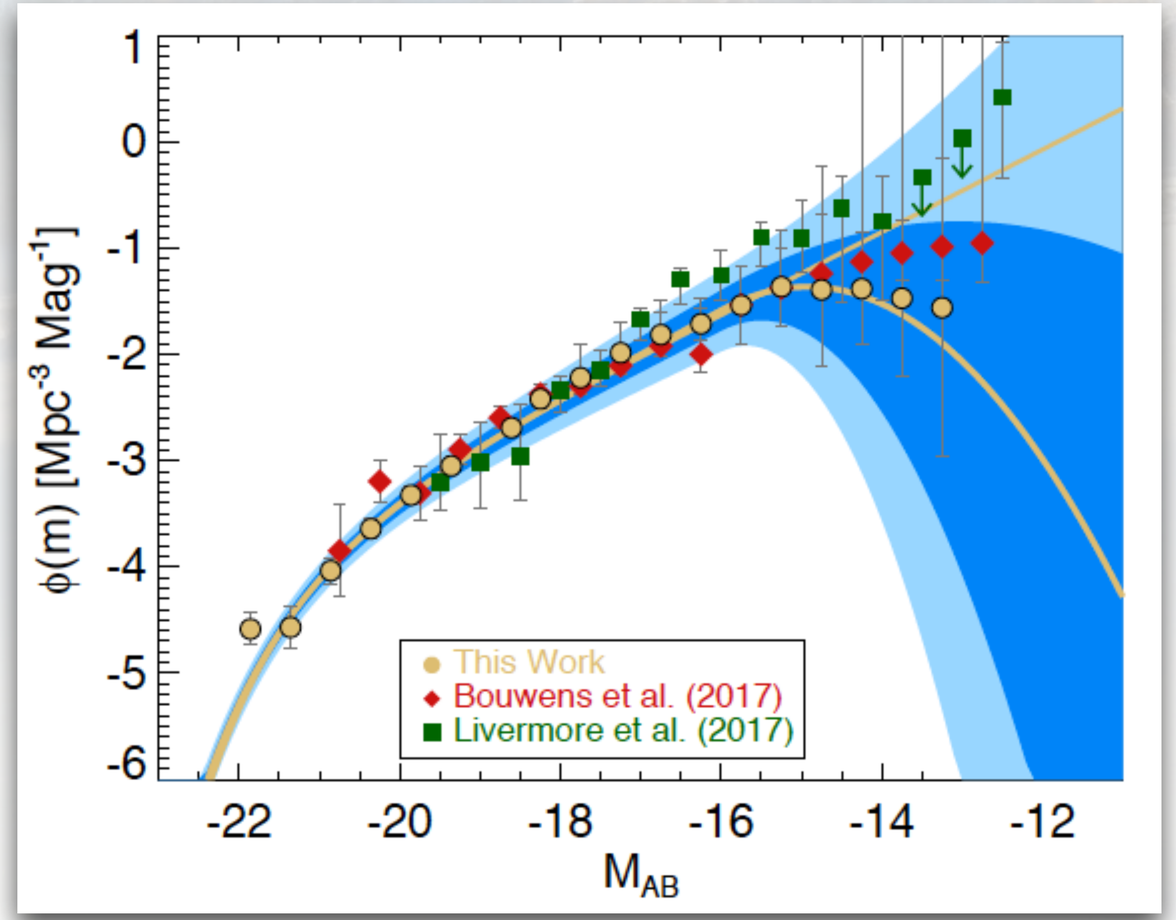


Long GRBs as tools to probe galaxies

Harikane+22



Atek+18



Long GRBs as tools to probe galaxies

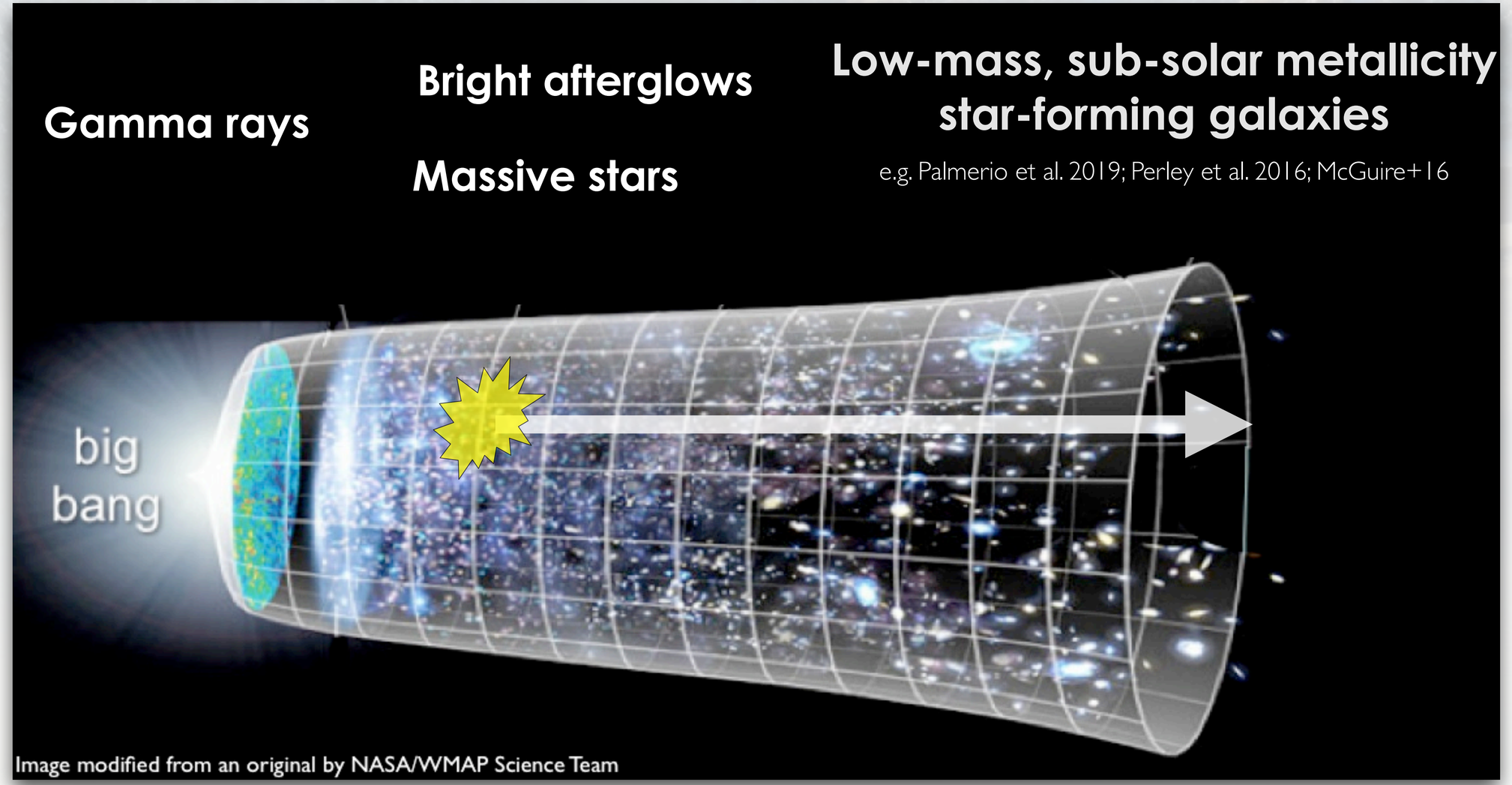
Gamma rays

Bright afterglows

Massive stars

Low-mass, sub-solar metallicity star-forming galaxies

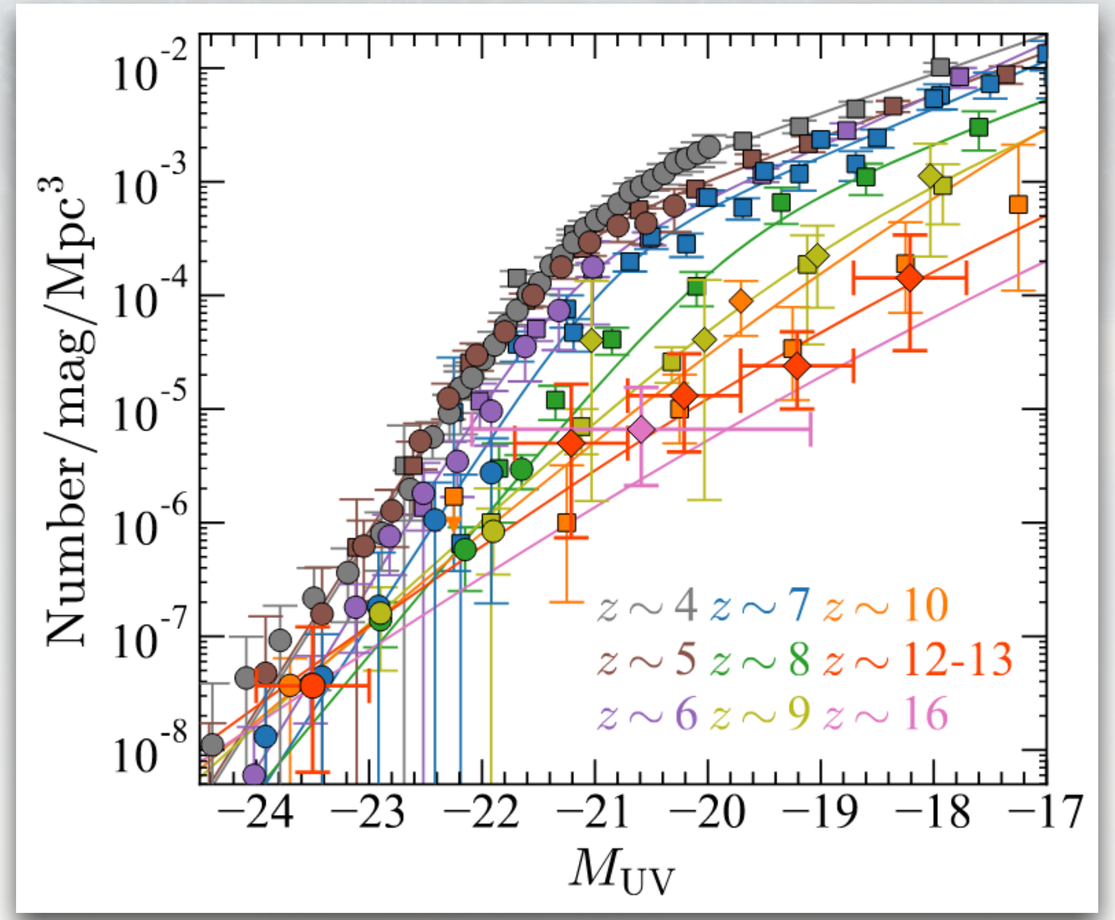
e.g. Palmerio et al. 2019; Perley et al. 2016; McGuire+16



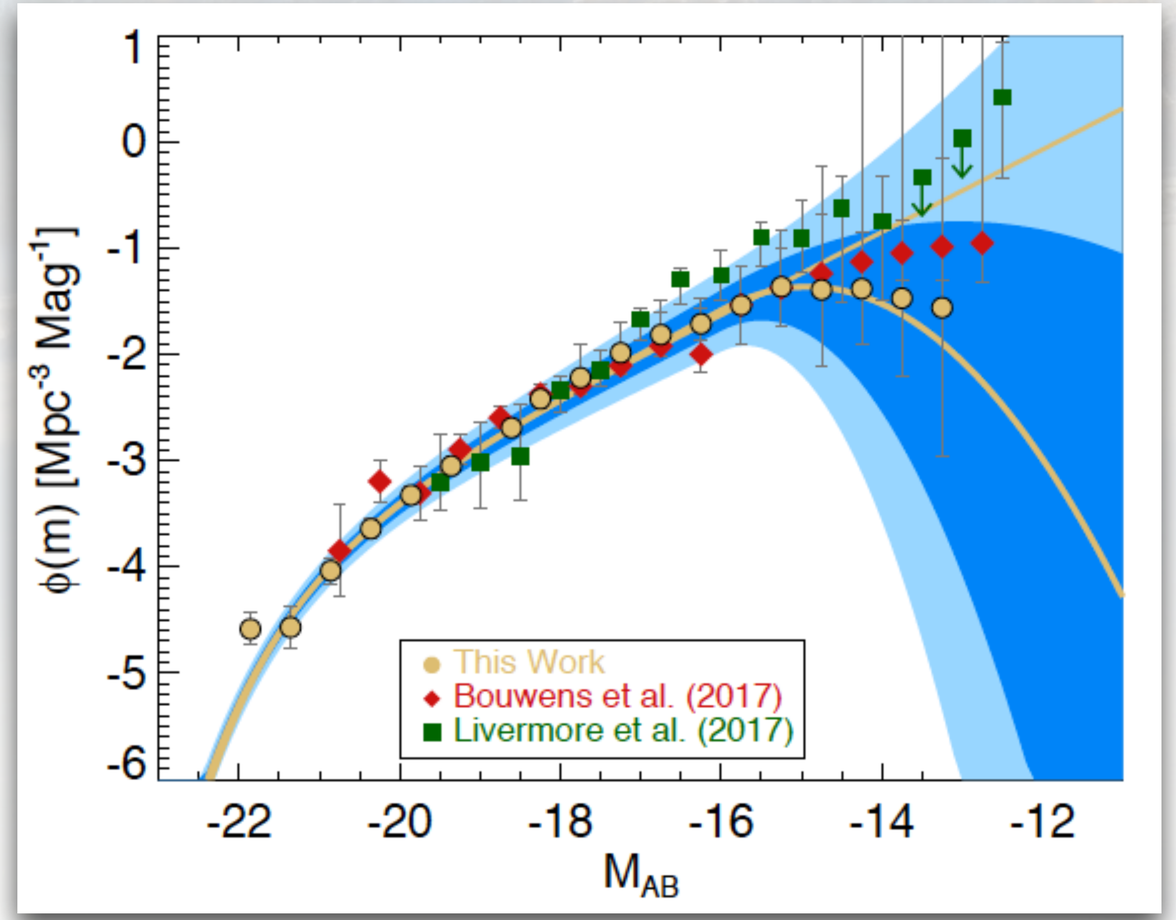
Tool to select and study in detail faint star-forming galaxies at all redshifts

Long GRBs as tools to probe galaxies

Harikane+22

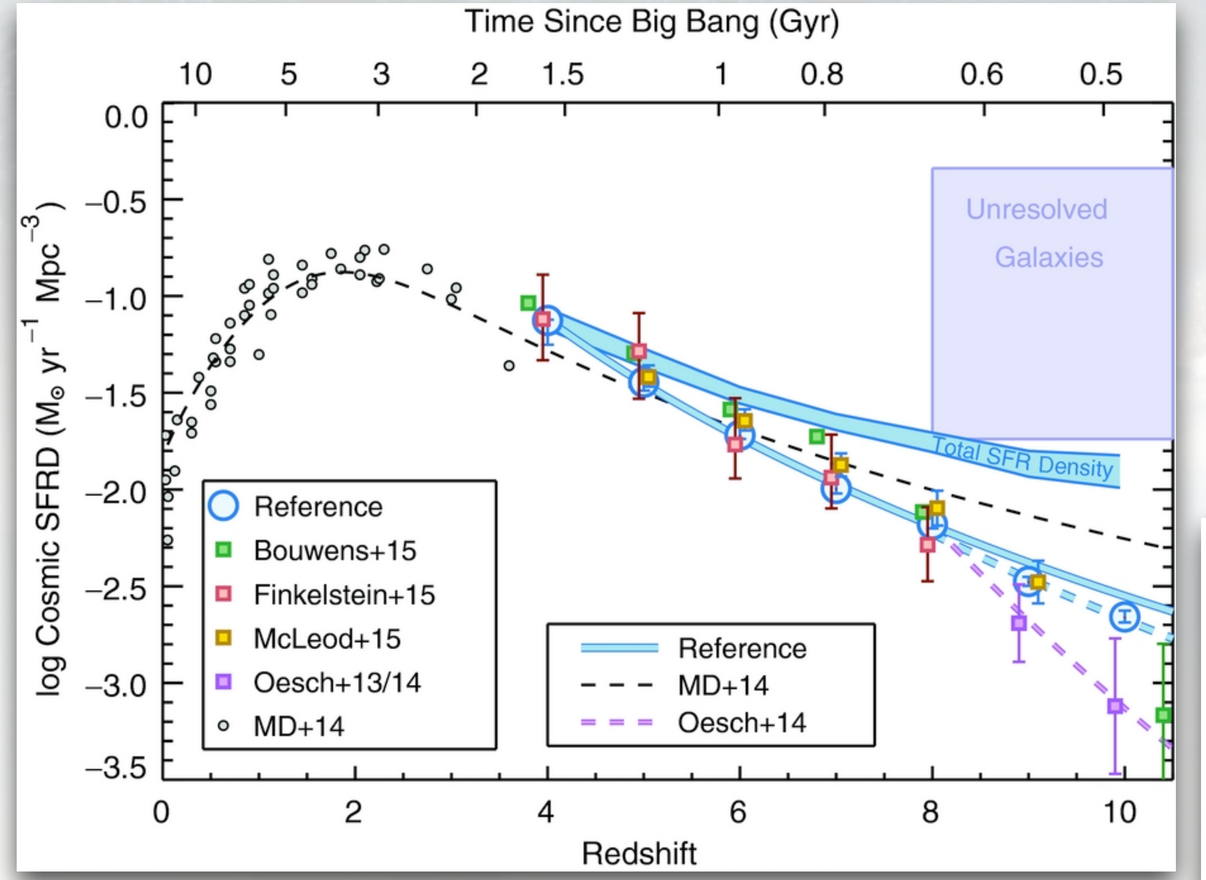


Atek+18

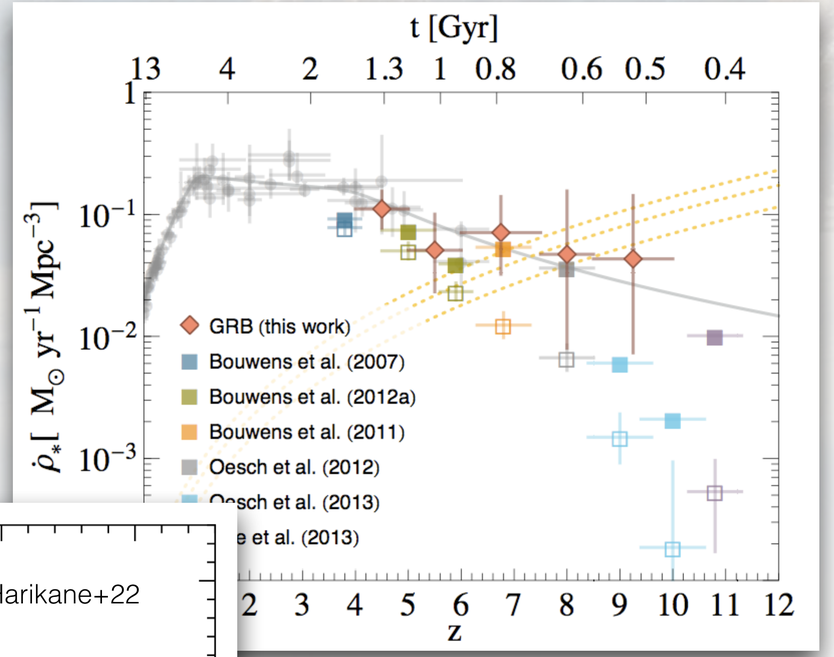


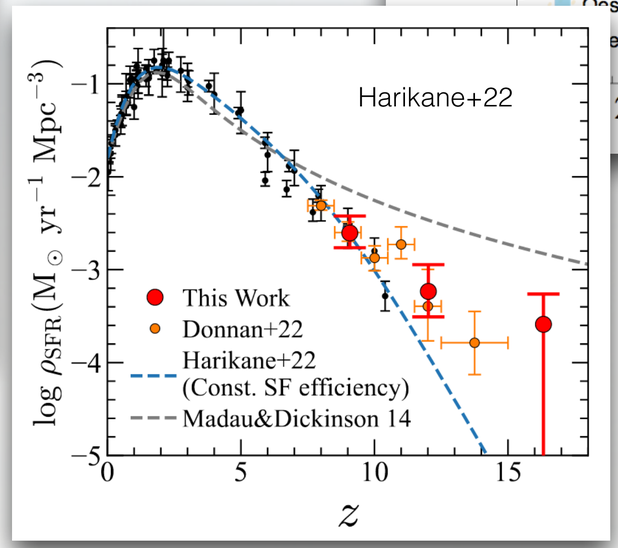
Long GRBs as tools to probe the high-z universe

Finkelstein 2016

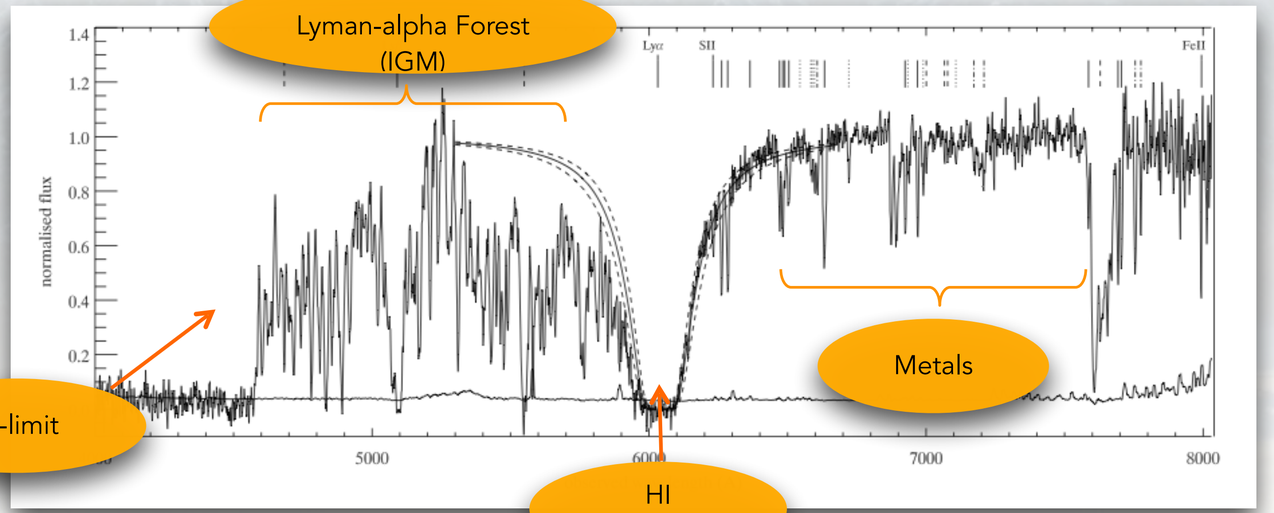


Kistler+13

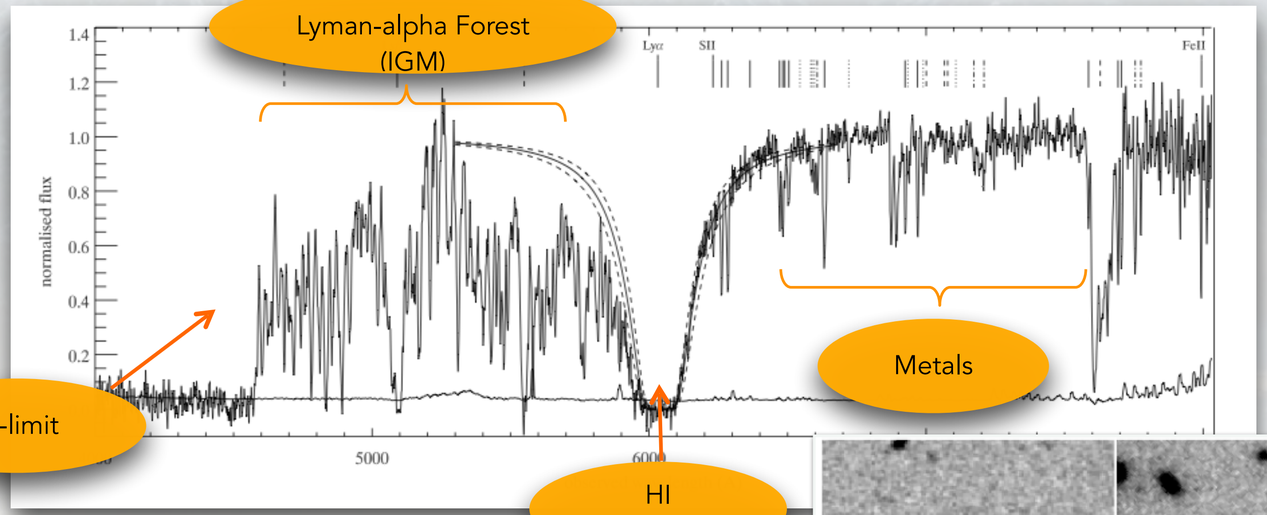




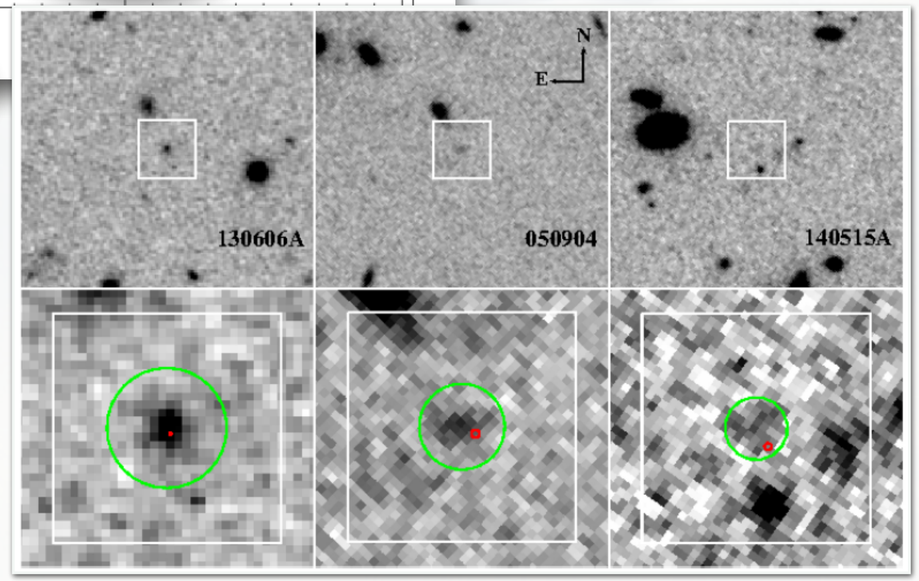
Long GRBs as tools to probe galaxies



Long GRBs as tools to probe galaxies

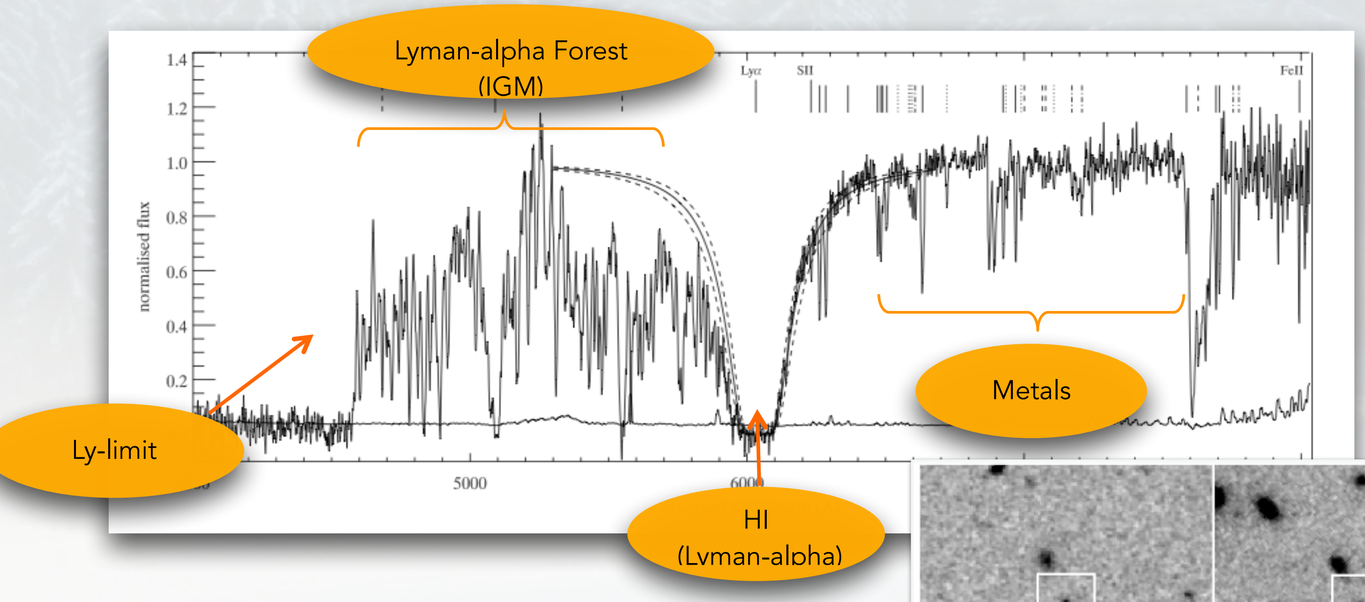


McGuire+16

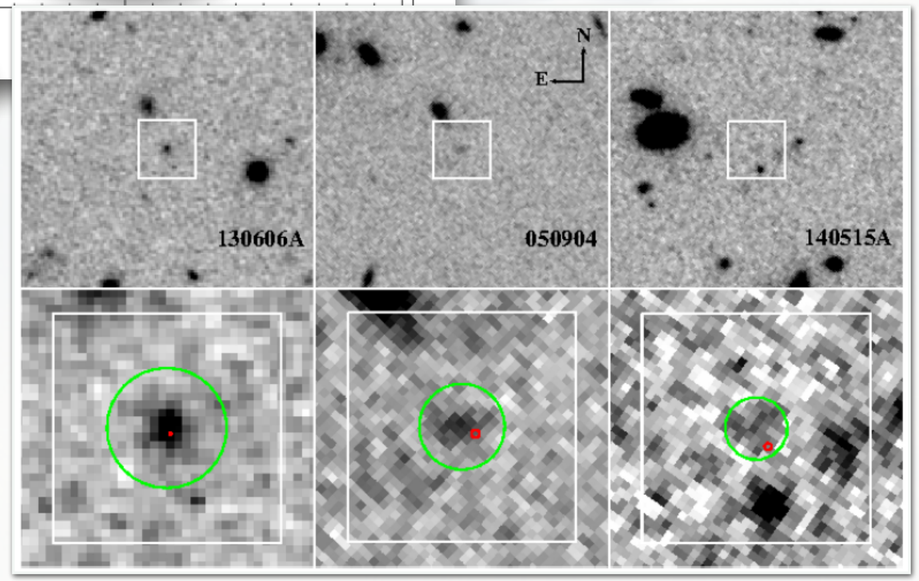


Identifier	130606A	050904	140515A[a]
$m_{\lambda_{obs}}$ (mag)	$26.34^{+0.14}_{-0.16}$	$27.56^{+0.18}_{-0.22}$	$28.30^{+0.25}_{-0.33}$

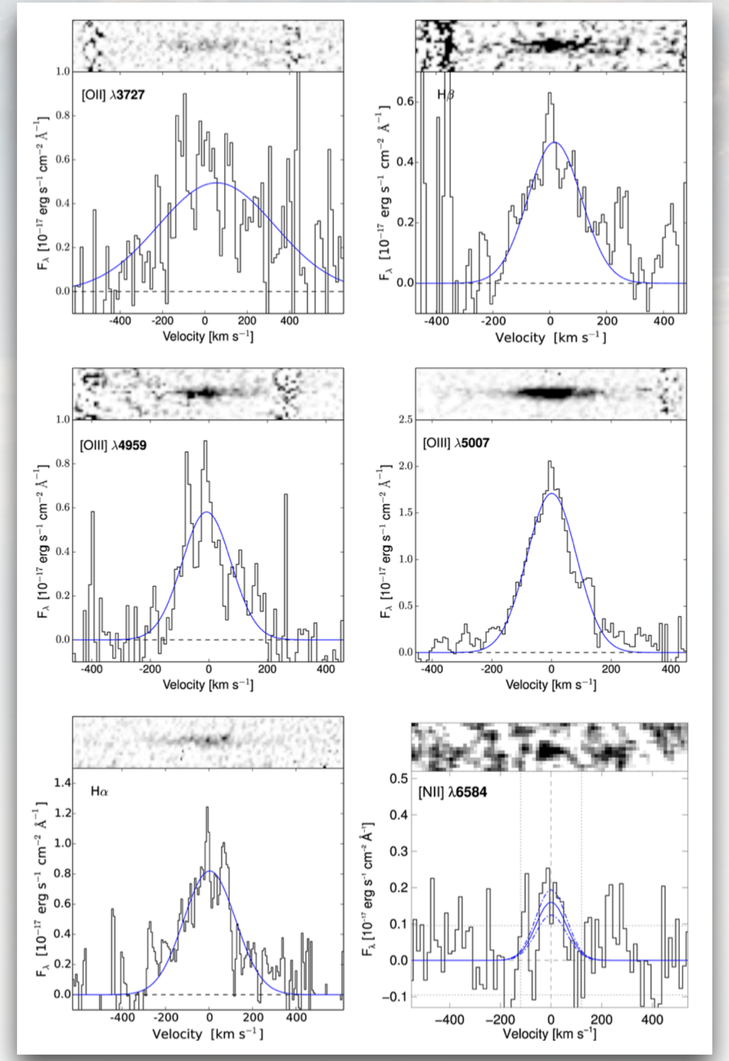
Long GRBs as tools to probe galaxies



McGuire+16



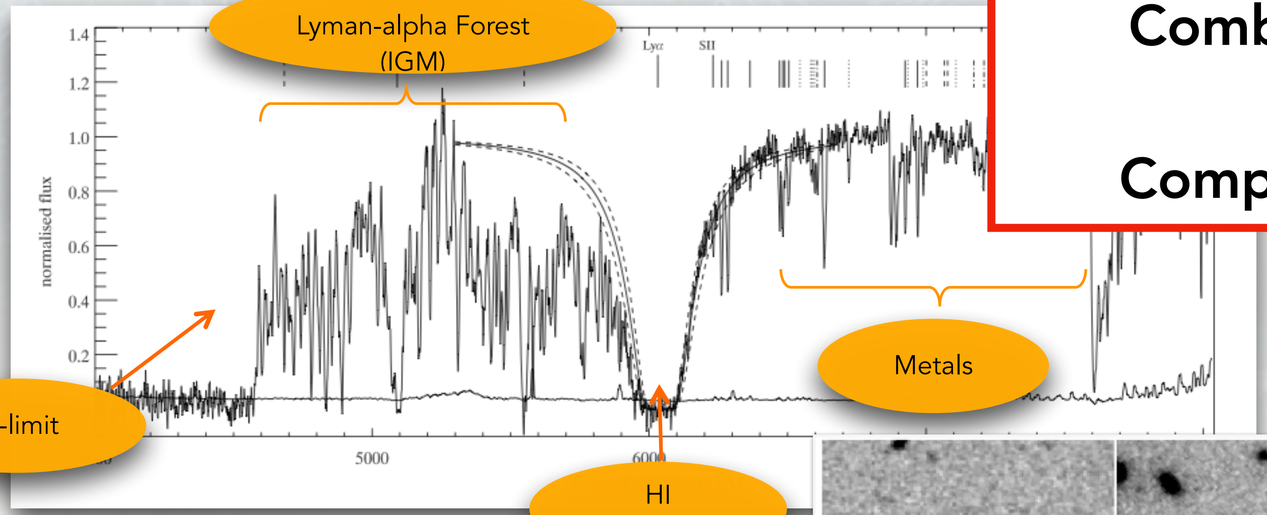
Identifier	130606A	050904	140515A[a]
$m_{\lambda_{obs}}$ (mag)	$26.34^{+0.14}_{-0.16}$	$27.56^{+0.18}_{-0.22}$	$28.30^{+0.25}_{-0.33}$



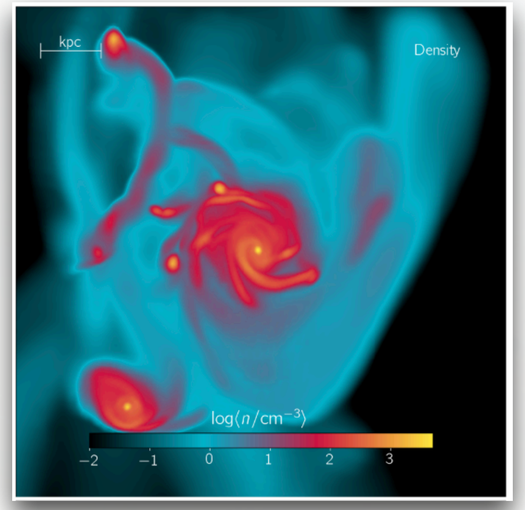
GRB121024A, z=2.3

Friis et al. 2015

Long GRBs as tools to probe galaxies

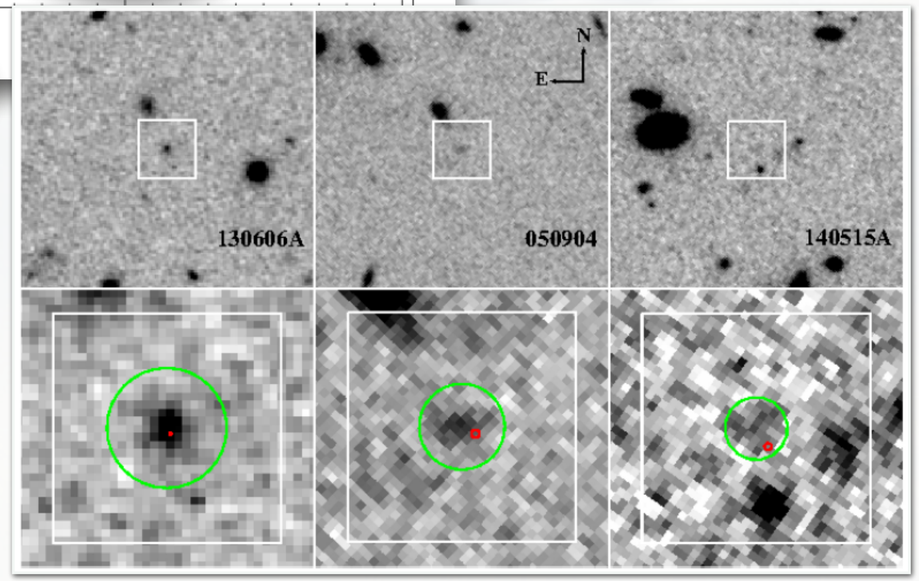


Combine the information
&
Compare with simulations

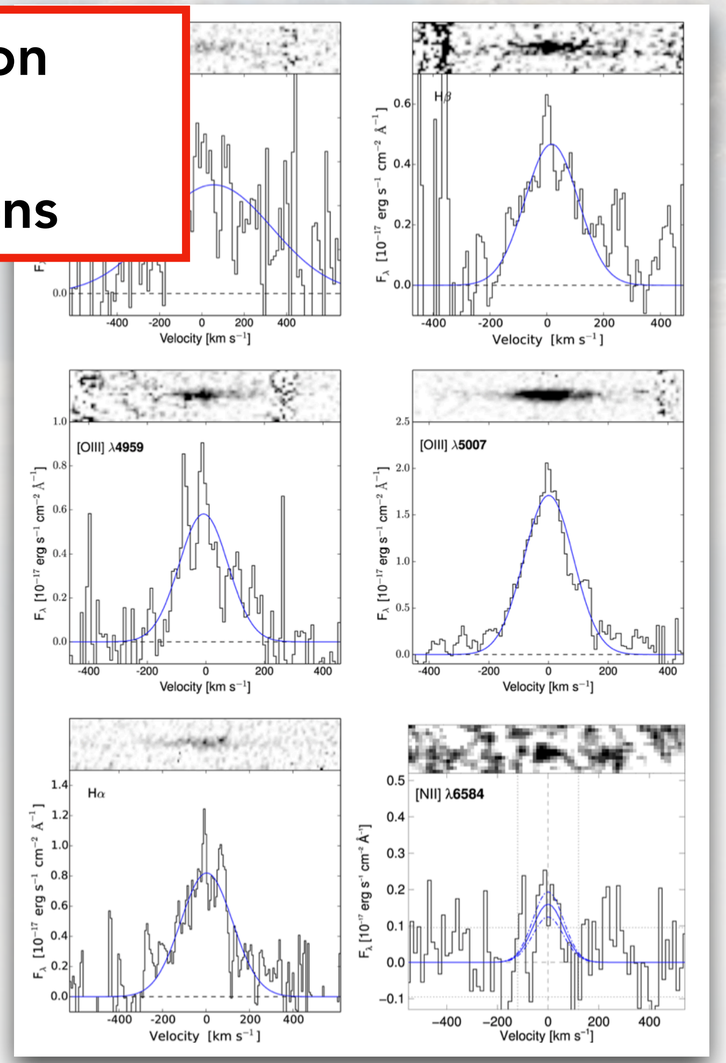


Pallottini+17

McGuire+16



Identifier	130606A	050904	140515A[a]
$m_{\lambda_{obs}}$ (mag)	$26.34^{+0.14}_{-0.16}$	$27.56^{+0.18}_{-0.22}$	$28.30^{+0.25}_{-0.33}$



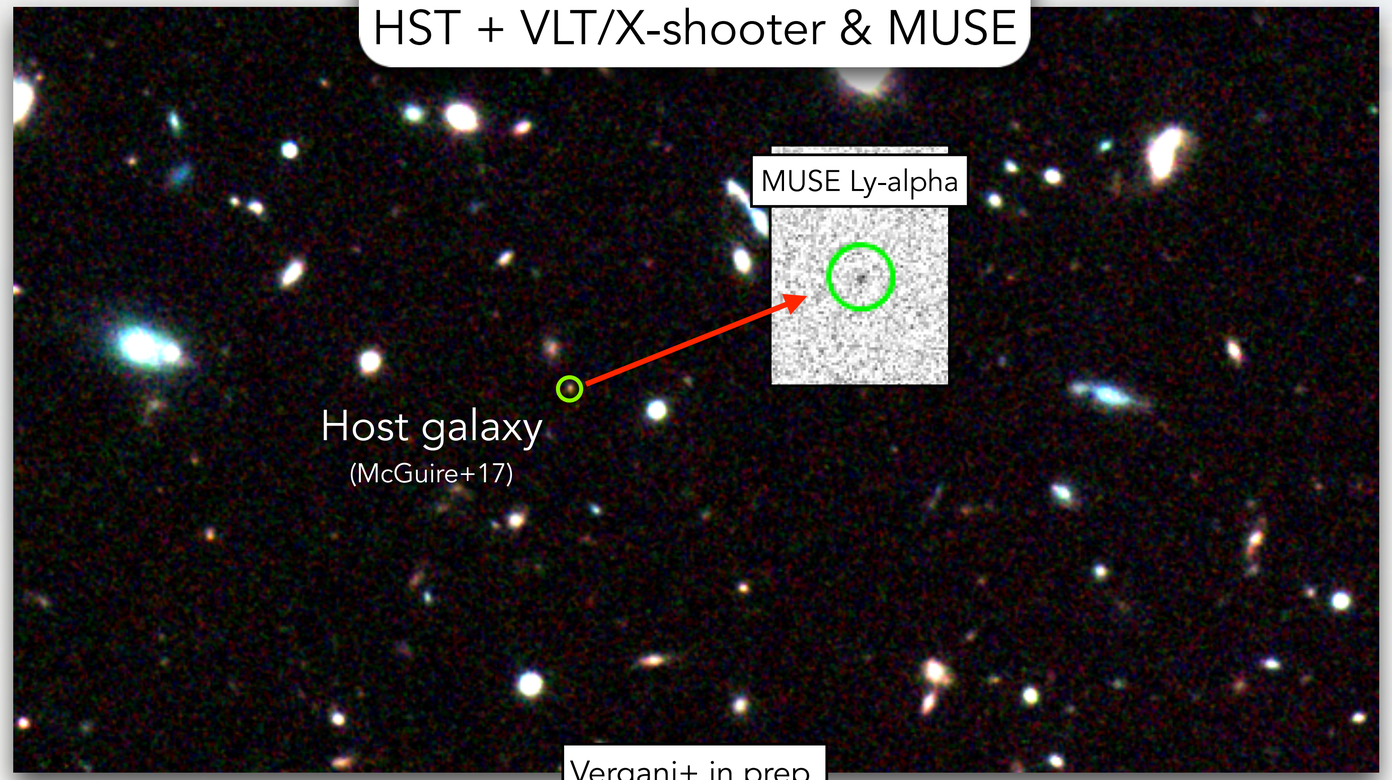
GRB121024A, z=2.3
Friis et al. 2015

Long GRBs as tools to probe galaxies

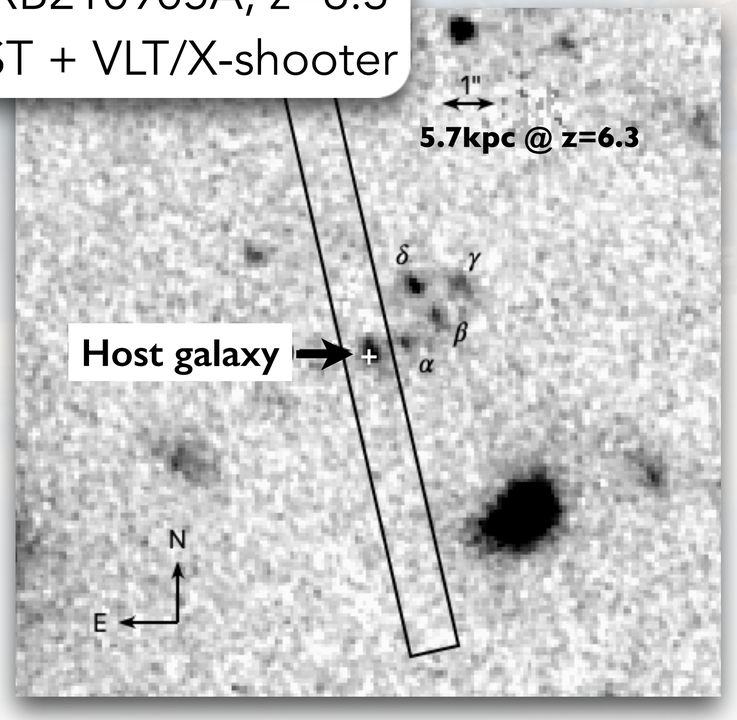
JWST !

Unique possibility to combine the information on the neutral and ionized gas

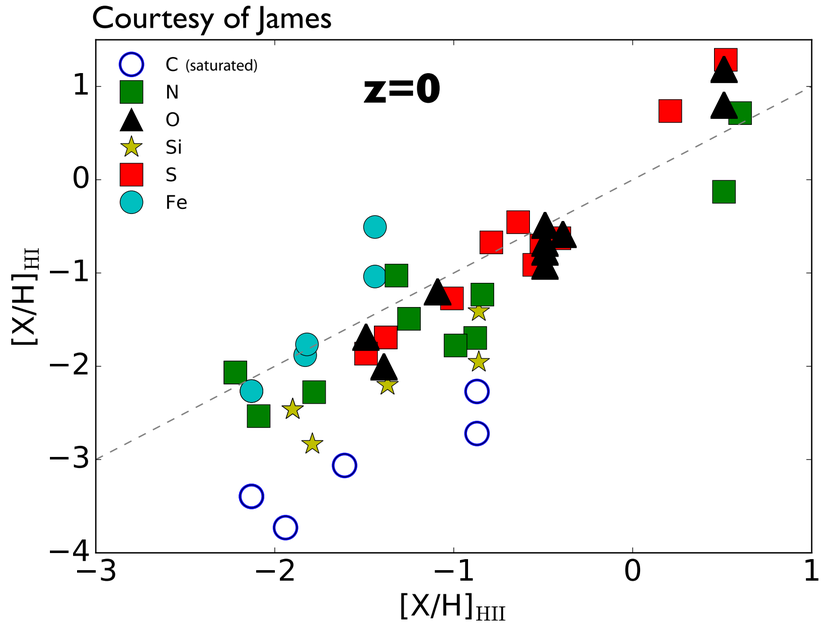
GRB130606A, z=5.9
HST + VLT/X-shooter & MUSE



GRB210905A, z=6.3
HST + VLT/X-shooter



Long GRBs as tools to probe galaxies



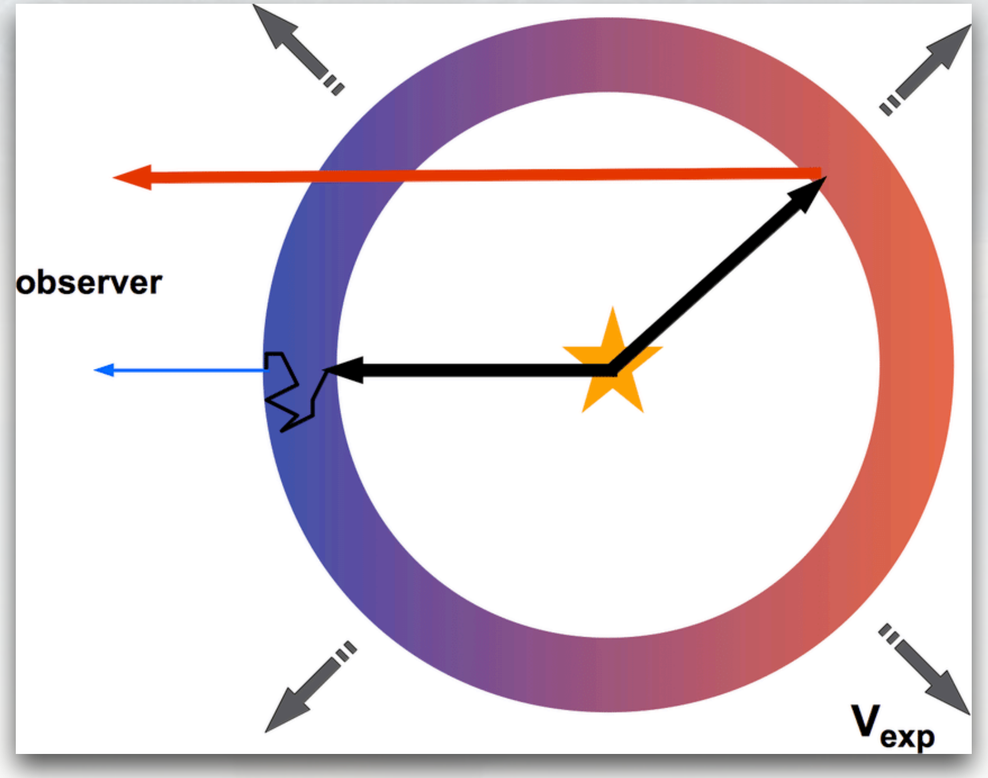
Mapping emission and absorption line metallicities onto the same universal scale

JWST - 22.5 hrs - PI: P. Schady

Neutral gas vs ionized gas metallicity @ **z=2-4**

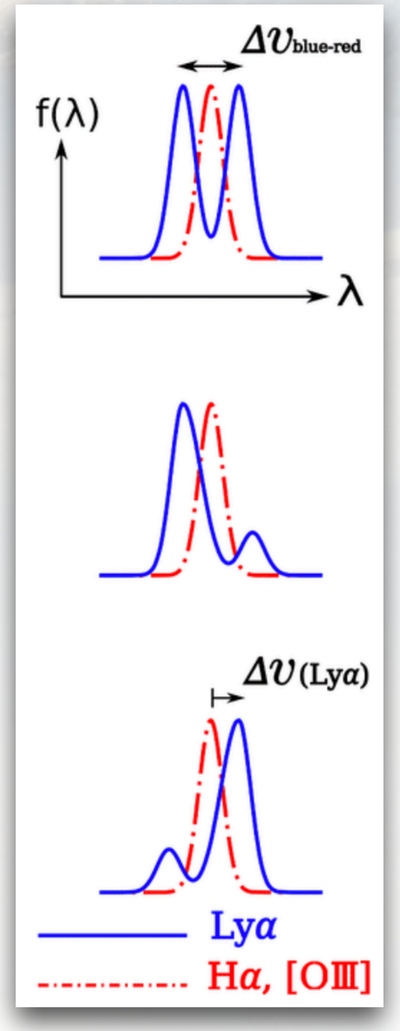
Lyman-alpha emission studies

Barnes+14



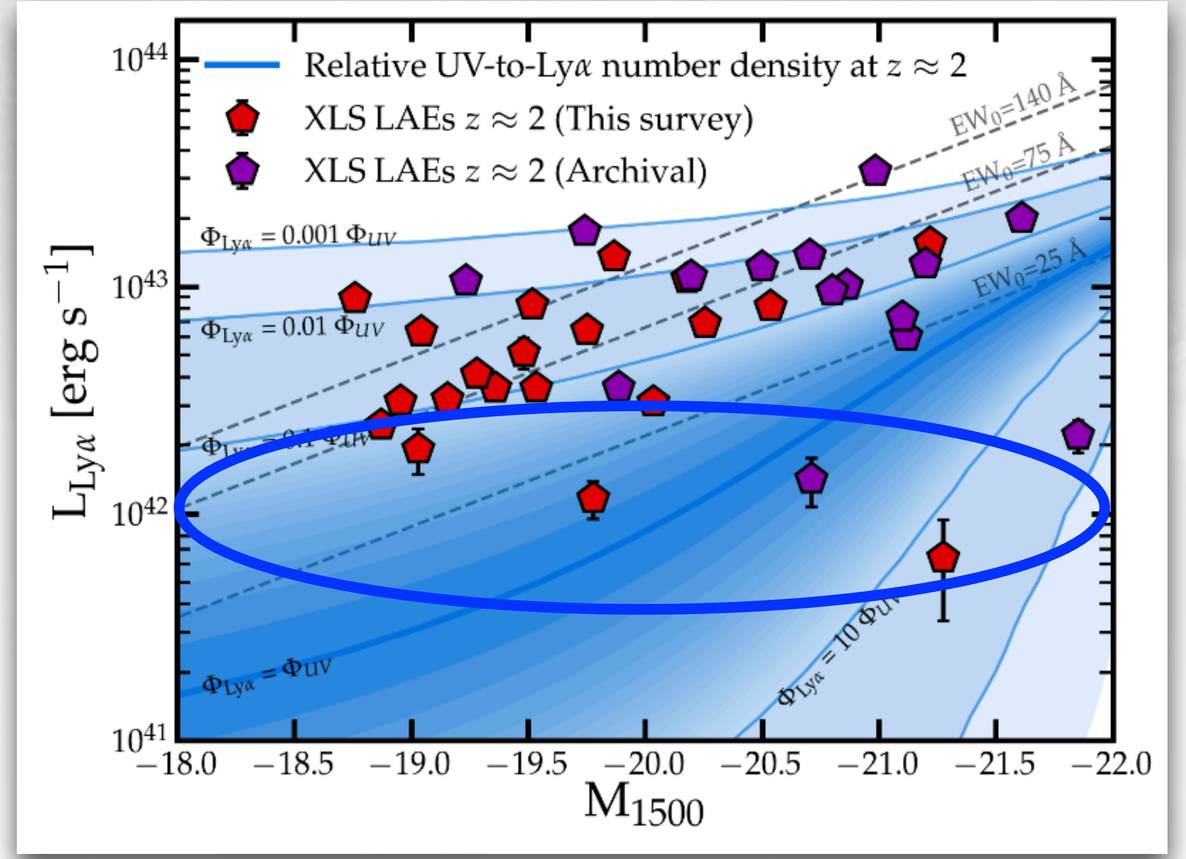
NHI
Gas velocity
Dust
Gas temperature

Yang+14

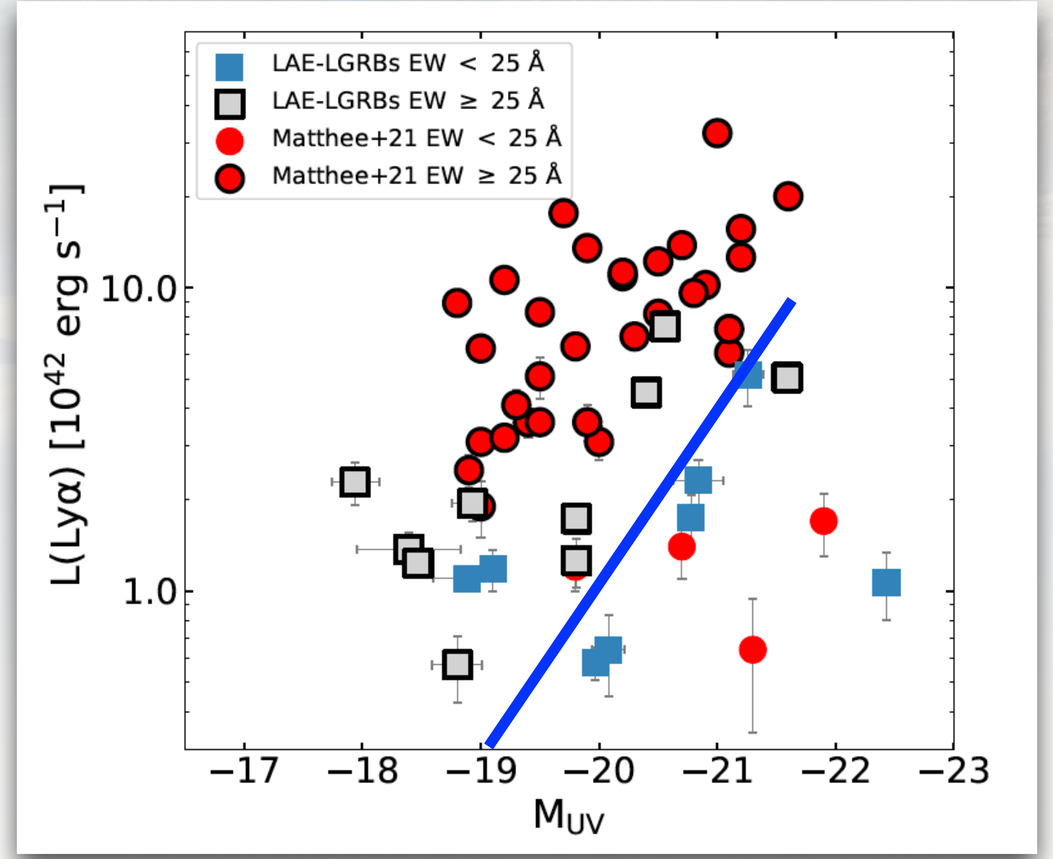


Lyman-alpha emission studies

Matthee et al. 2021



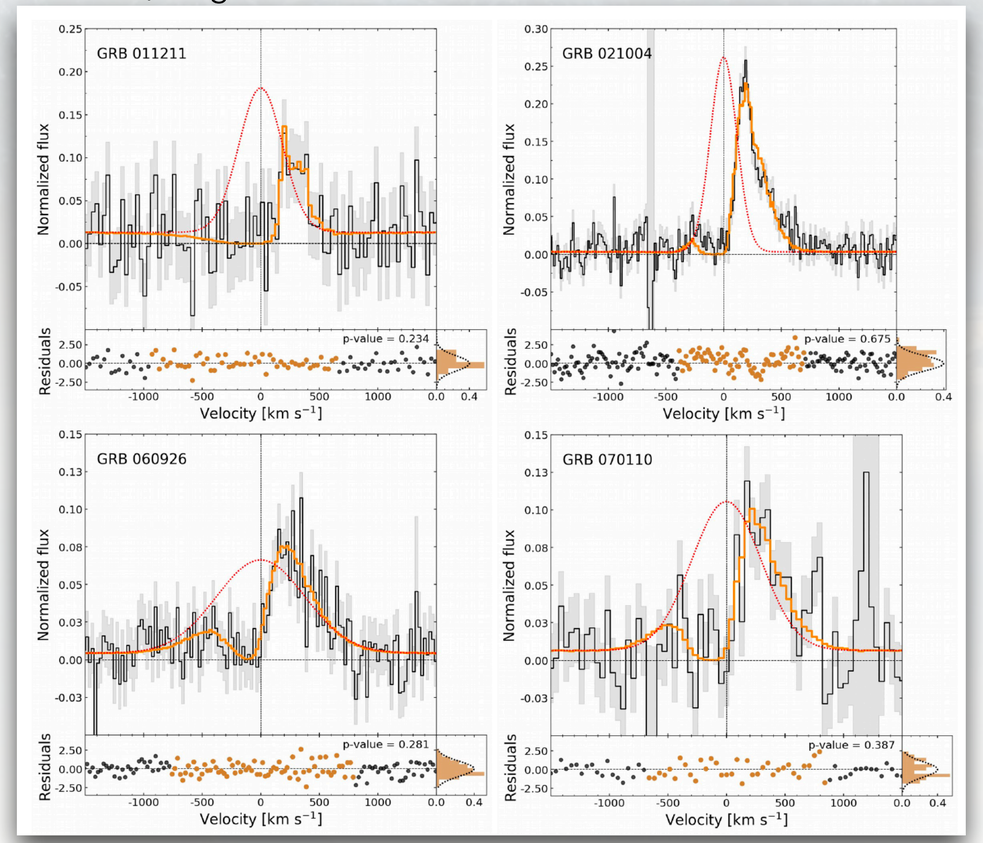
Vielfaure, Vergani et al. 2021



GRB hosts that are LAE represent much better the population of UV-selected galaxies

Lyman-alpha emission studies

Vielfaure, Vergani et al. 2021

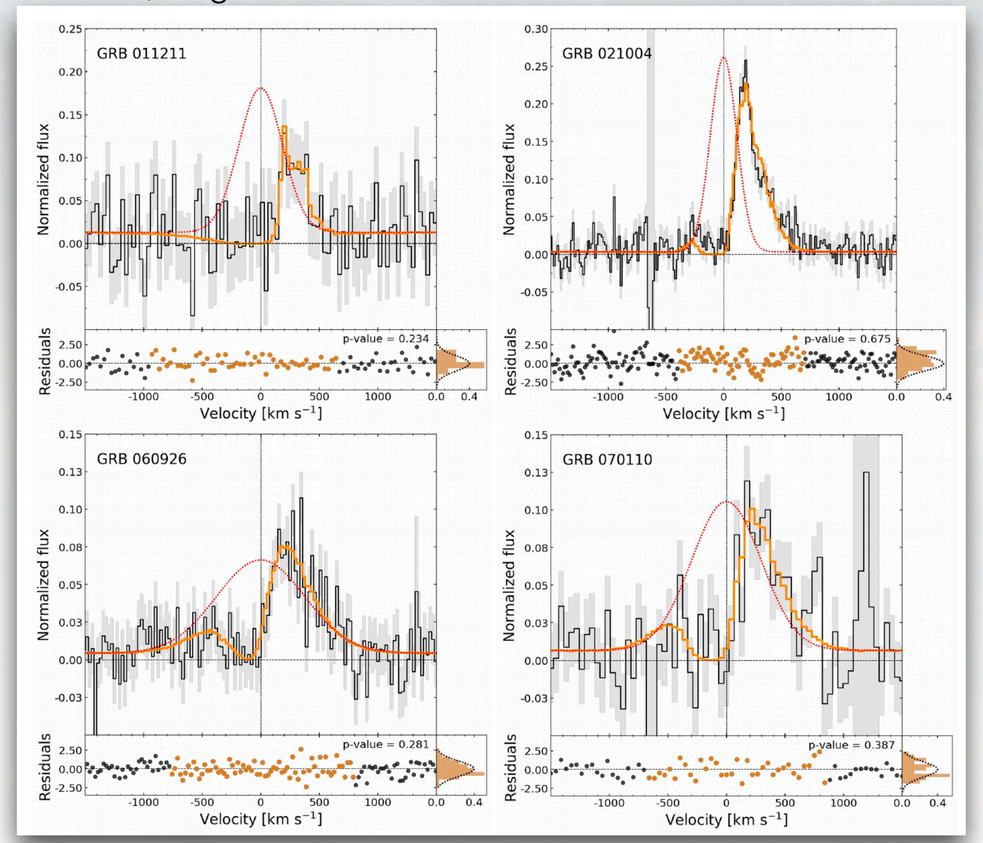


Output of the Lyman-alpha line fit :

- **Redshift**
- **NHI**
- **Dust**
- **Velocity of the gas**
- **Temperature of the gas**
- **Intensity, FWHM of the intrinsic Lyα**

Lyman-alpha emission studies

Vielfaure, Vergani et al. 2021



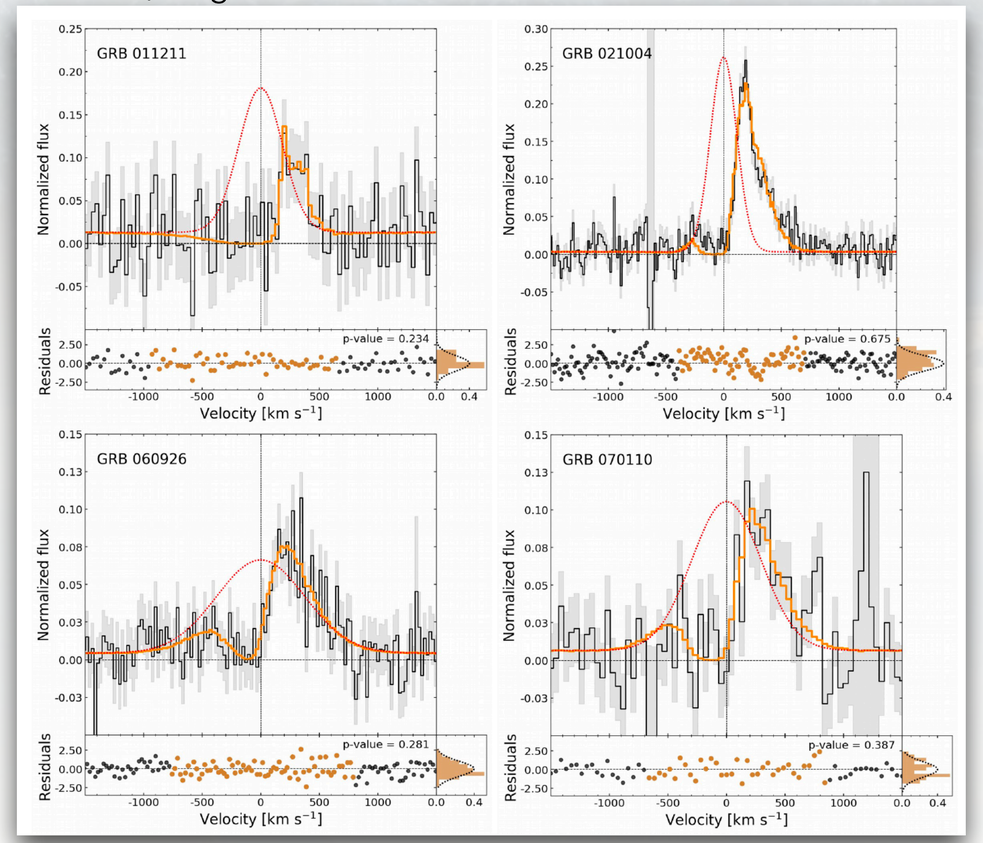
LGRBs to study Lyman-alpha emission and test models

Input of the Lyman-alpha line fit :

- Redshift
- NHI
- Dust
- Velocity of the gas
- Temperature of the gas
- Intensity, FWHM of the intrinsic Lyα

Lyman-alpha emission studies

Vielfaure, Vergani et al. 2021



LGRBs to study Lyman-alpha emission and test models

Input of the Lyman-alpha line fit :

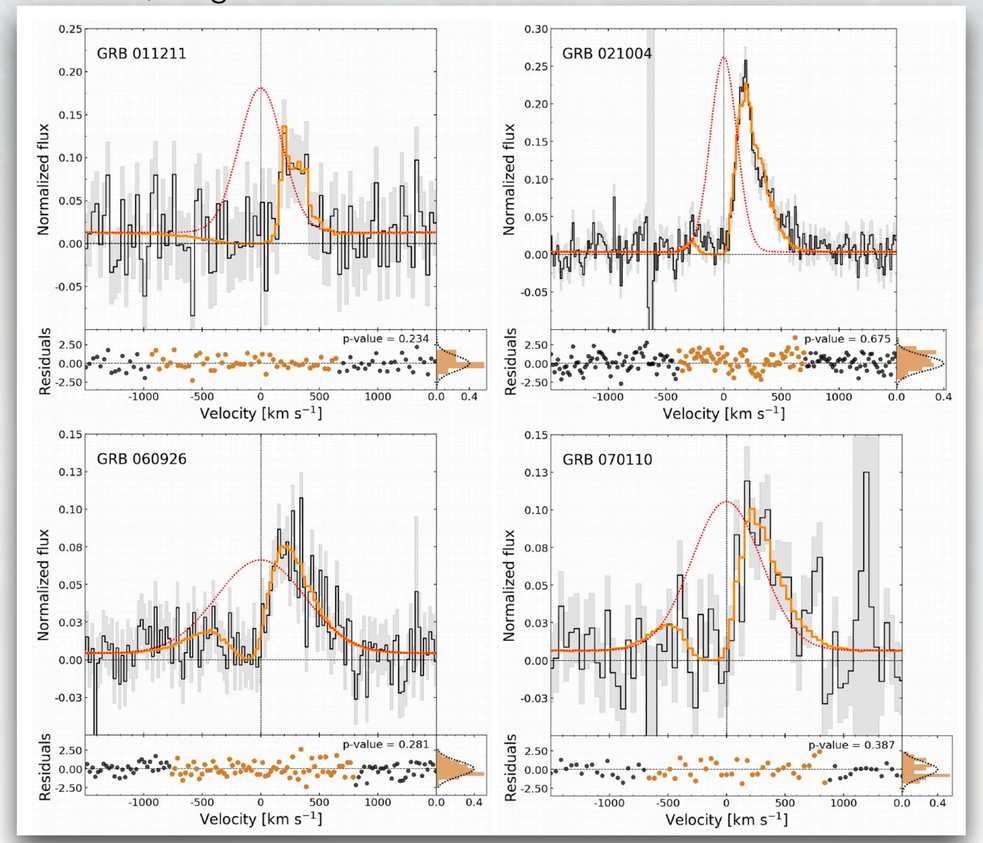
- **Redshift**
- **NHI**
- **Dust**
- **Velocity of the gas**
- **Temperature of the gas**
- **Intensity, FWHM of the intrinsic Lyα**

Parameters determined from GRB host and afterglow spectra

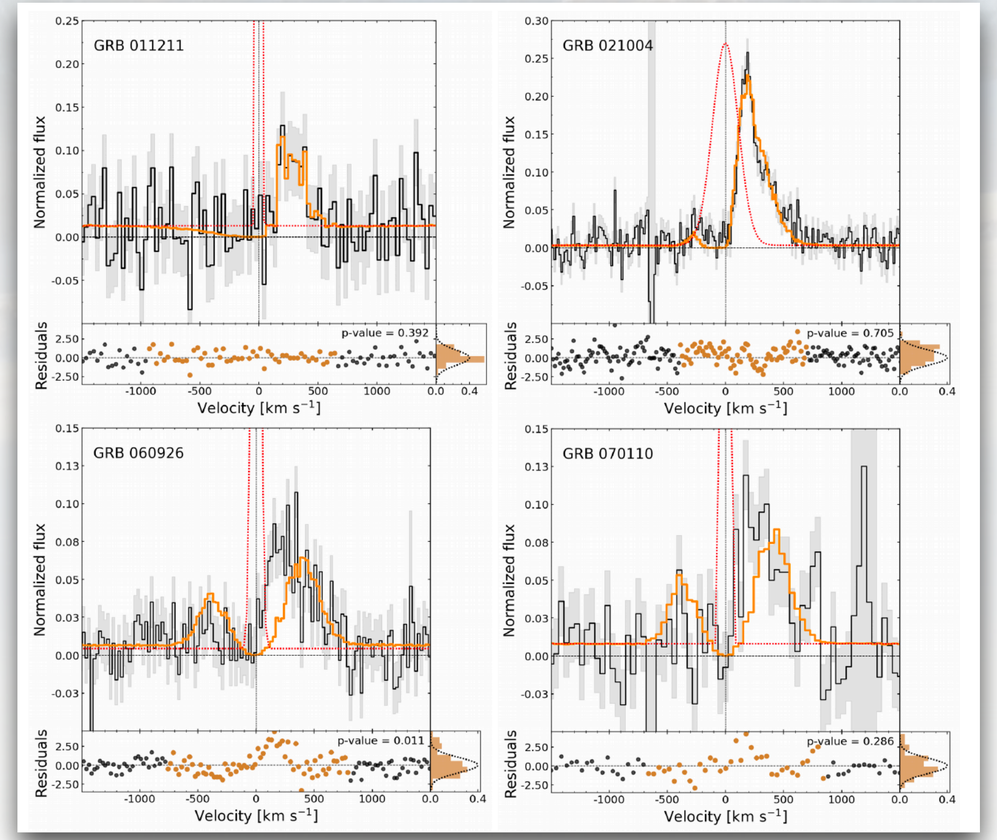
GRB happen in massive star regions
Statistically we probe photon escaping paths

Lyman-alpha emission studies

Vielfaure, Vergani et al. 2021



Free parameters
Check the results with measures

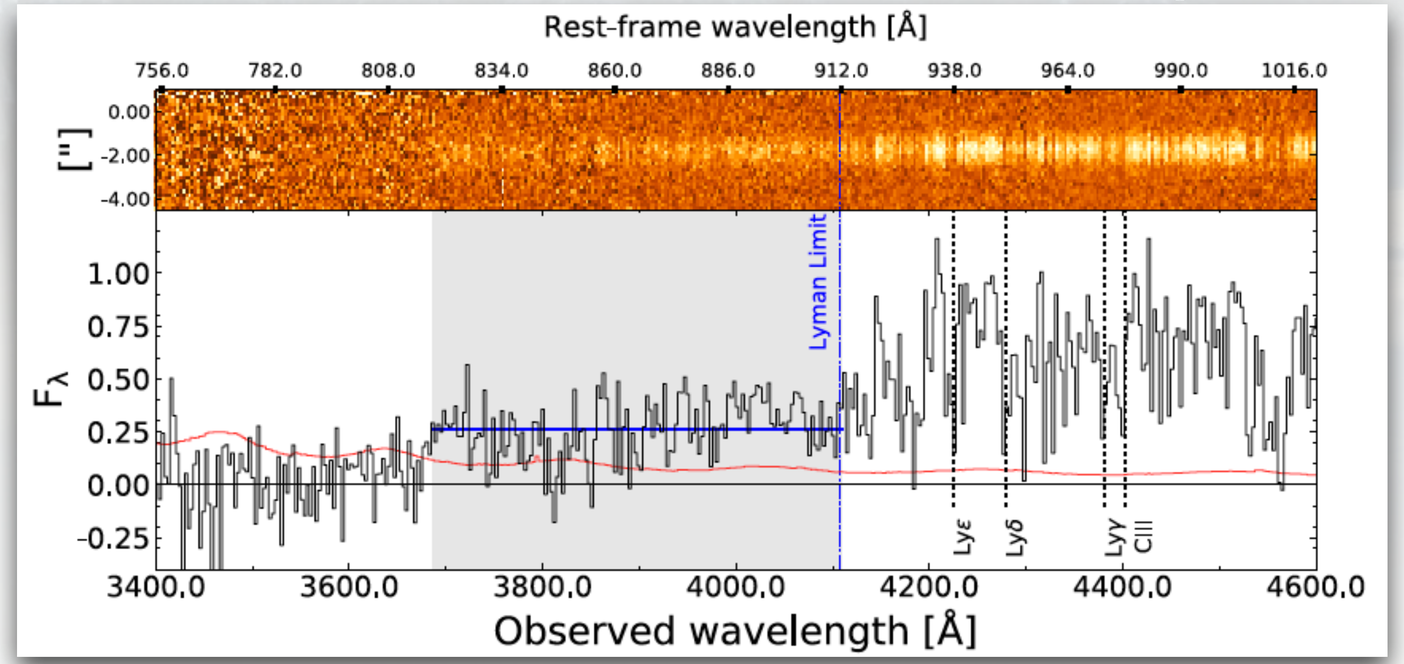


Parameters constrained
by measures

Lyman-continuum studies

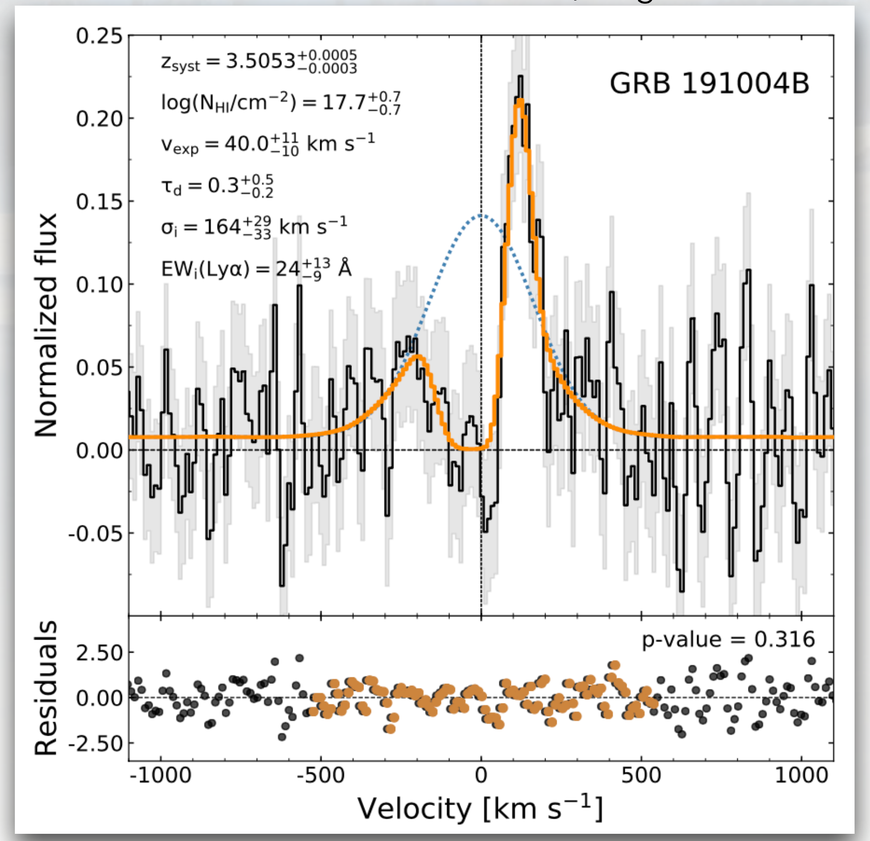
GRB191004B, z=3.5

Vielfaure, Vergani et al. 2020



Lyman-alpha emission

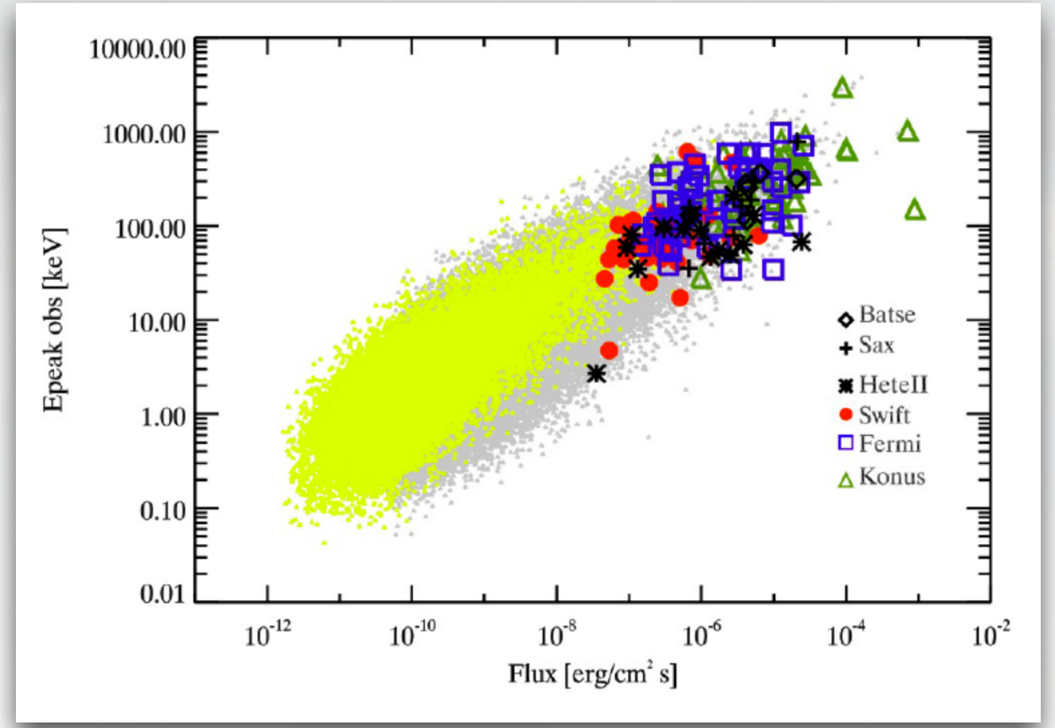
Vielfaure, Vergani et al. 2020



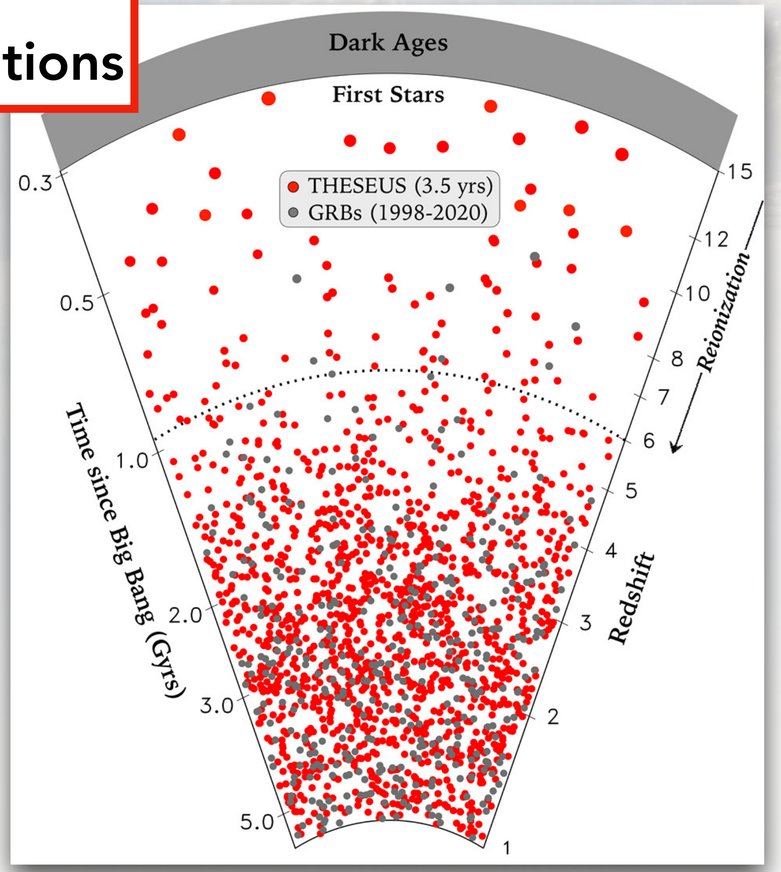
Long GRBs as tools to probe galaxies

Limited by number of events!
Need of satellites with new specifications

Ghirlanda+ 2015



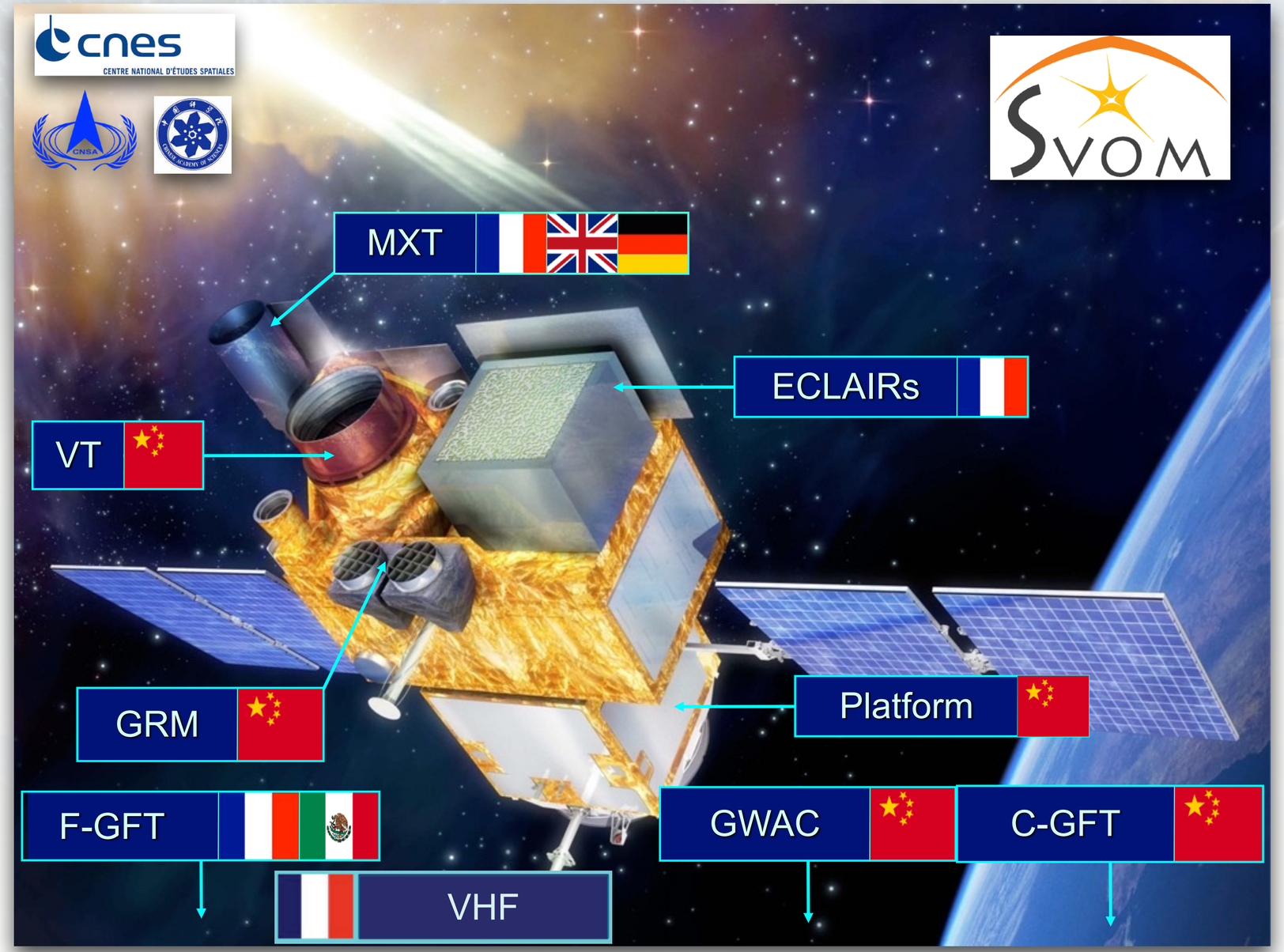
THESEUS YB



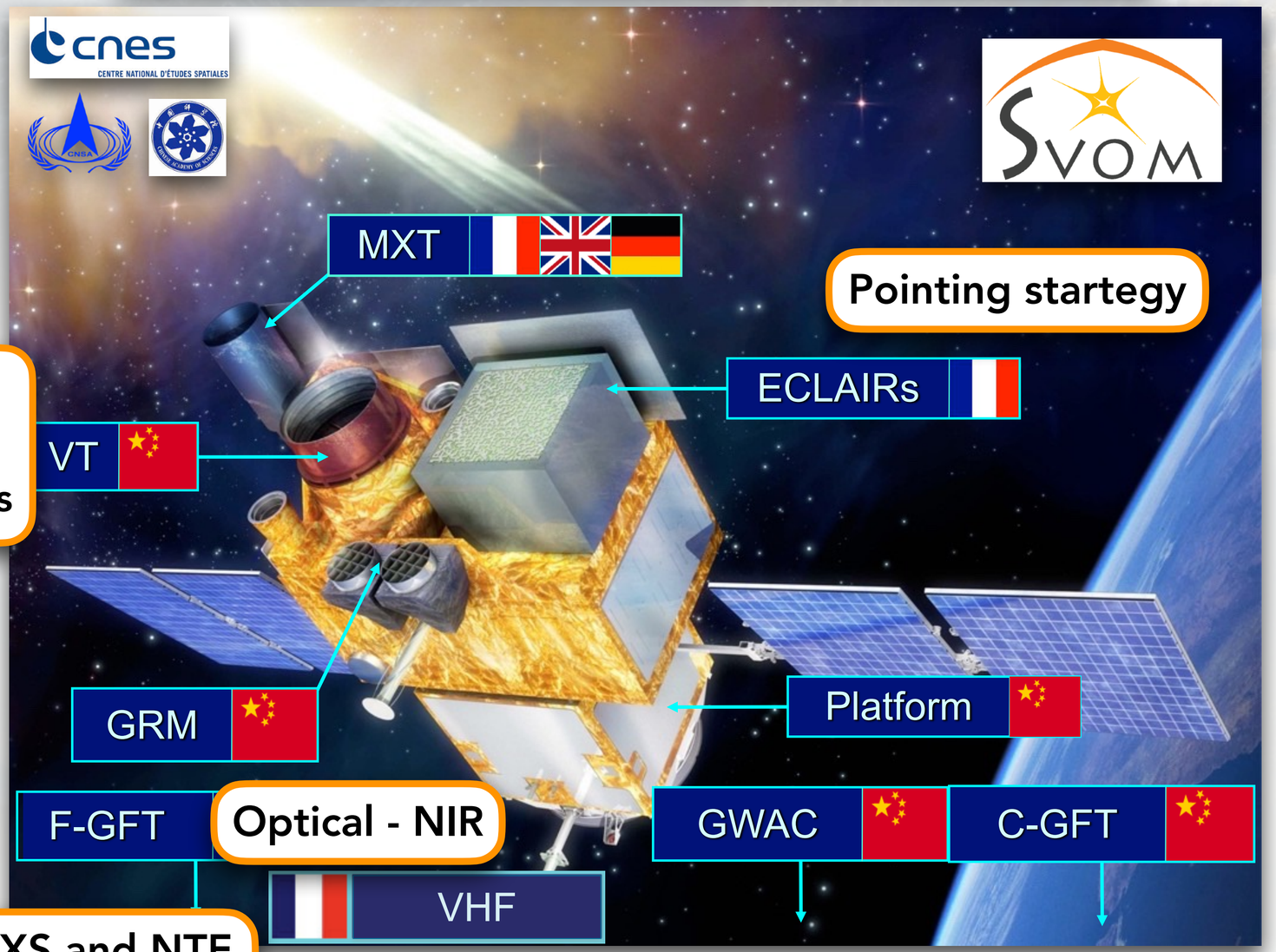
theseus
TRANSIENT HIGH ENERGY SKY AND EARLY UNIVERSE SURVEYOR

www.isdc.unige.ch/theseus

In the meanwhile…



Enlarge the fraction of GRBs with redshift
(*Swift* ~30%)



Pointing startegy

400-1000nm
(2 bands)
m=22.5 in 300s

+ MoUs with SOXS and NTE

Thank you

Long GRBs as tools to probe galaxies

Bouwens+22