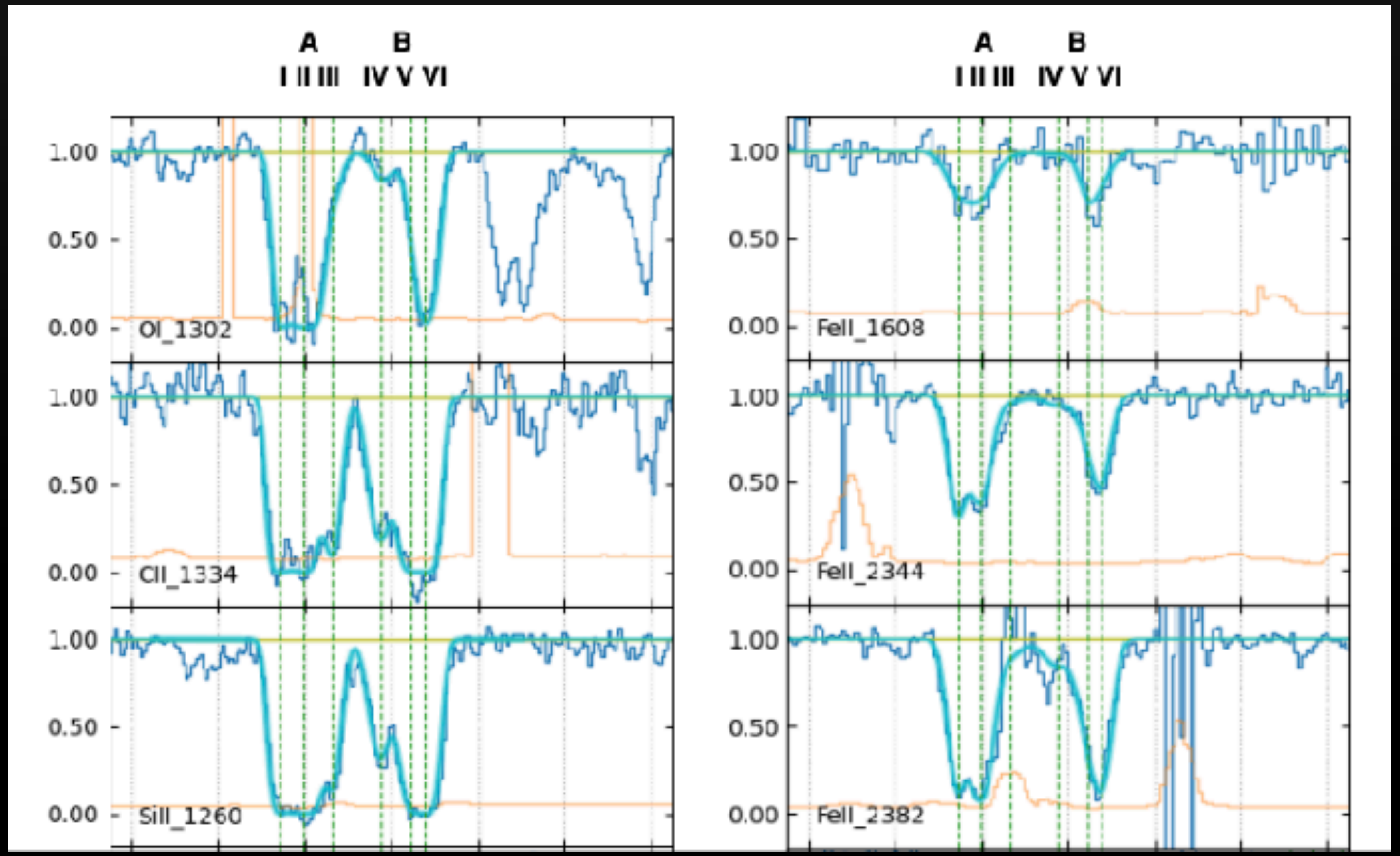
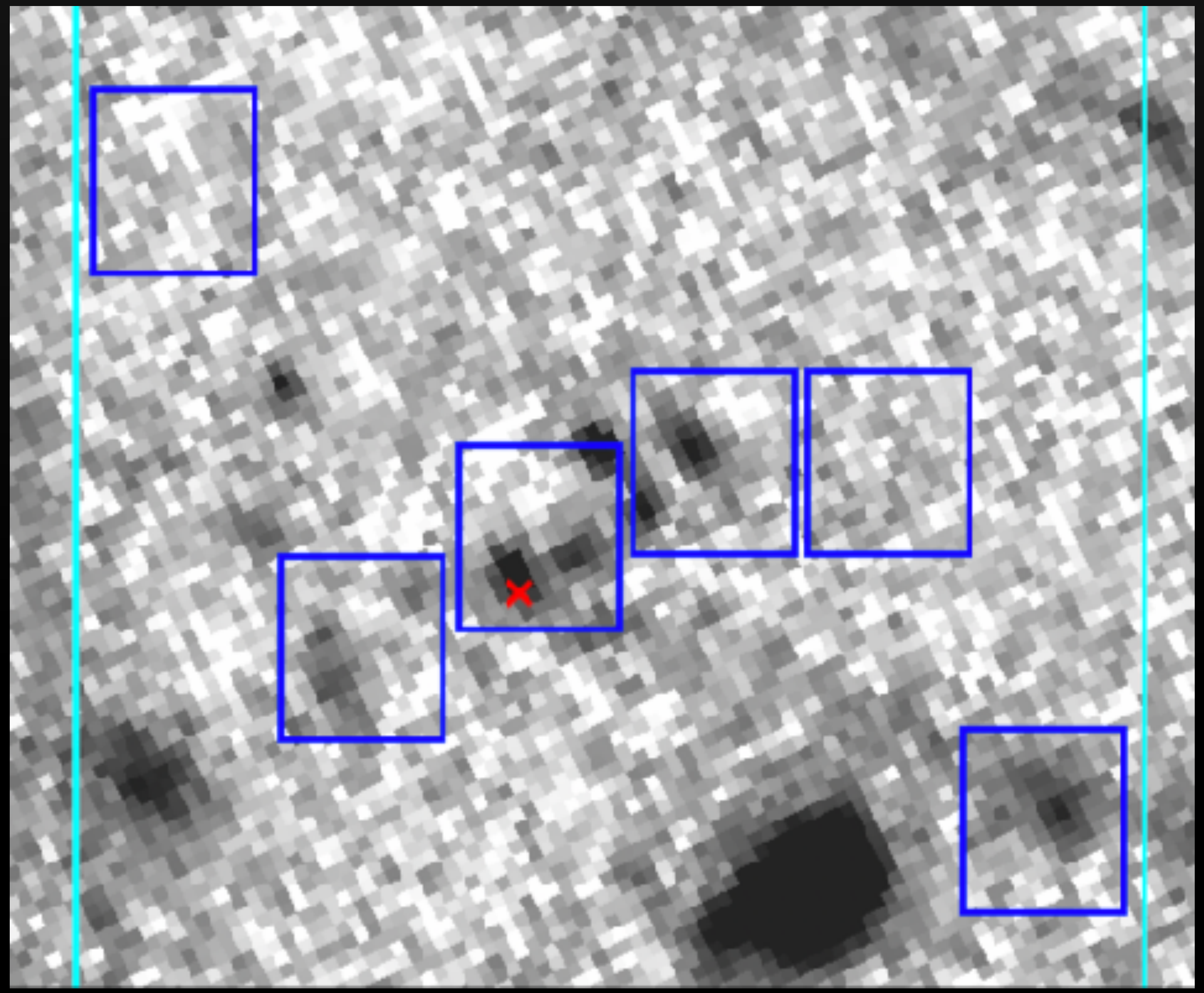
THE ENVIRONMENT OF TRANSIENTS HOST GALAXIES AT HIGH REDSHIFTS AS OBSERVED BY SHARP





L. Izzo (INAF-OACN & DARK/NBI)

Unveiling the Universe with SHARP - Oct 2 - Milano

Introduction

What kind of transients hosts do we expect to observe with SHARP?

Explosions of very massive stars' life

Explosion (partially) induced by a relativistic jet

Astrophysical sources:
- Long GRBs and their associated Ic-BL SNe
- Super-luminous SNe
- Pop-III like / pair-instability explosions

(Courtesy NASA)

High-z environments to investigate their progenitors

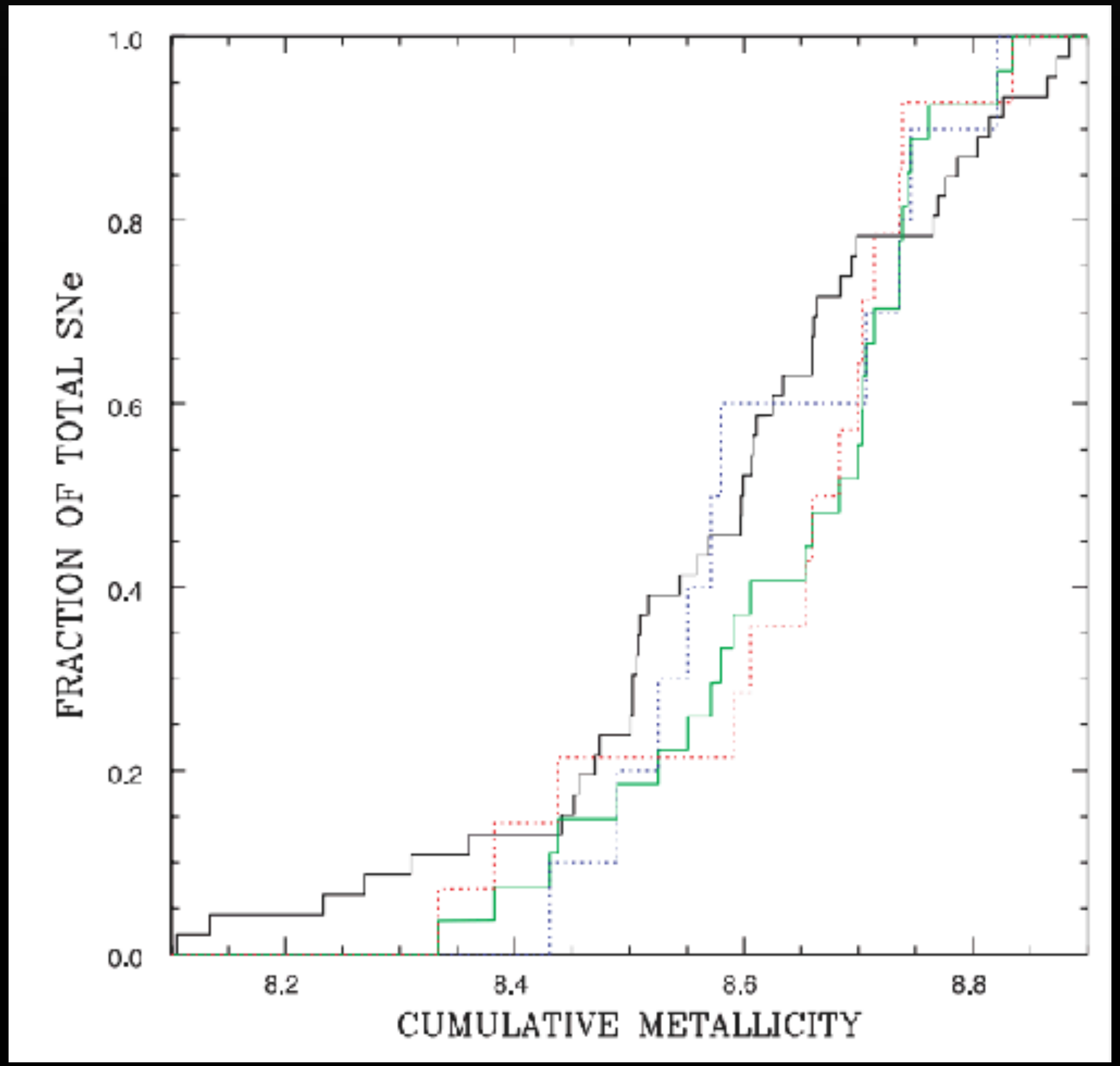
Introduction

Global host galaxies studies have been used to compare progenitor with environments

models with the expected environments

However, inferred physical properties from global studies may not be representative of the *conditions in the vicinity of the progenitor*

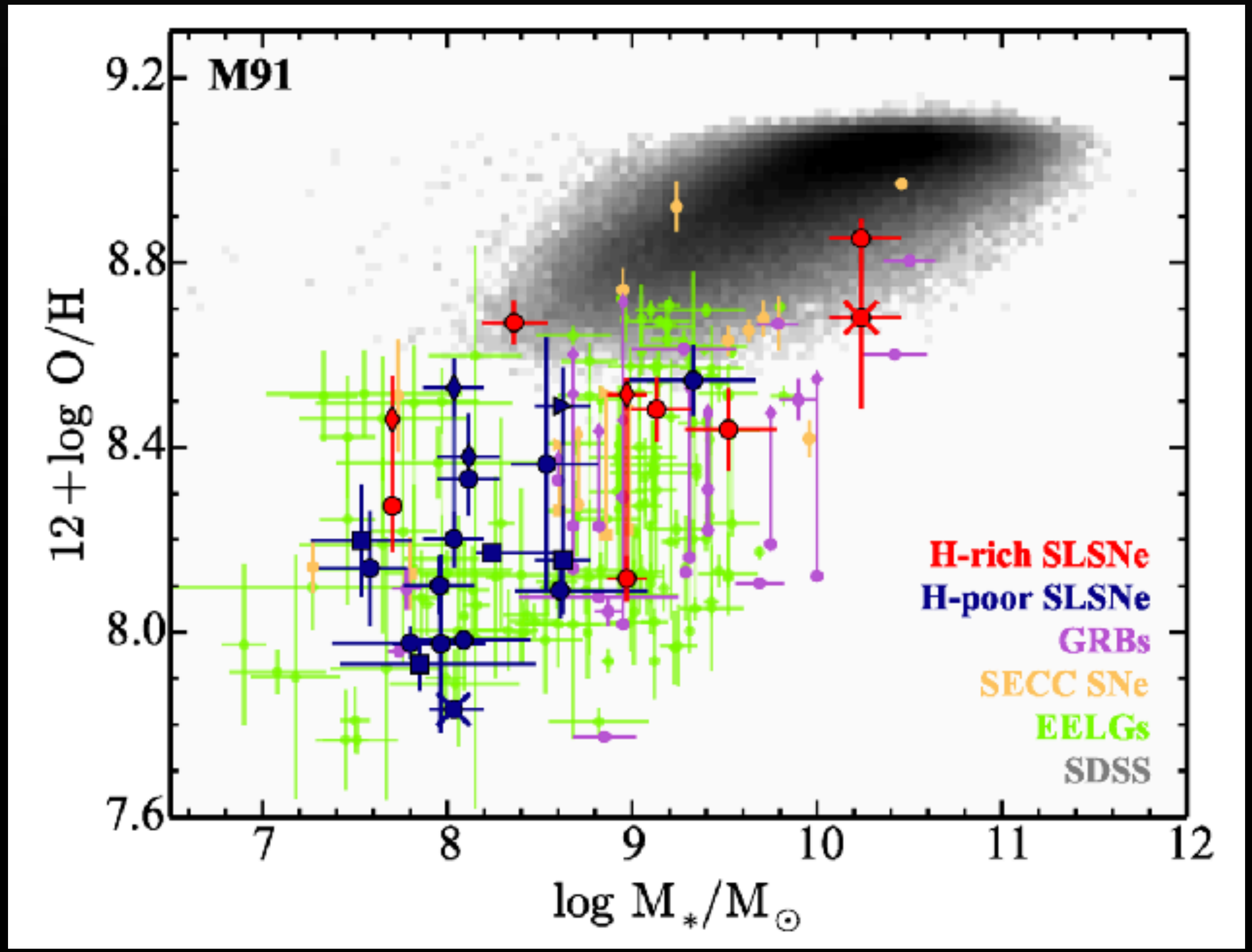
(Anderson+ 2010)



steep metallicity gradients and inhomogeneities may result in galaxy-integrated metallicities that are different to the metallicity at the position of the SN

(Schady 2021)

(Leloudas+ 2015)



Introduction

Global host galaxies studies have been used to compare progenitor with environments

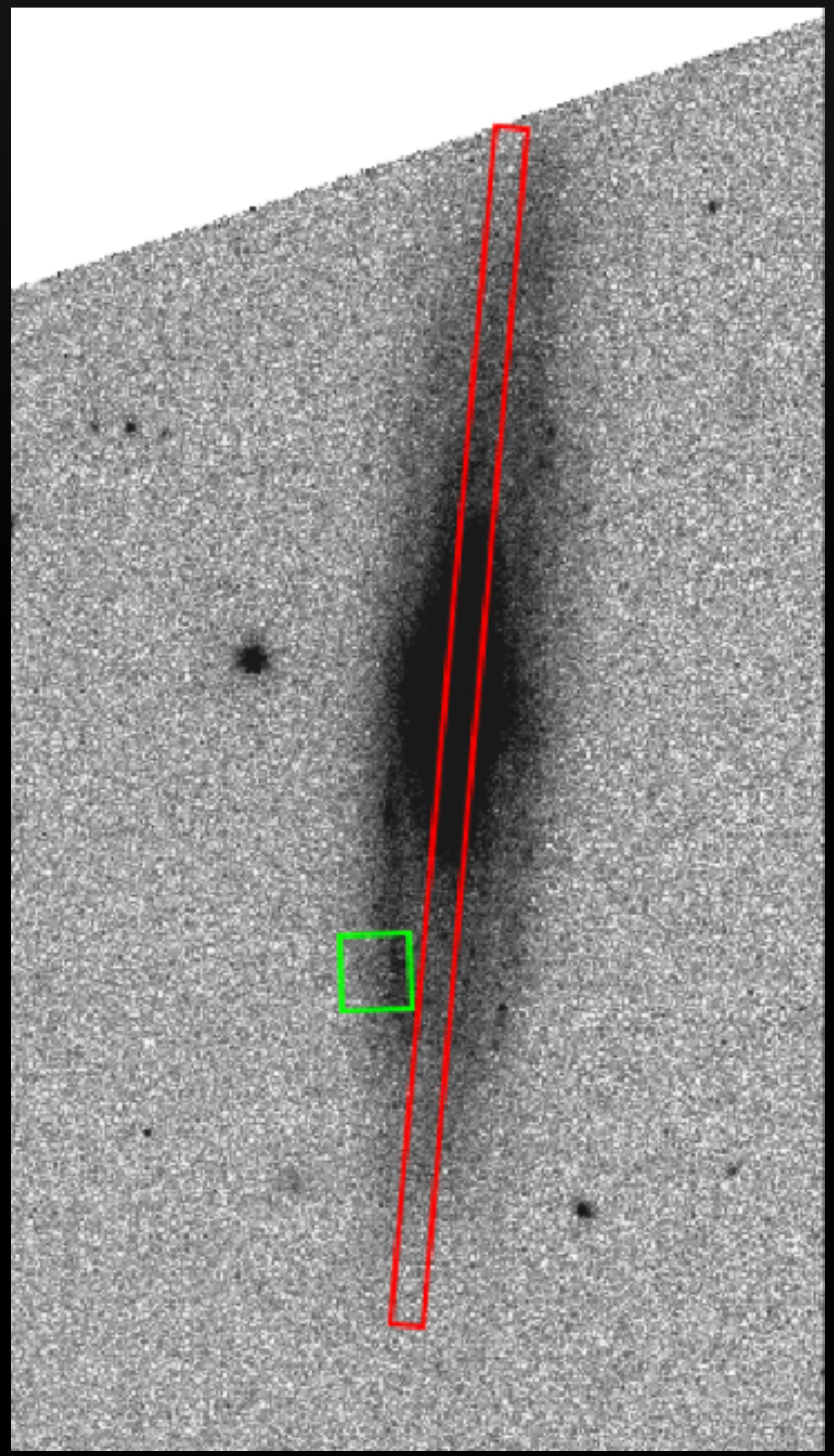
models with the expected environments

Properties of the underlying stellar populations at SN location will be averaged out if based on not spatially-resolved observations

GRB1908298A

Host galaxy

HST & IFU data



(Schady 2021, LI+ in prep.)

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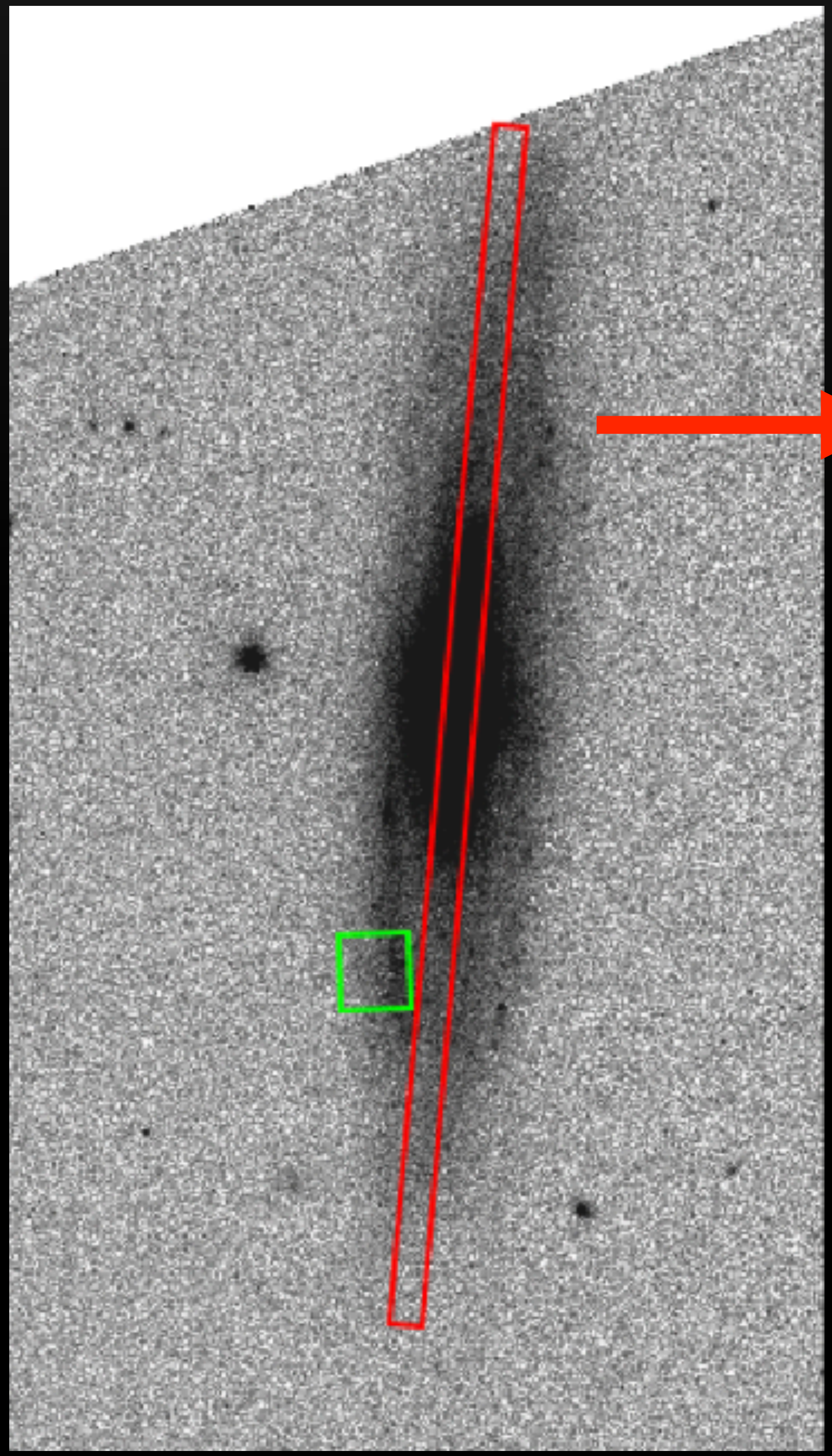

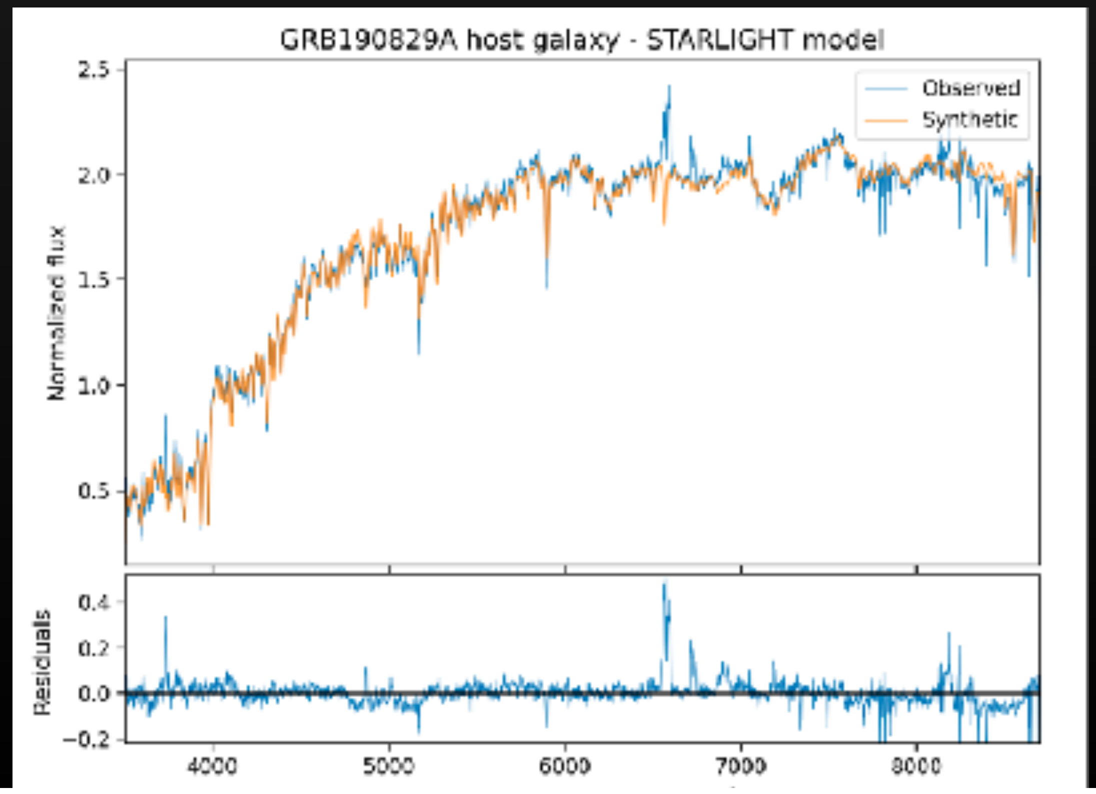

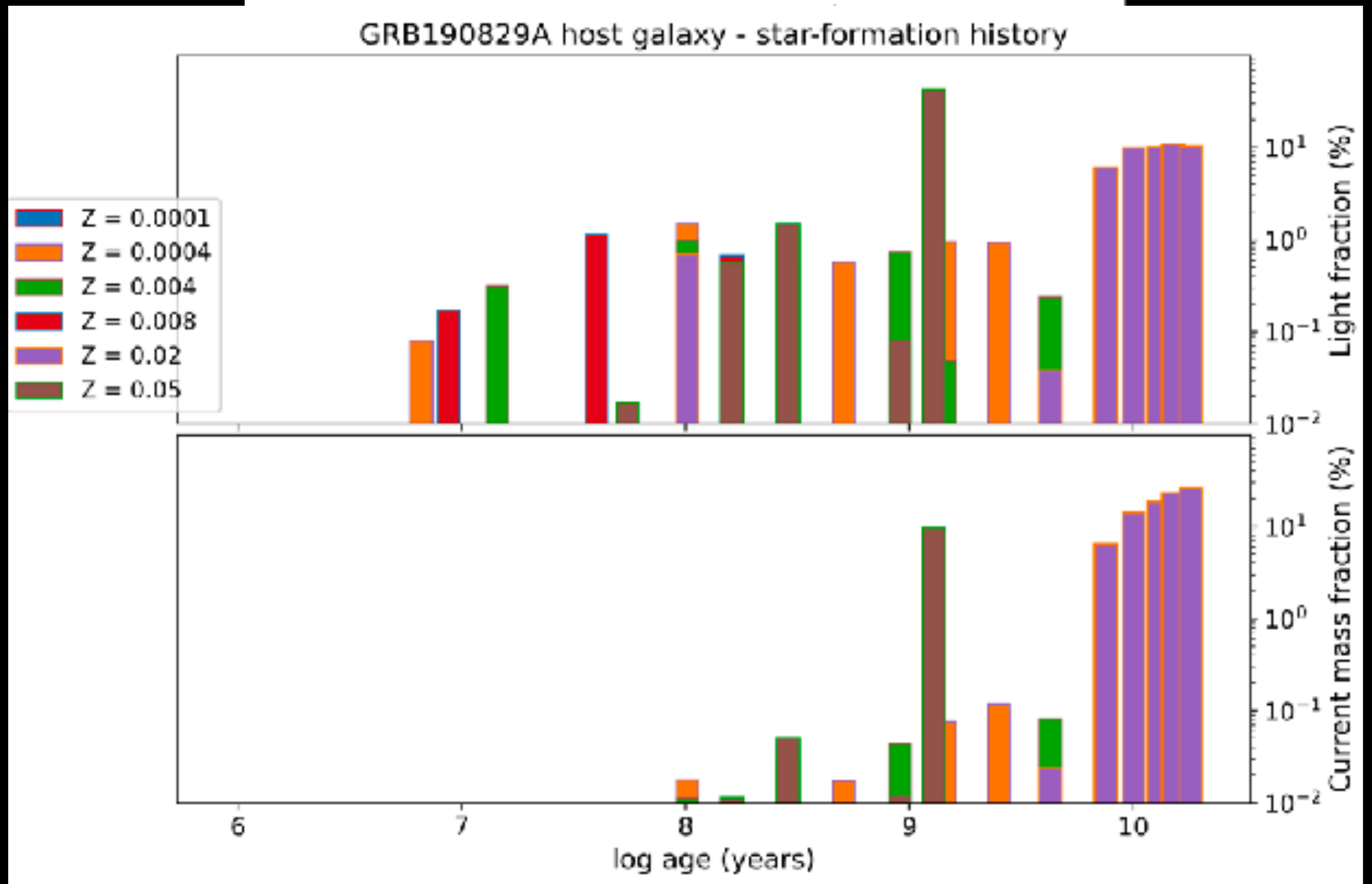

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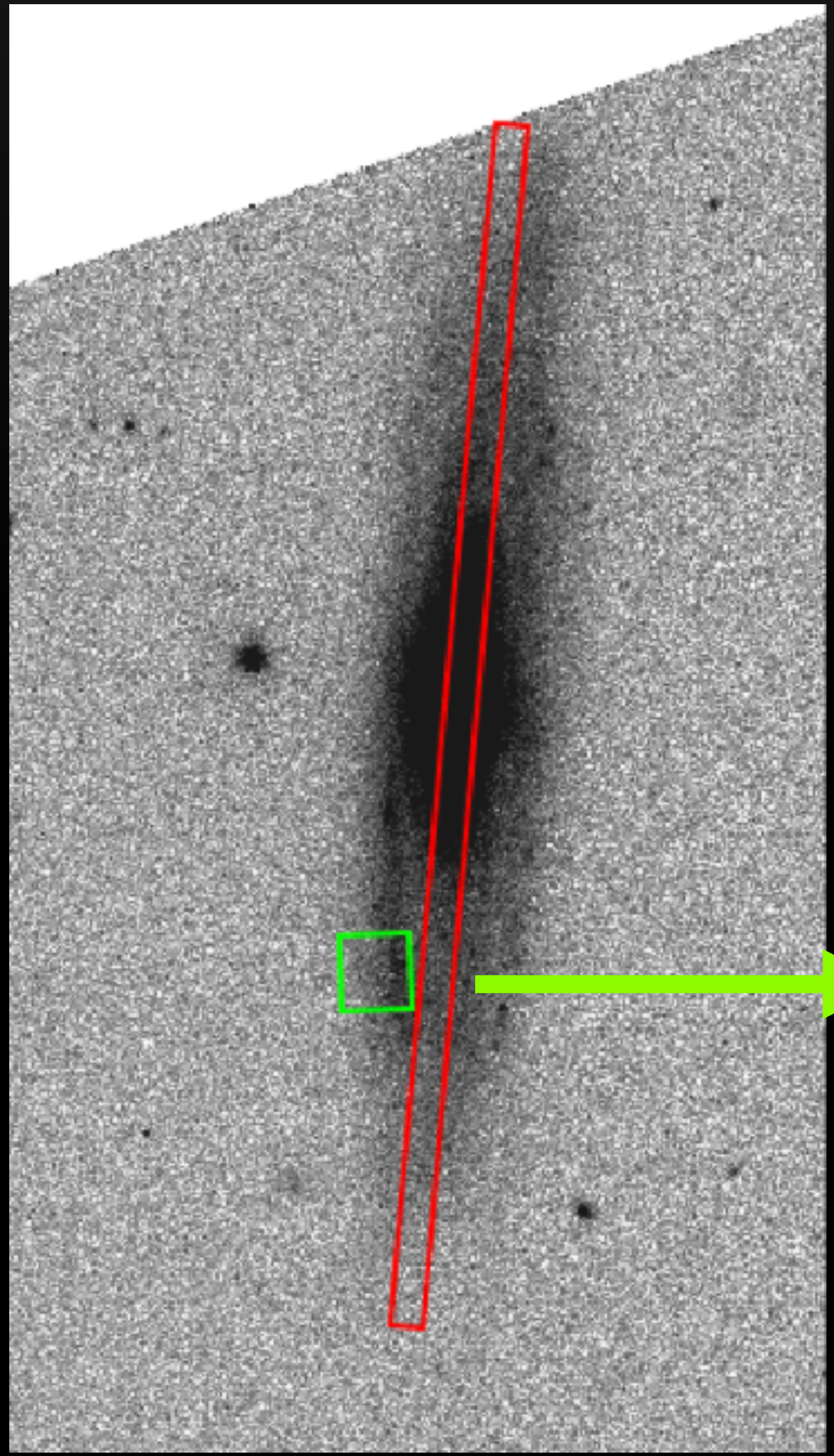
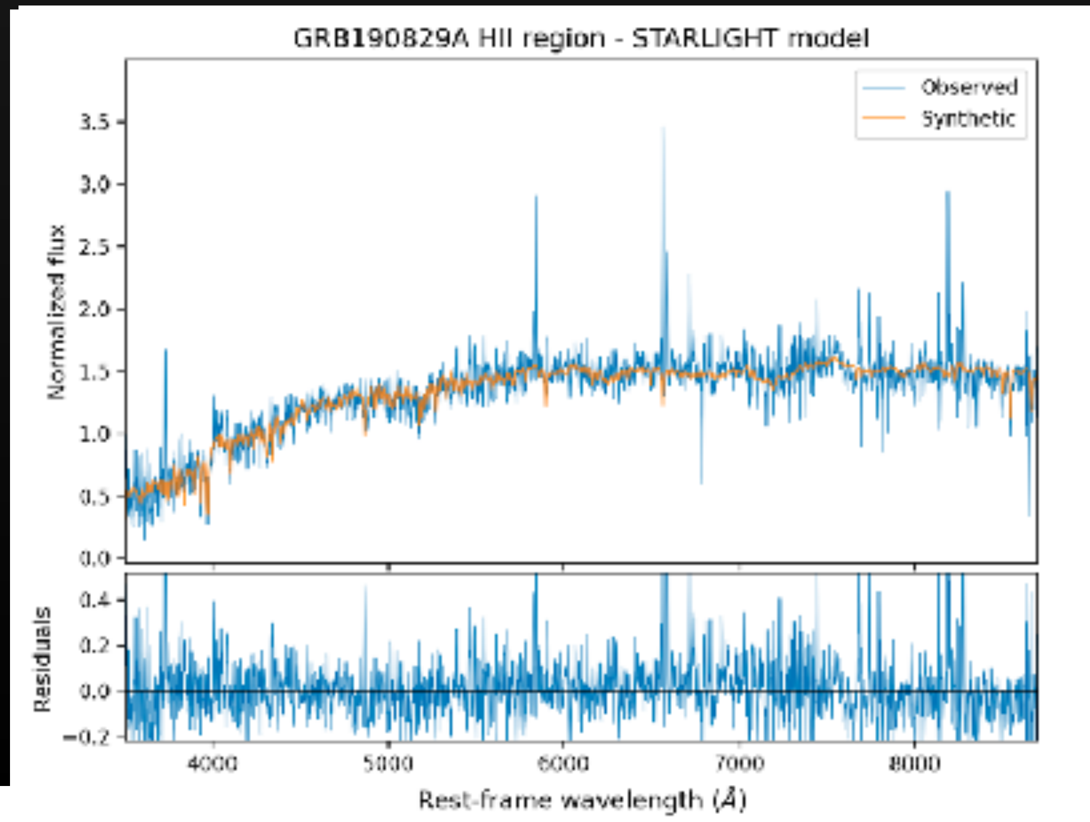
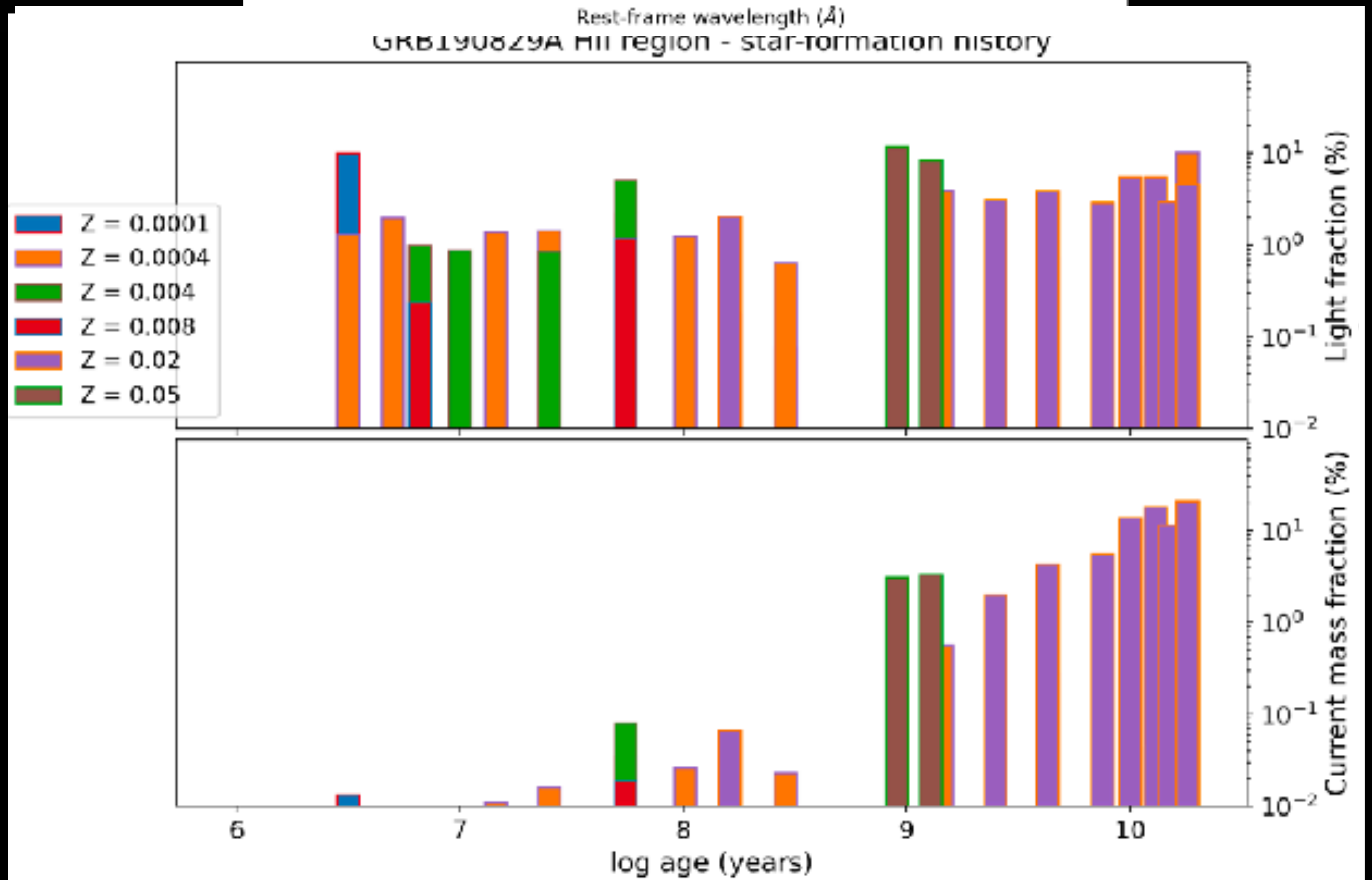






(Schady 2021, LI+ in prep.)

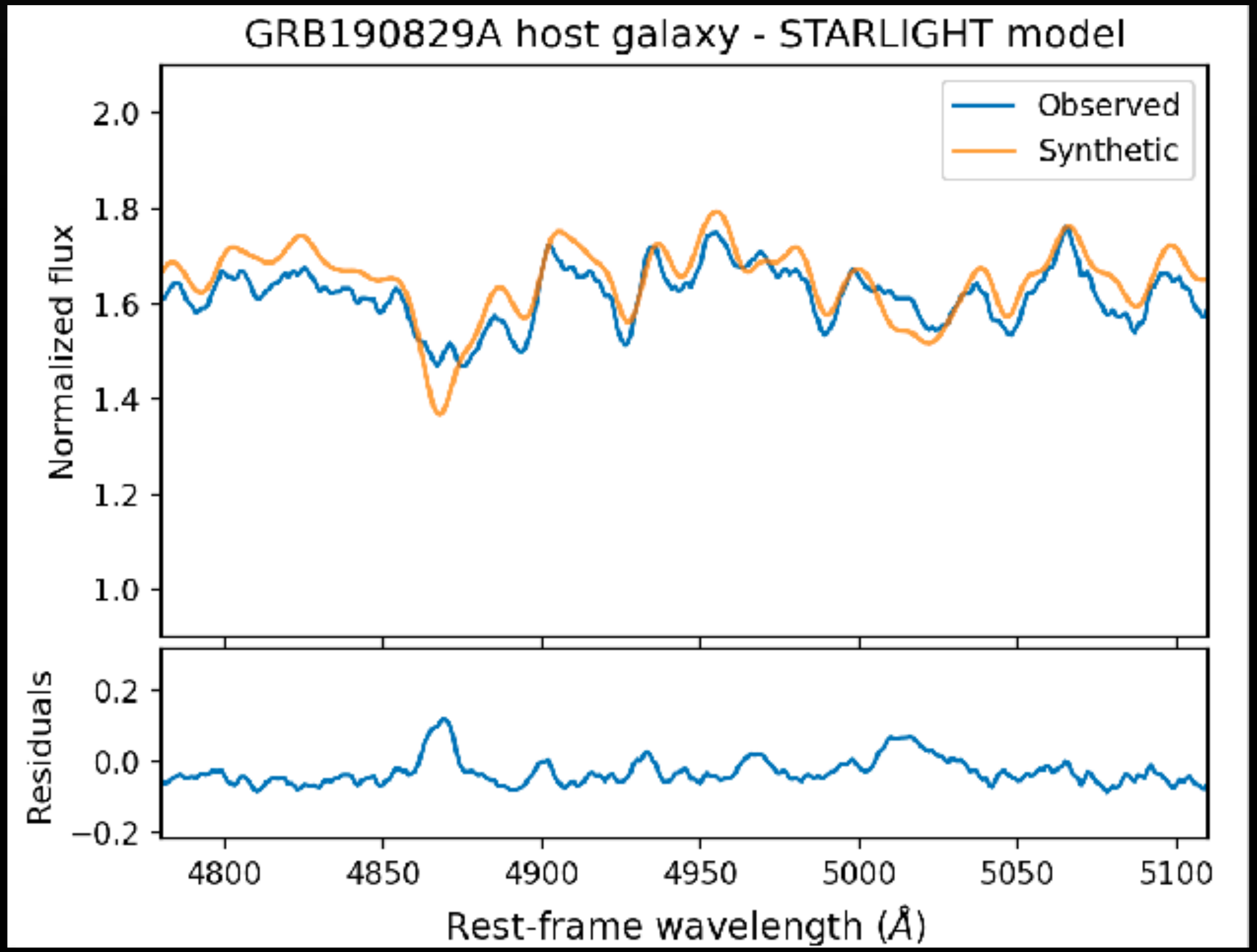
Introduction

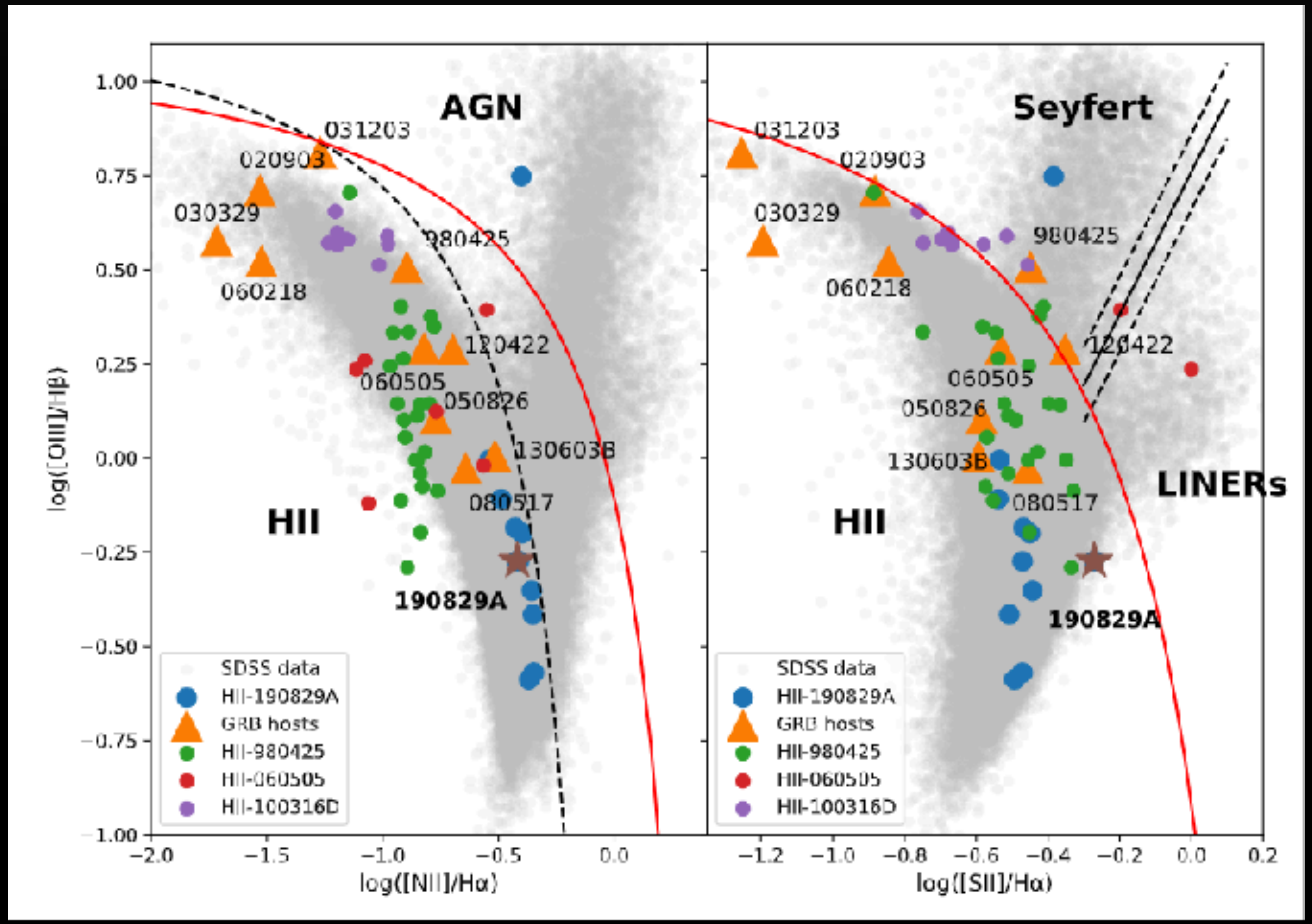
Gas (ionized) phase physical properties

=> using the SPS best-fit to accurately recover the flux of emission lines

Emission-line diagnostics to distinguish the ionisation mechanism acting in different (HII) regions of their hosts - calibrated at low-z

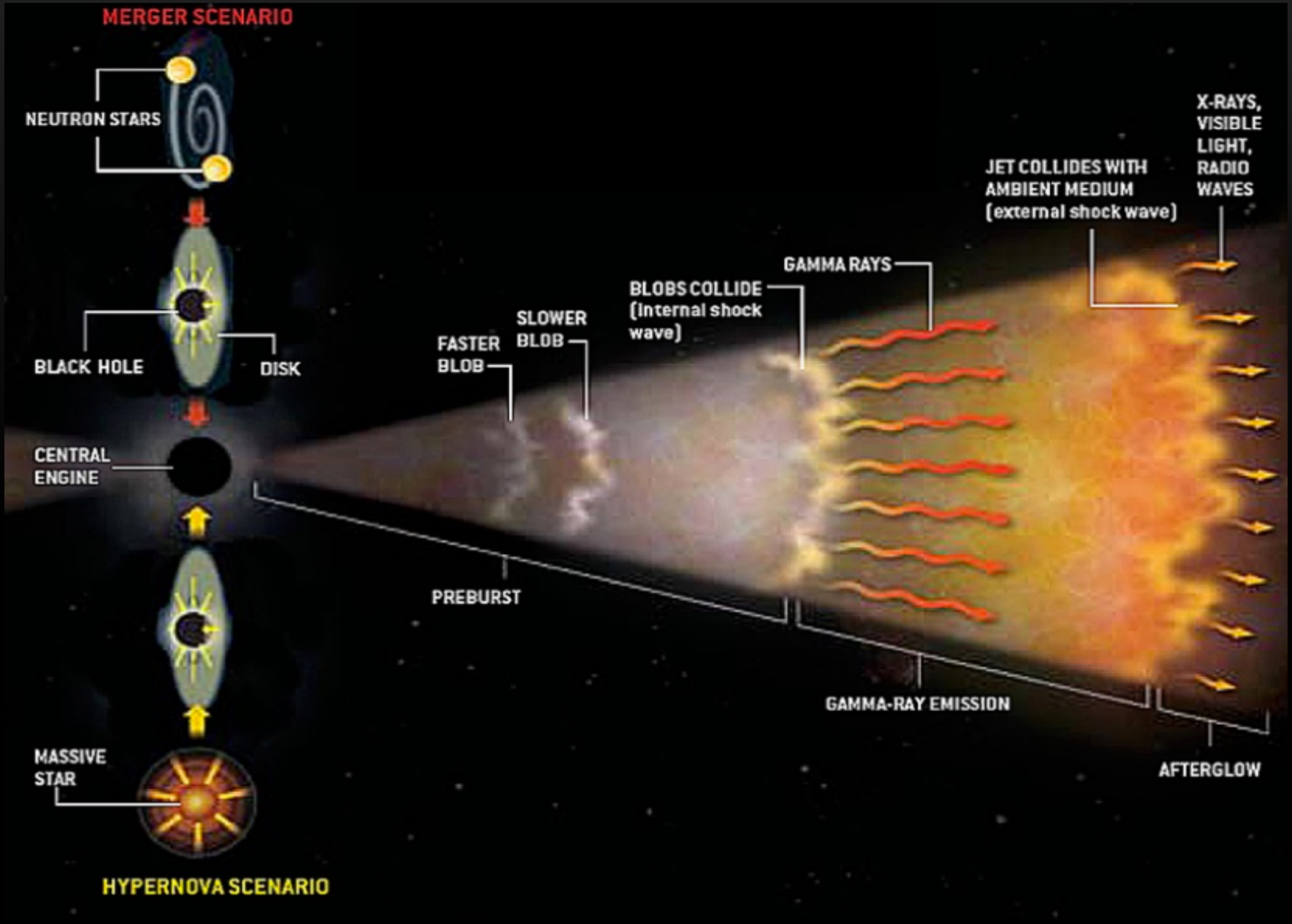
(LI+ 2018)





(Baldwin+ 1981)

Gamma-ray burst

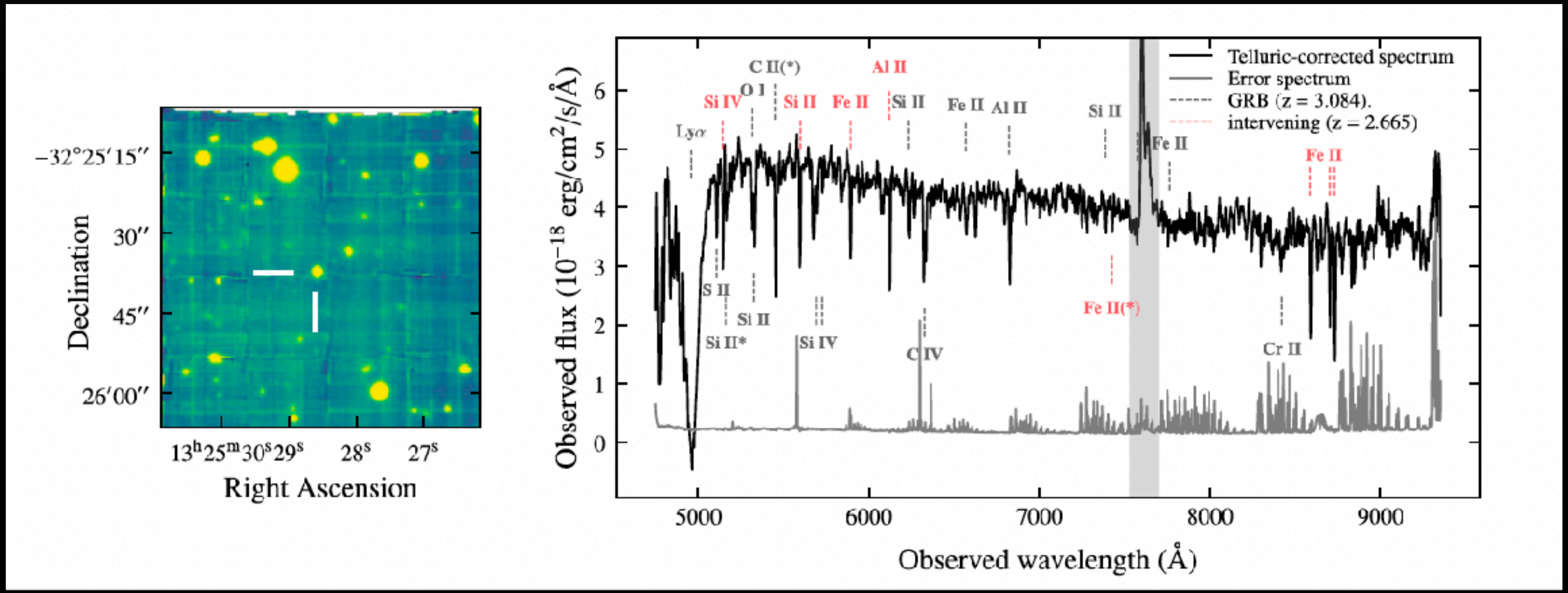


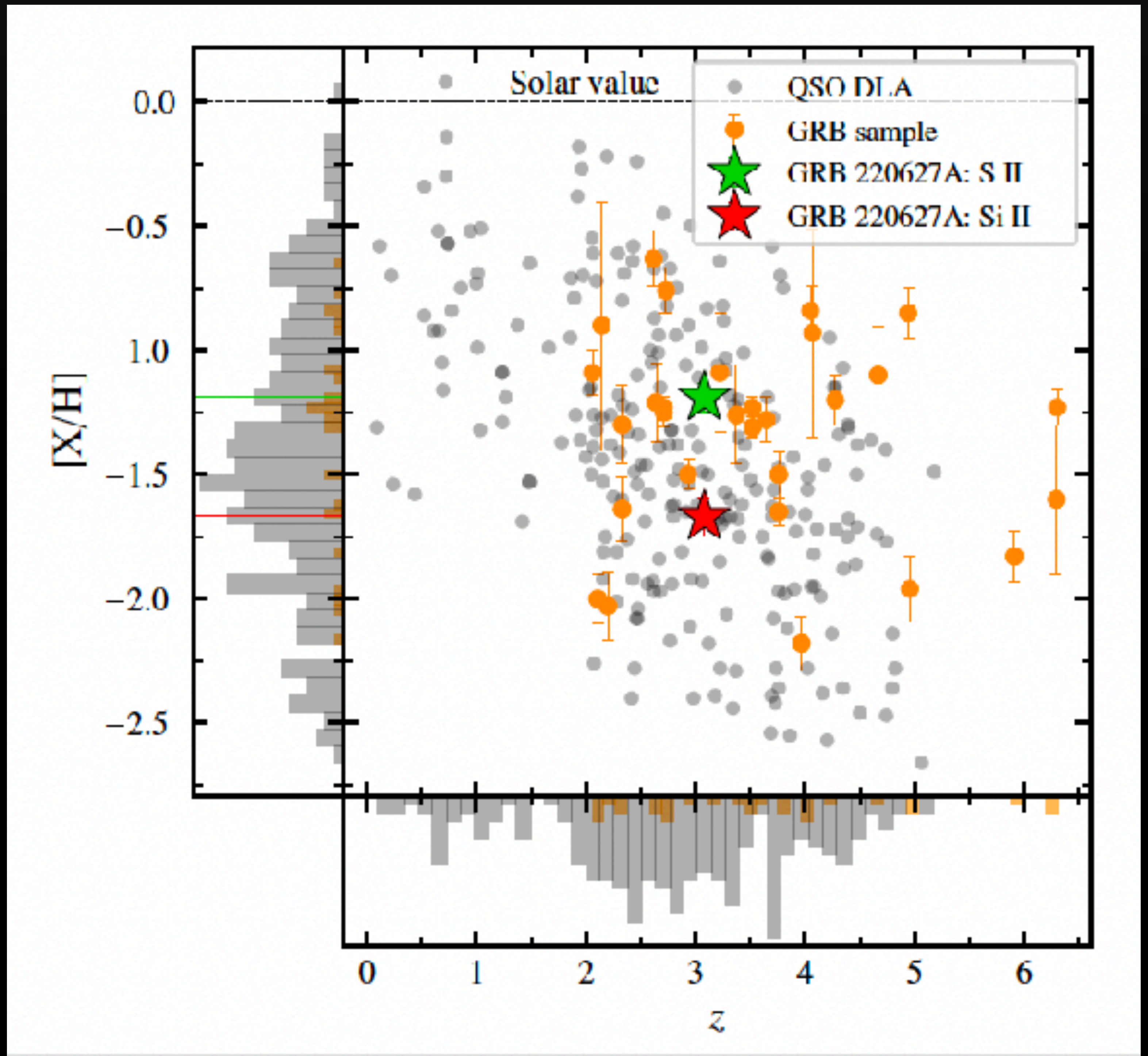
Gamma-ray burst

Absorption line metallicities from GRB afterglow - Neutral cold (ISM) phase

GRB bright afterglows penetrate the (multiple) gas clouds in the SF regions (~few 100 pc)

=> perfect probe for the ISM at high-z





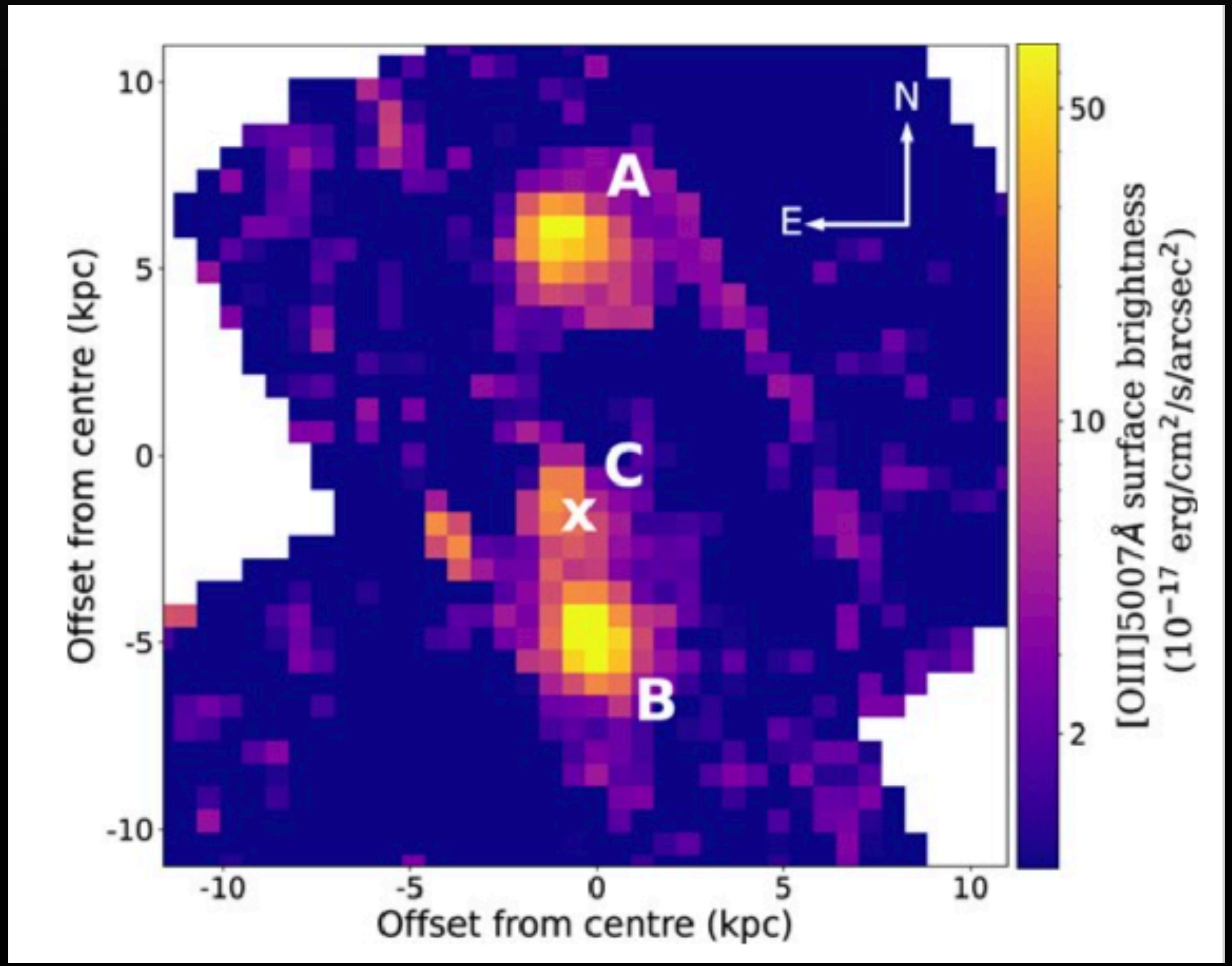
(De Wet, LI+ 2023)

Gamma-ray burst at high-z

Multiple contiguous absorbing clouds when moving at high-z

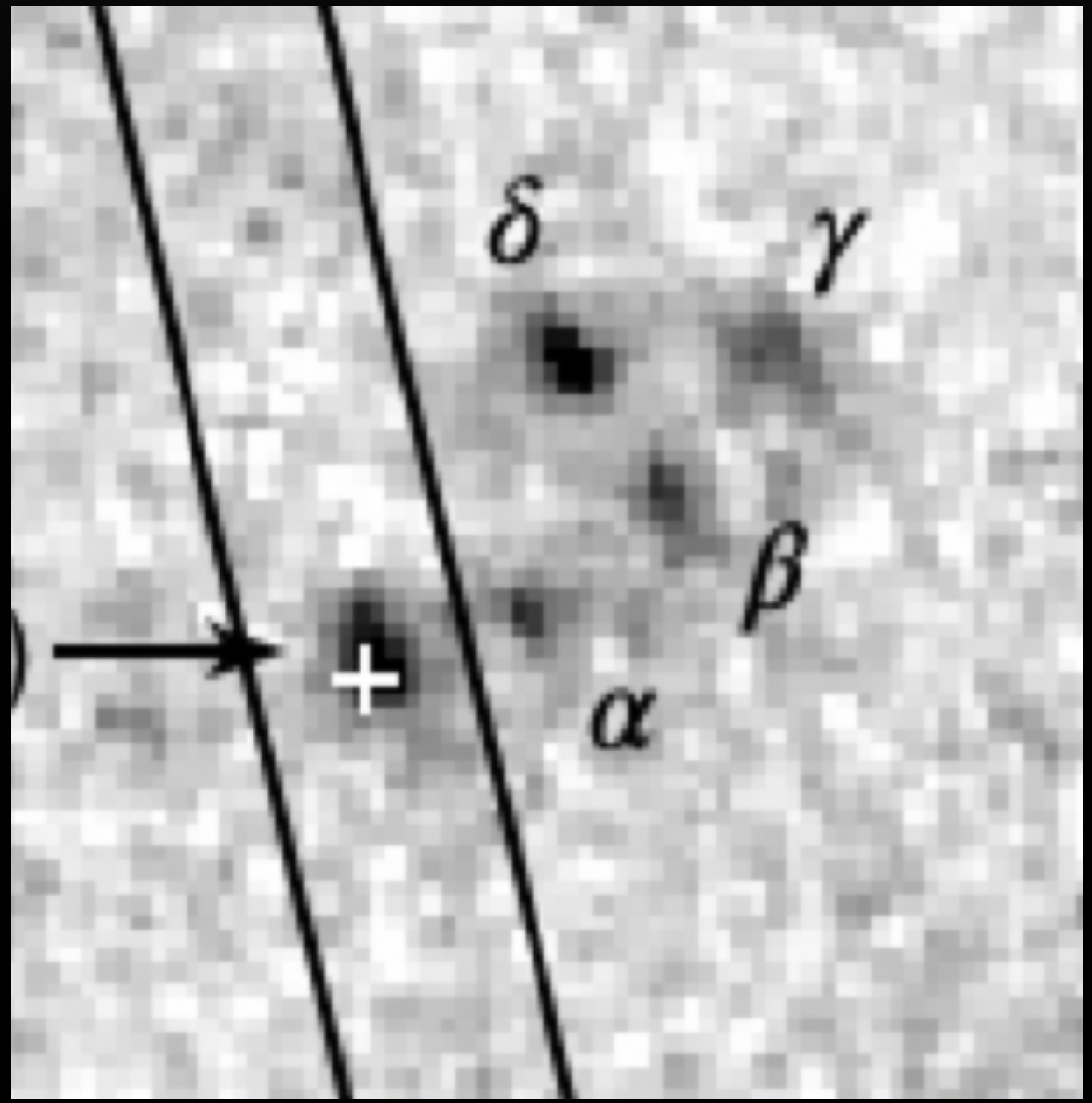
Spatially-resolved system of bright regions (possibly faint galaxies)

GRB 050820A @ z = 2.6



(Schady+ 2023)

GRB 210905A @ z = 6.3

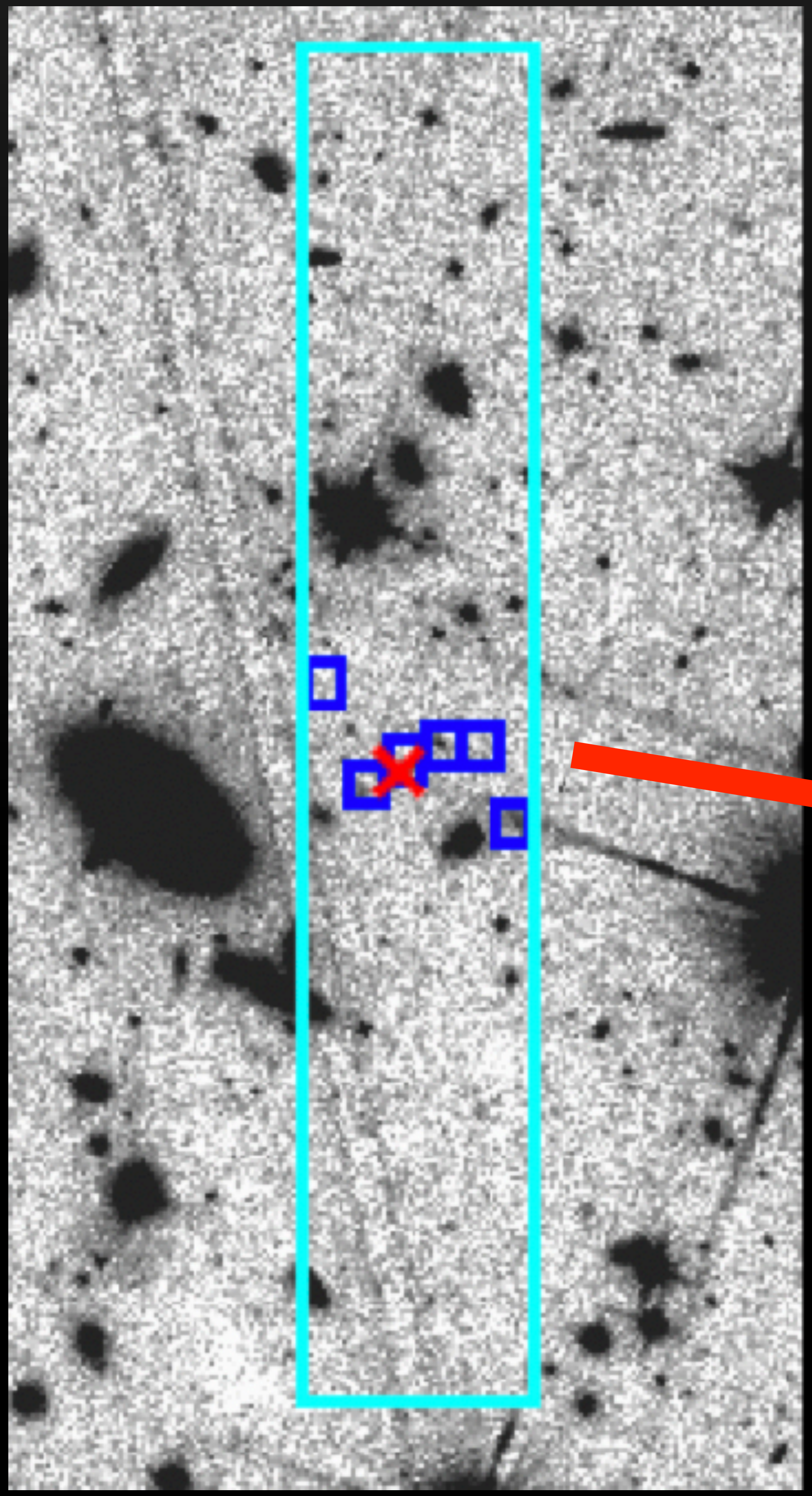


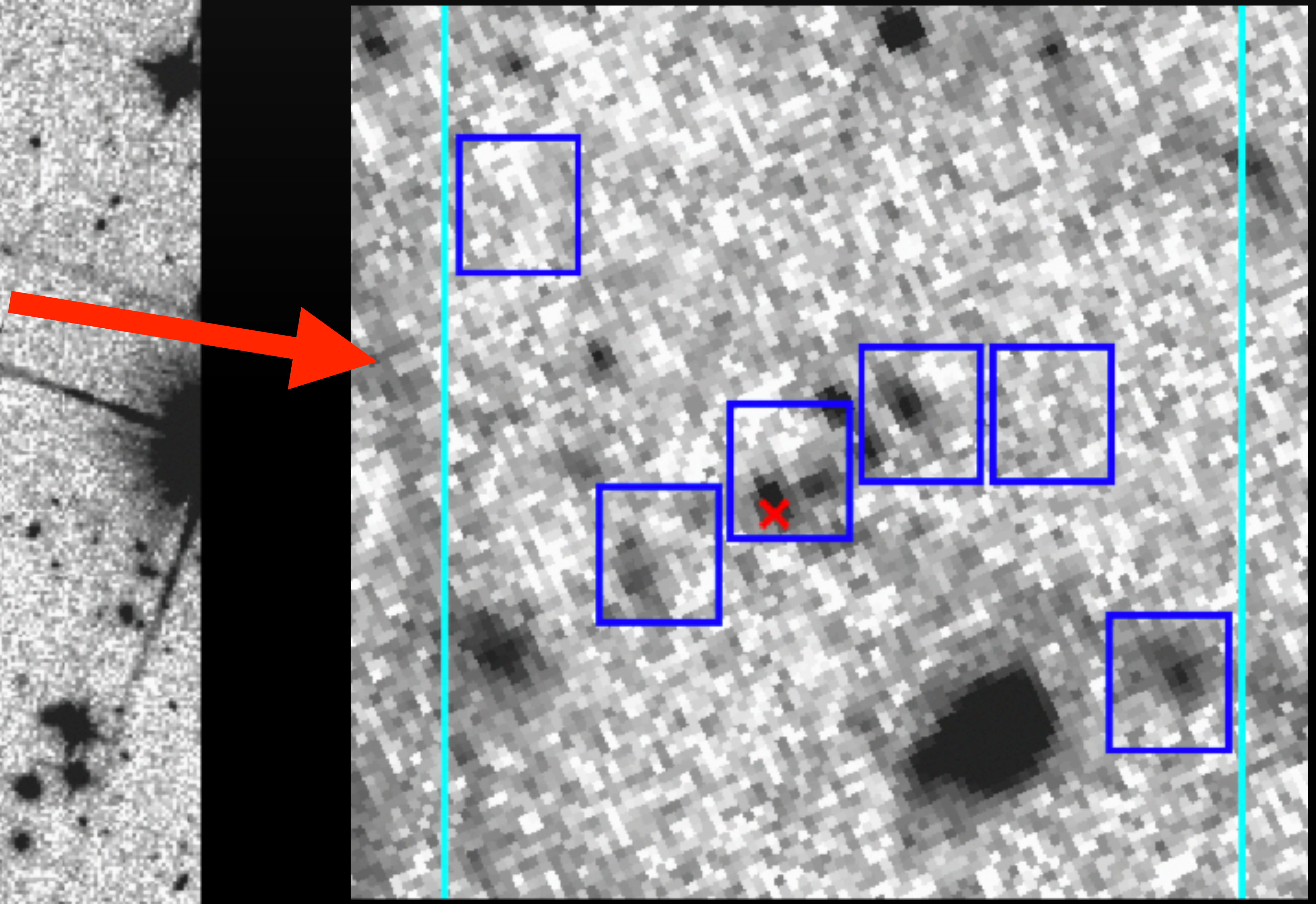
(Saccardi+ 2023)

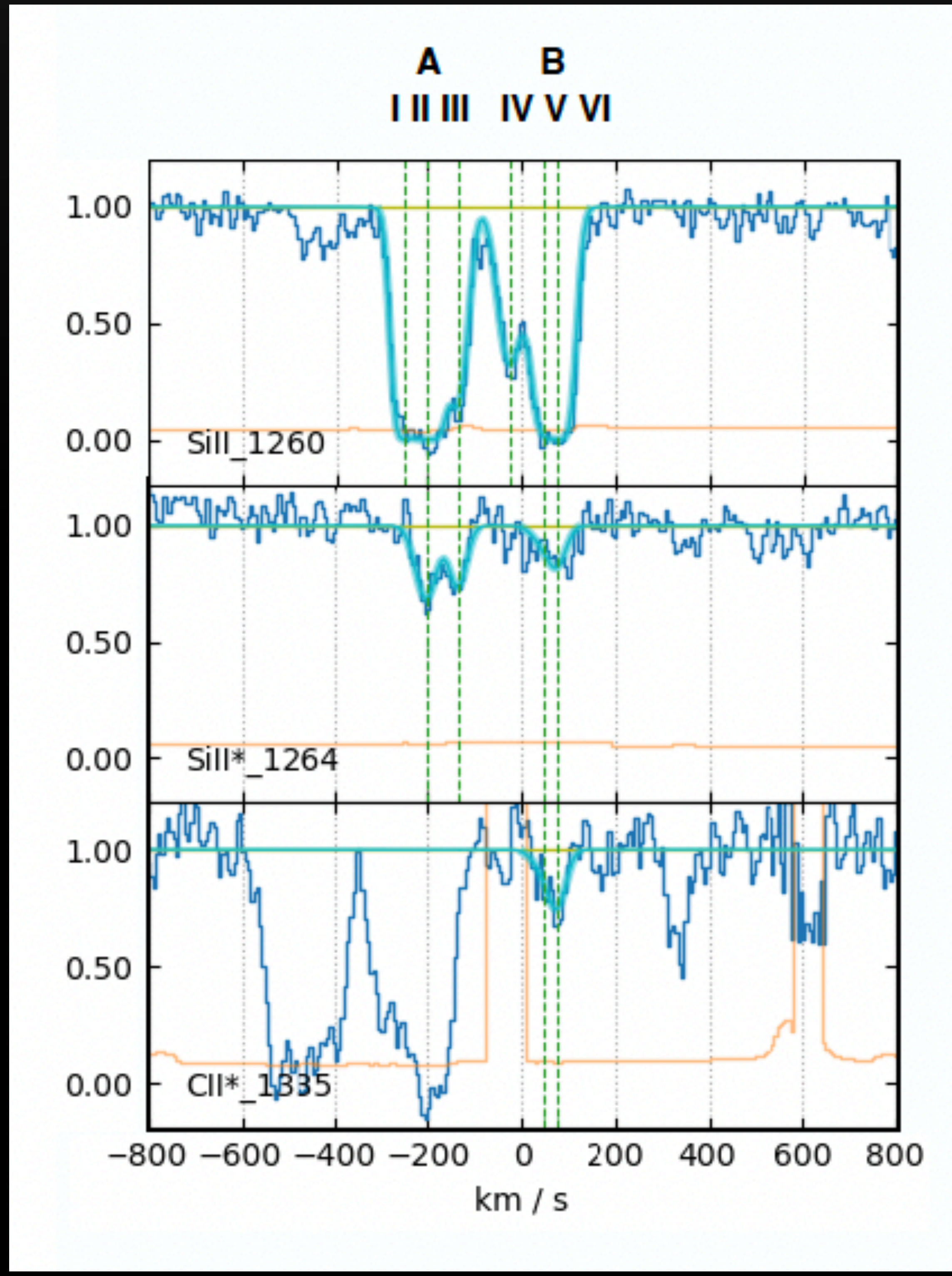
Gamma-ray burst at high-z

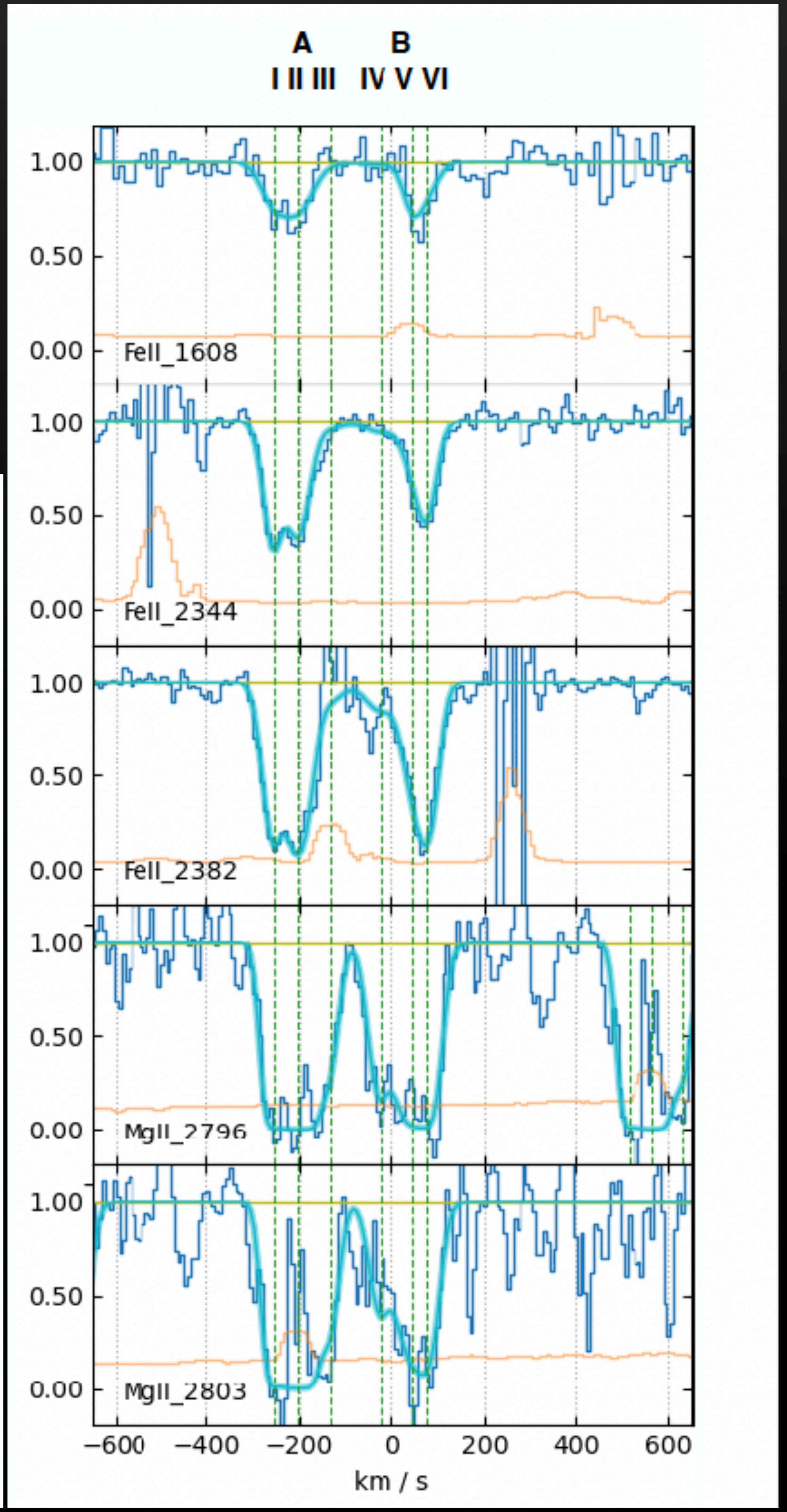
GRB 210905A @ z = 6.3

Best example to study ionized vs cold phase









(Saccardi+ 2023)

Gamma-ray burst at high-z

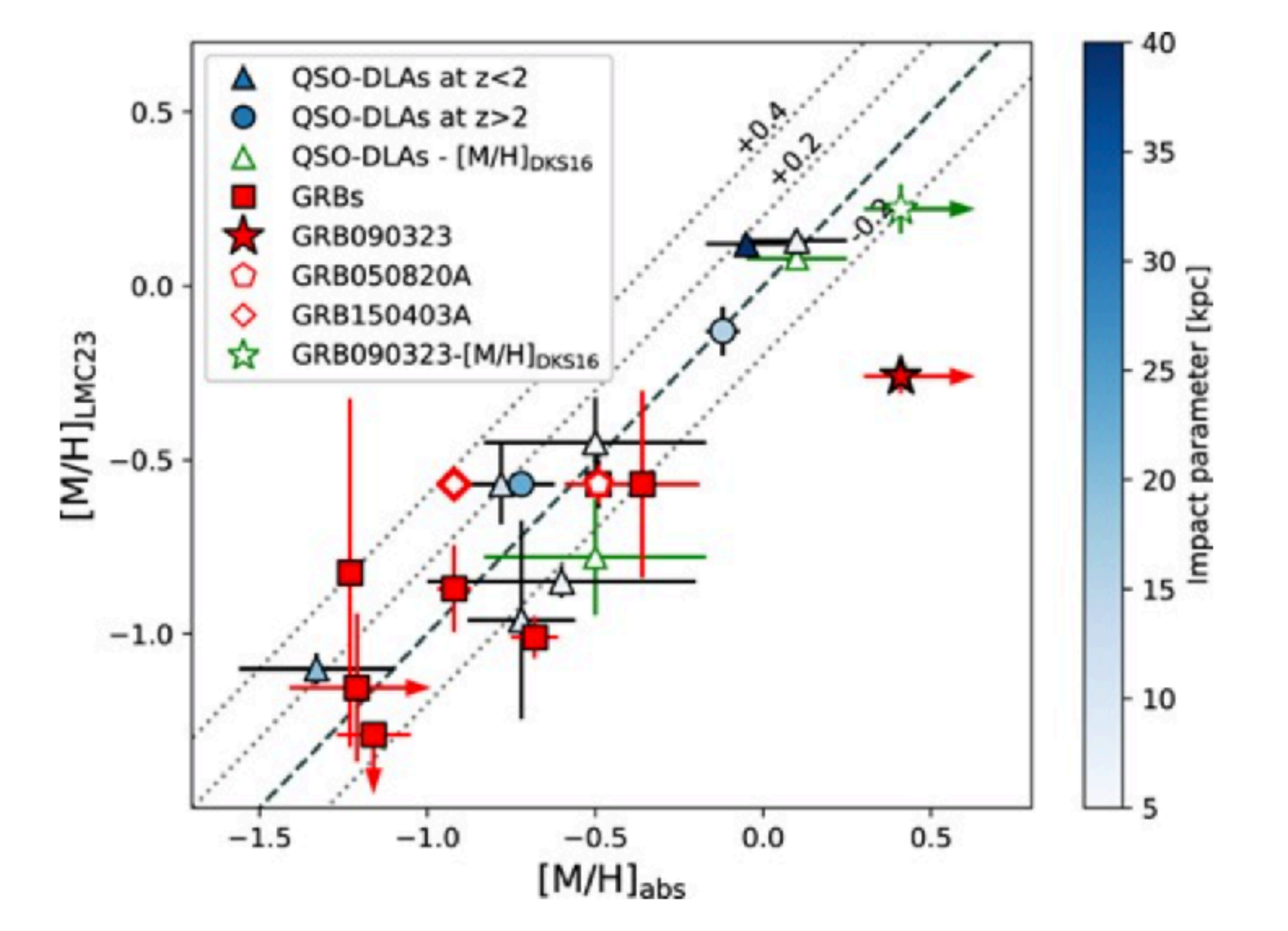
Ionized vs cold gas @ high-z

Careful selection of emission line diagnostics

Agreement between absorption and emission Z

Investigate metallicity at high-z using just emission line diagnostics

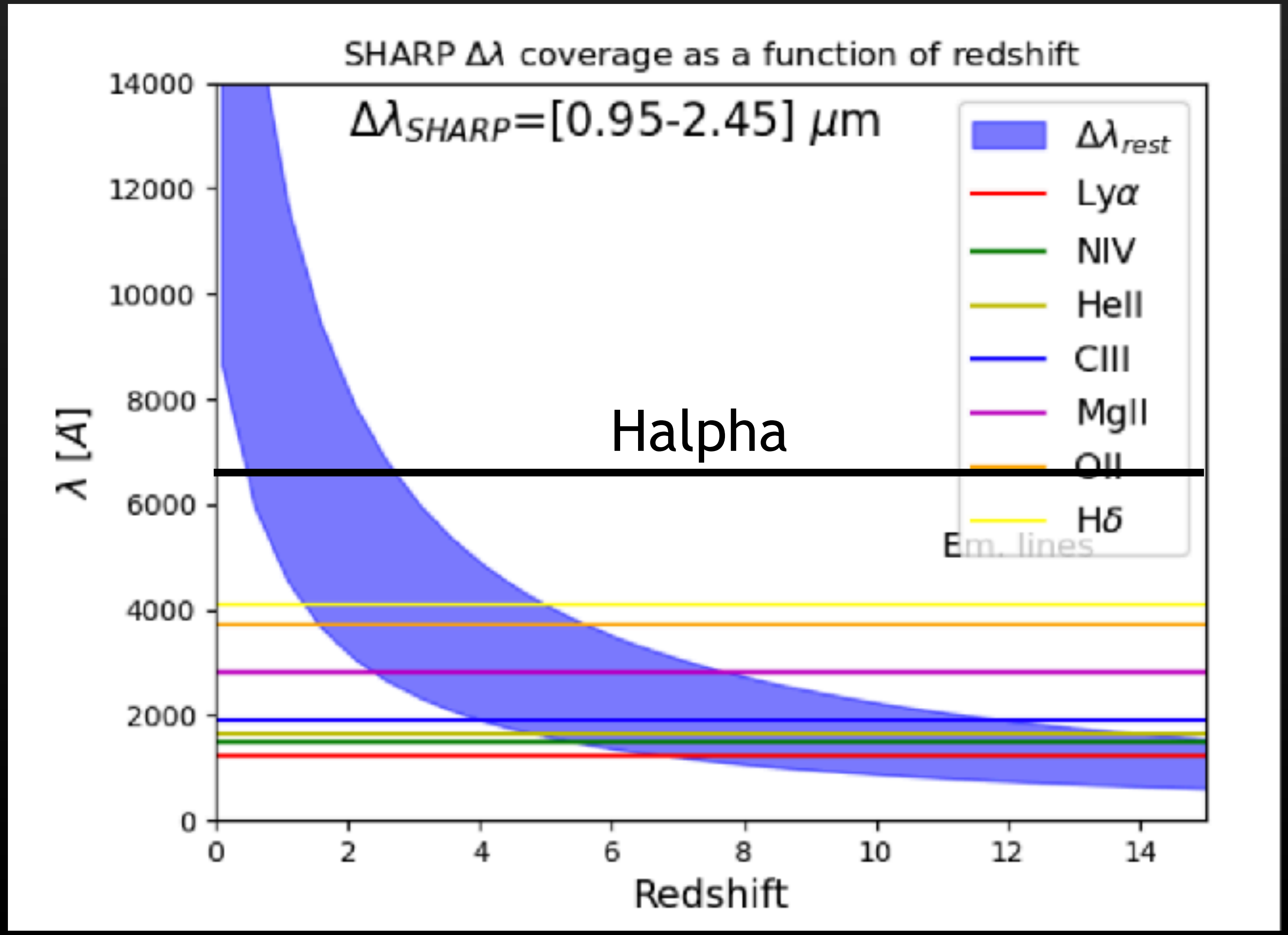
Similar composition of ionized and neutral regions



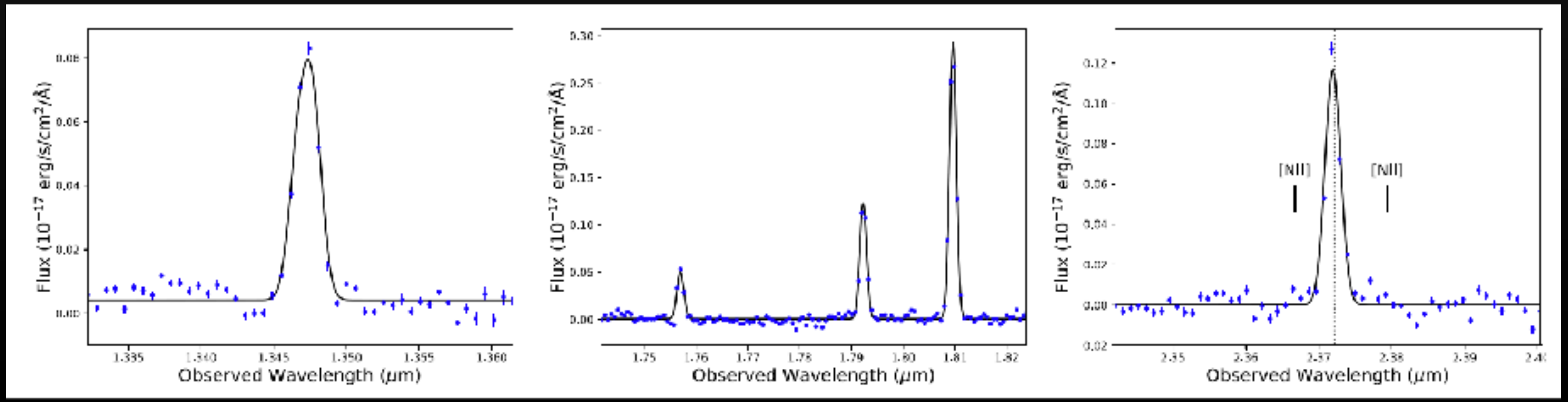
(Schady+ 2023)

Gamma-ray burst at high-z

(Schady+ 2023)



GRB host	z_{abs}	z_{em}	Line Flux (10^{-17} erg cm^{-2} s^{-1}) Hβ	Hα	[O II]λλ3726,3729	[O III]λ4959	[O III]λ5007
030323	3.372[a]	3.3710	0.17 ± 0.06	0.43 ± 0.04	0.11 ± 0.05	0.27 ± 0.06	0.73 ± 0.06
050820A	2.615[b,c]						
galaxy-integrated		2.6133	2.49 ± 0.13	8.81 ± 0.22	4.56 ± 0.36	5.71 ± 0.13	16.06 ± 0.15
component A		2.6129	0.82 ± 0.05	3.17 ± 0.11	1.67 ± 0.08	2.04 ± 0.06	4.95 ± 0.06
component B		2.6133	1.20 ± 0.10	4.12 ± 0.09	2.05 ± 0.10	2.84 ± 0.11	8.49 ± 0.12
component C		2.6136	0.31 ± 0.04	1.02 ± 0.12	0.74 ± 0.07	0.44 ± 0.03	1.55 ± 0.04

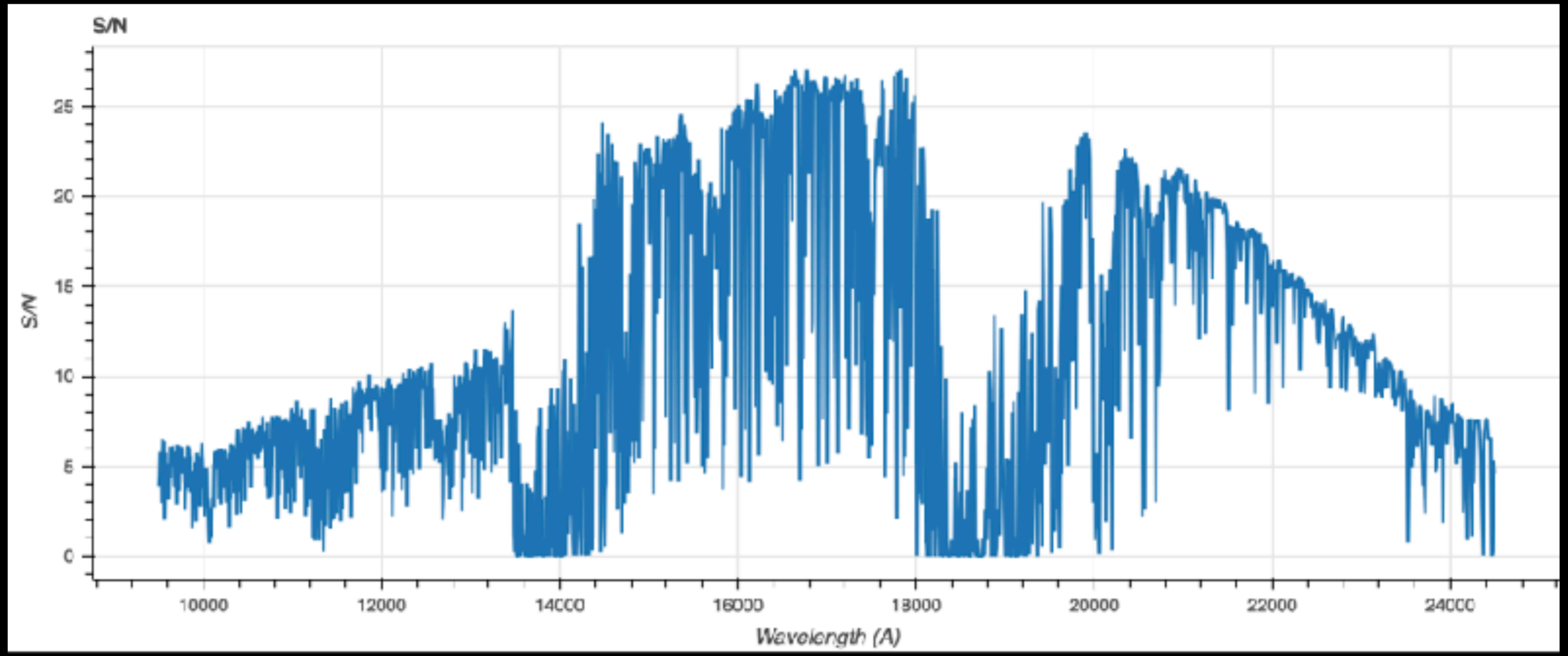


ETC input

R=2000

BC016_Chab_Zsun_05Gyr

i′ = 26 mag



Text = DITxNDIT = 1500s

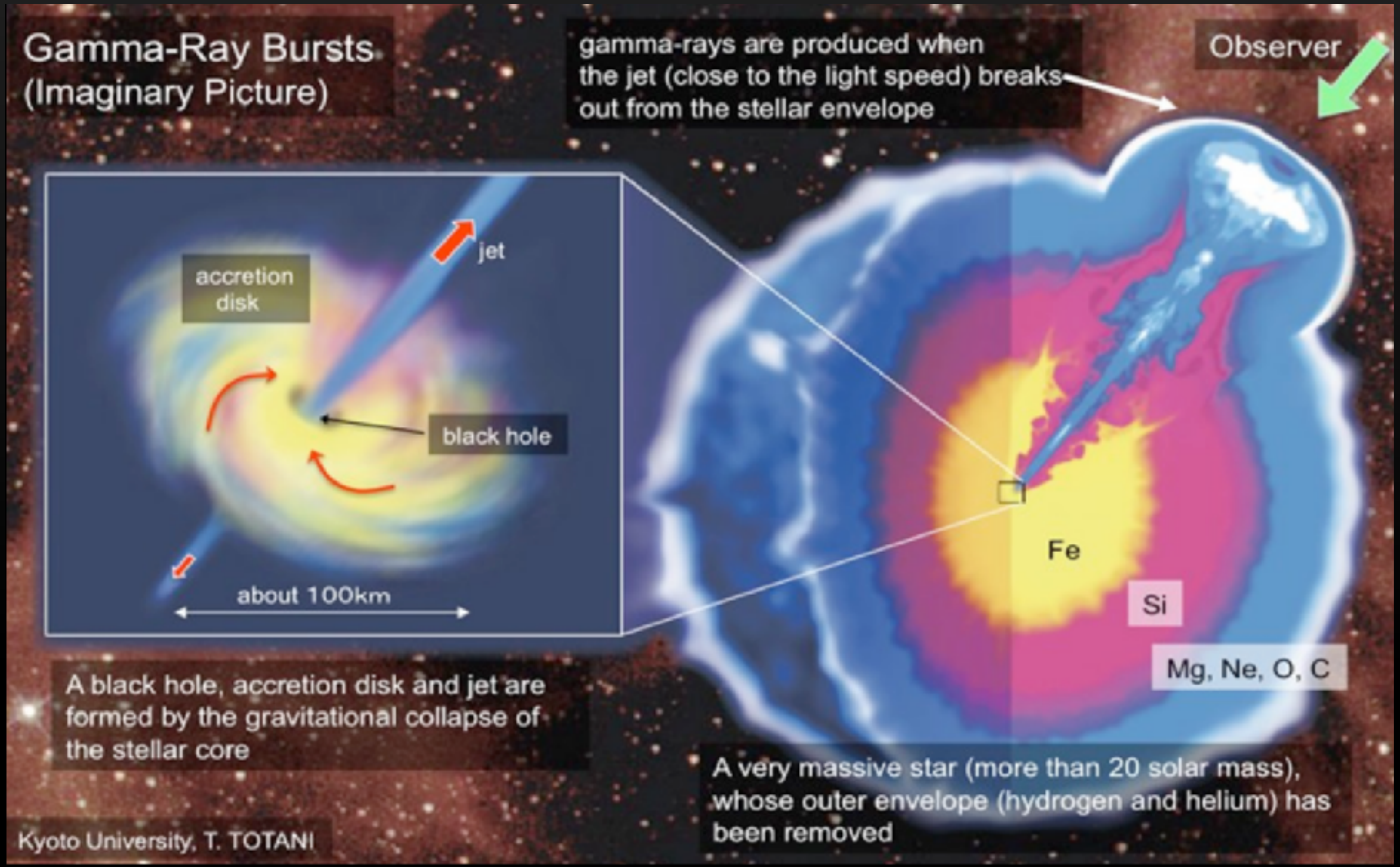
(No overheads)

Good for SSP

Very good for emission lines

(TBC)

GRB-SNe



- Fast-rotating Fe core
- H (and likely He) stripped-envelope progenitor
- Low metallicity (mass-loss is Z-dependent)

Collapsar scenario

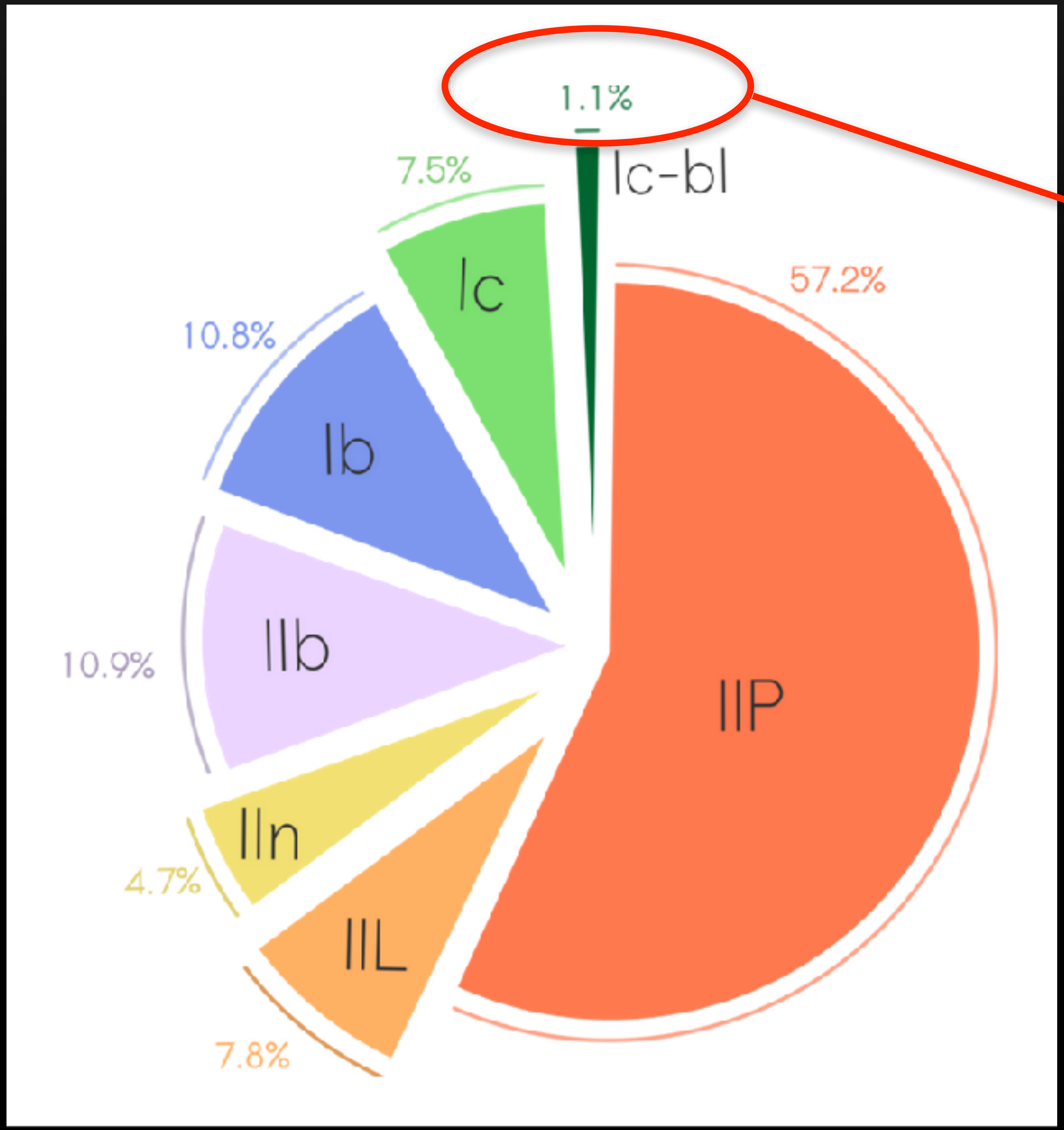
(Woosley 1993, MacFadyen & Woosley 1999)

20 MSun star has a life of ~ 10-30 Myrs (Maund+ 2018)

GRB-SNe explode in the same HII regions where they have been formed

Ic BL SNe w/o GRBs

Relative number of CC-SNe



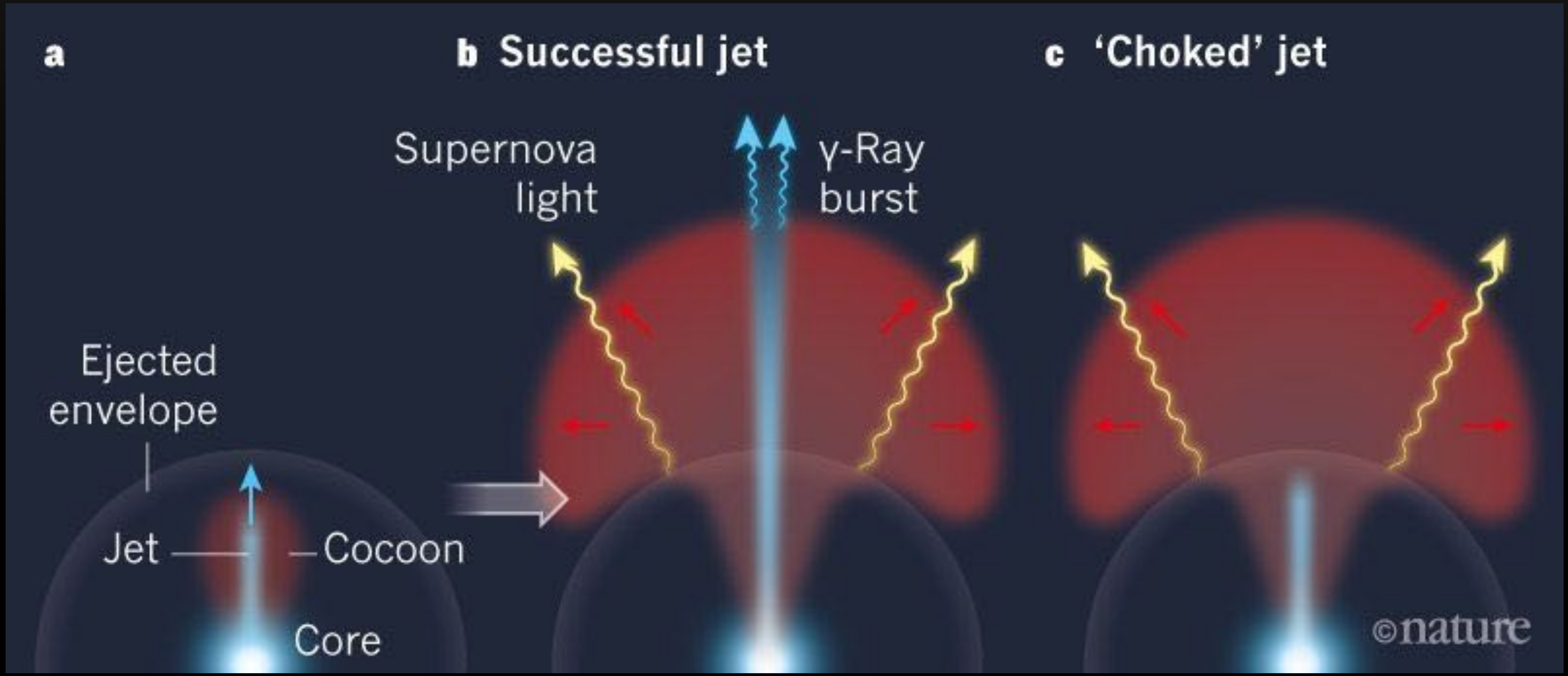
<10% of Ic-BL SNe are "apparently" associated with a GRB

What about the remaining 90%?

(Shivvers+ 2017, courtesy Stevance)

Ic BL SNe w/o GRBs

Off-axis GRB and/or Choked jet
or other mechanisms at play (?)



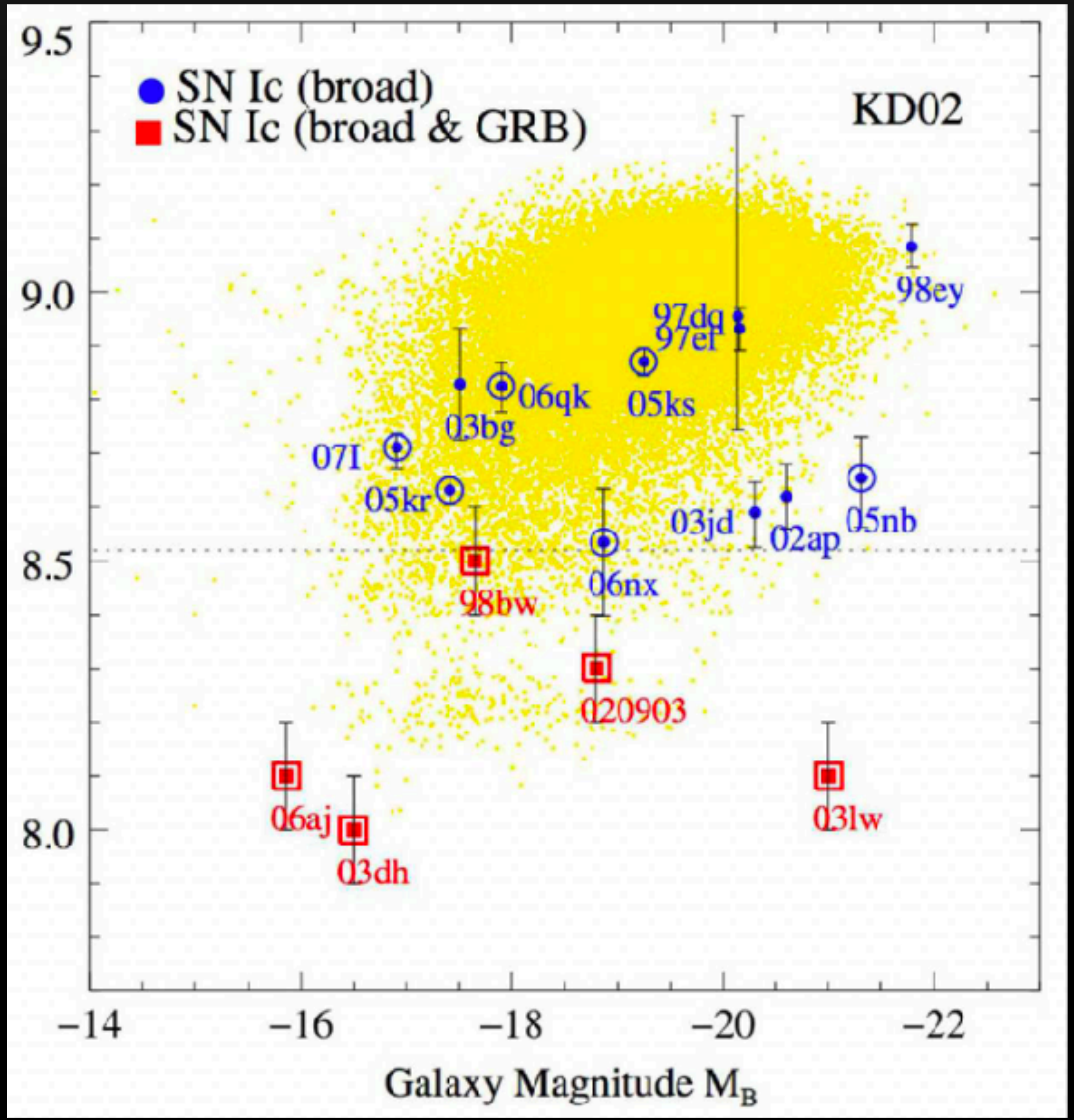
(Nakar 2019)

Ic BL SNe w/o GRBs

(AMUSING survey)

Metallicity from long-slit host galaxy spectra

<u>Metallicity threshold ???</u>

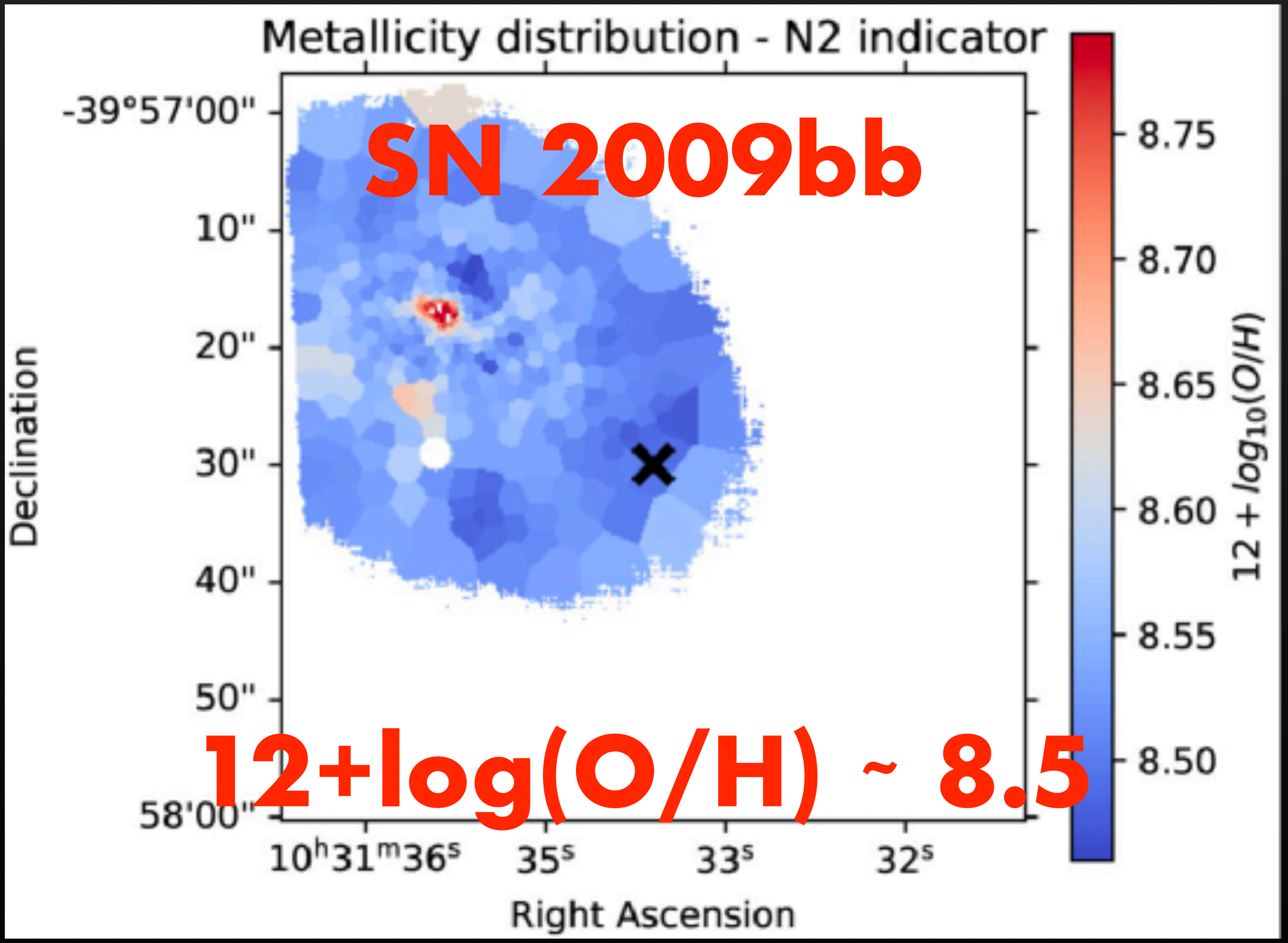


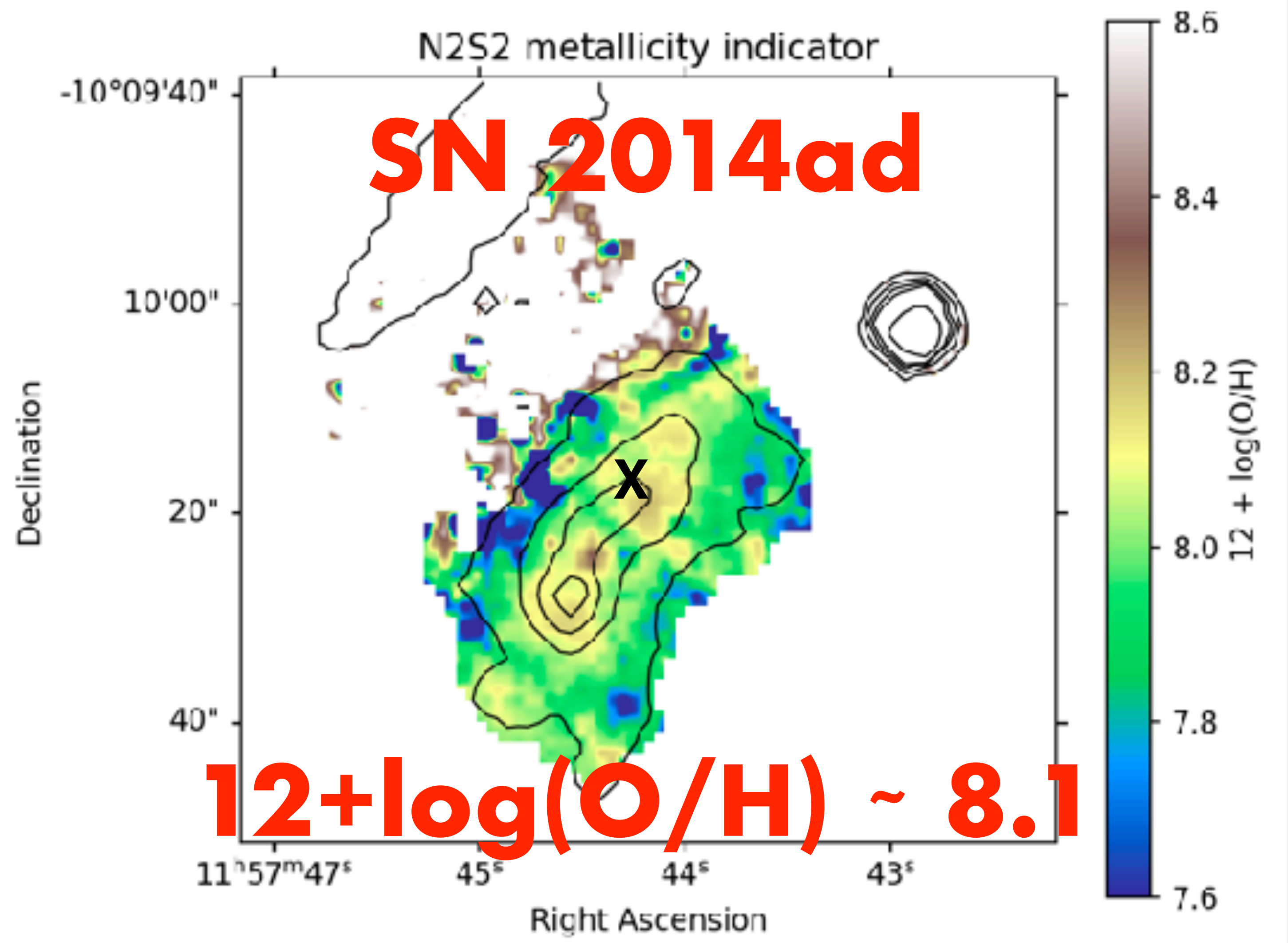
(Modjaz+ 2008)

Moving to IFUs

Accurate measurements
For metallicity

<u>What about high-z ???</u>

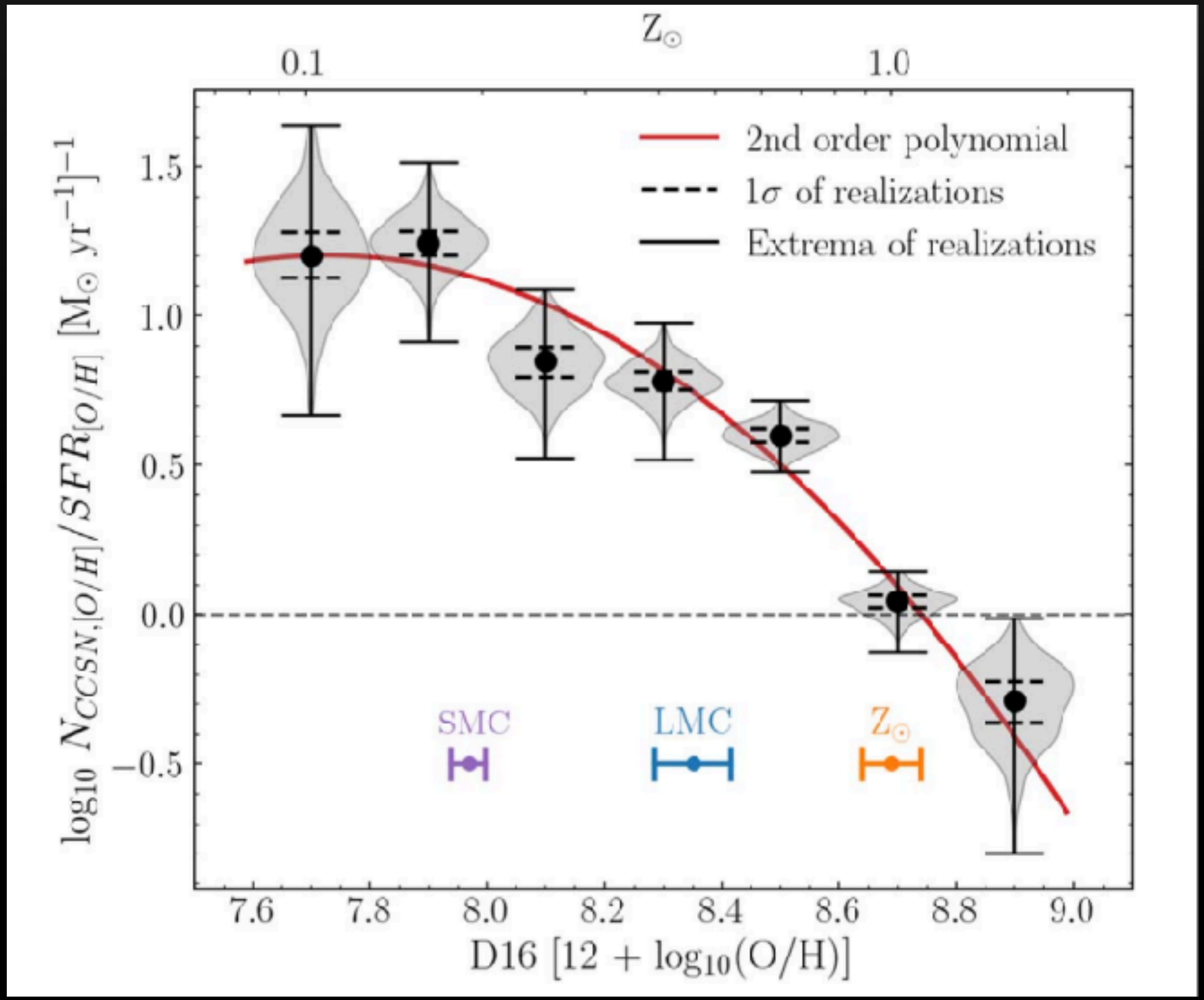




(LI+ in prep)

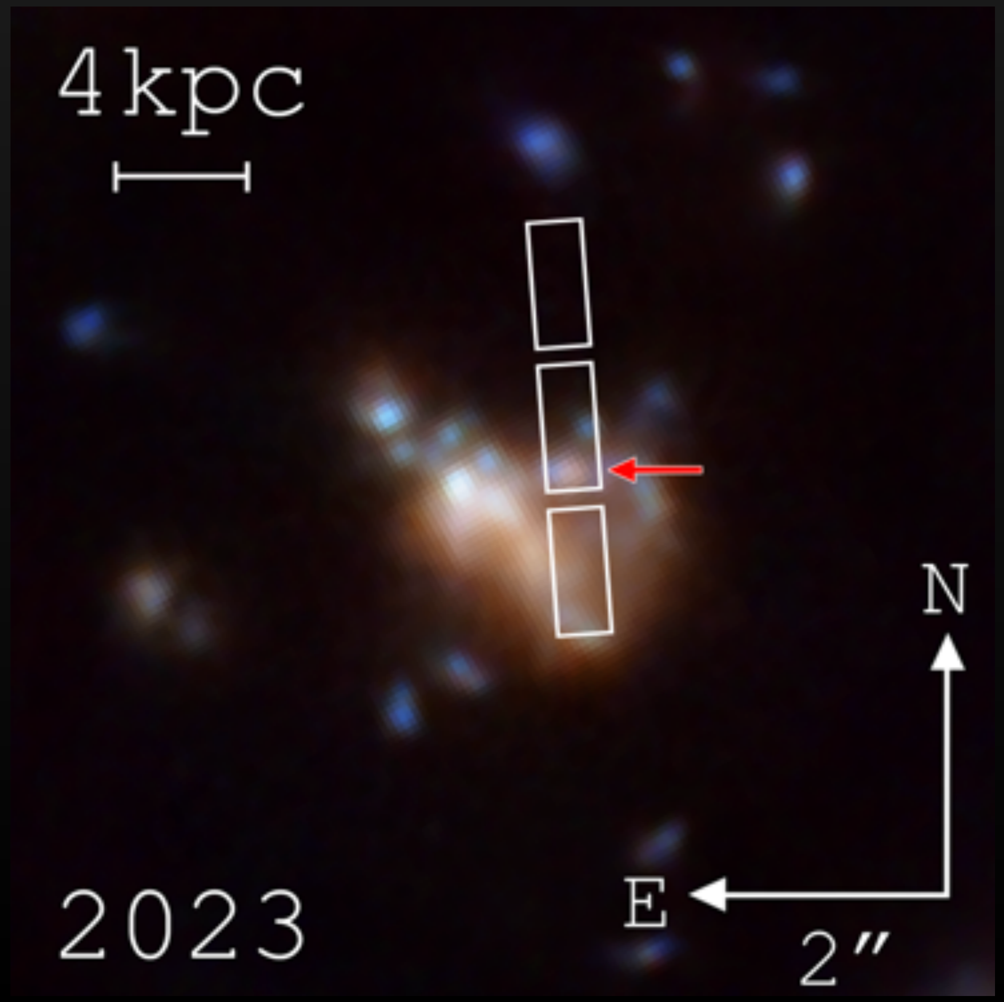
Moving to high-z/low-Z

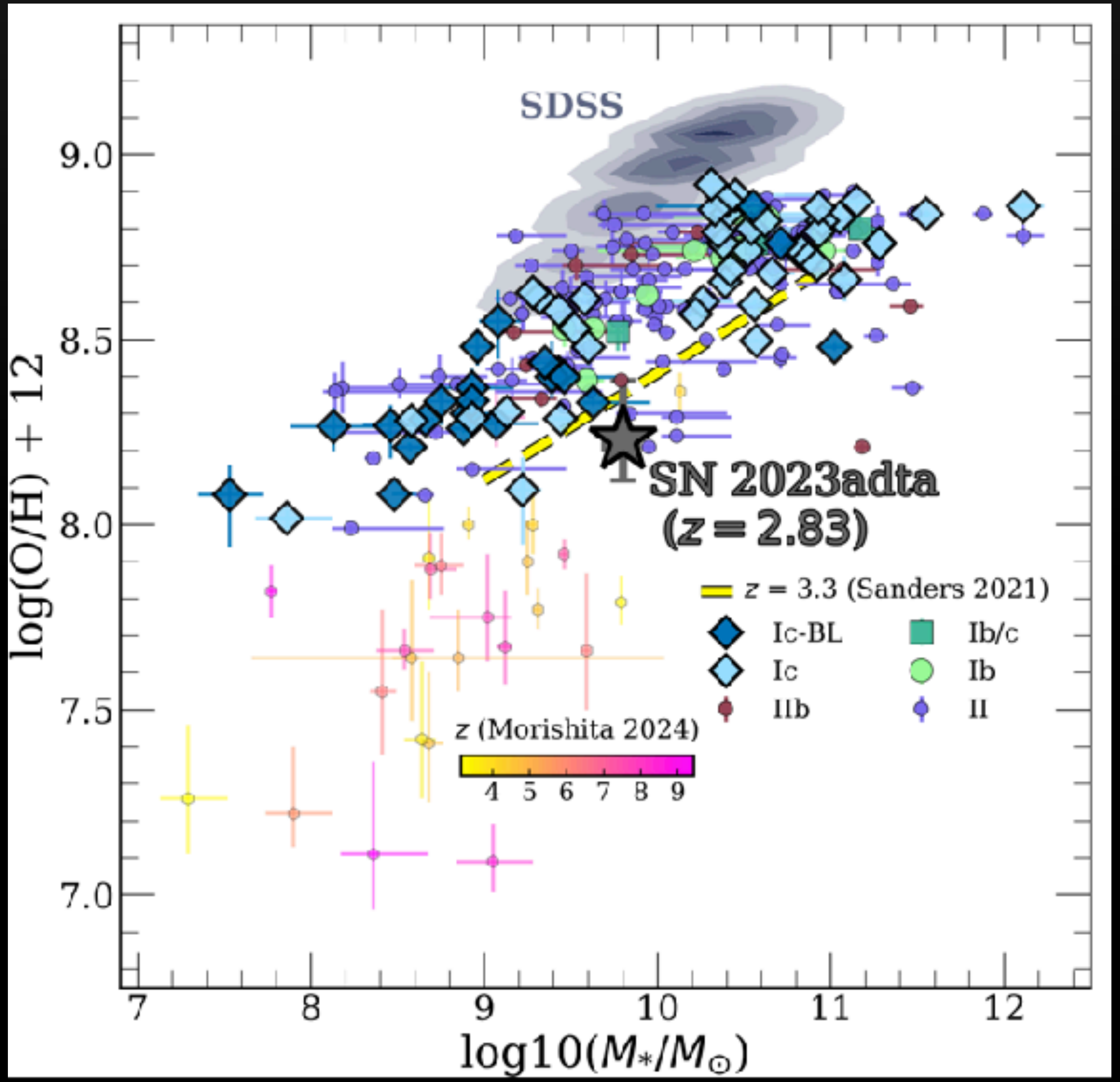
Metallicity-dependence on occurrence
Of CC SNe



(Pessi+ 2023)

JWST detection of Ic-BL at z = 2.83





(Siebert+ 2024)

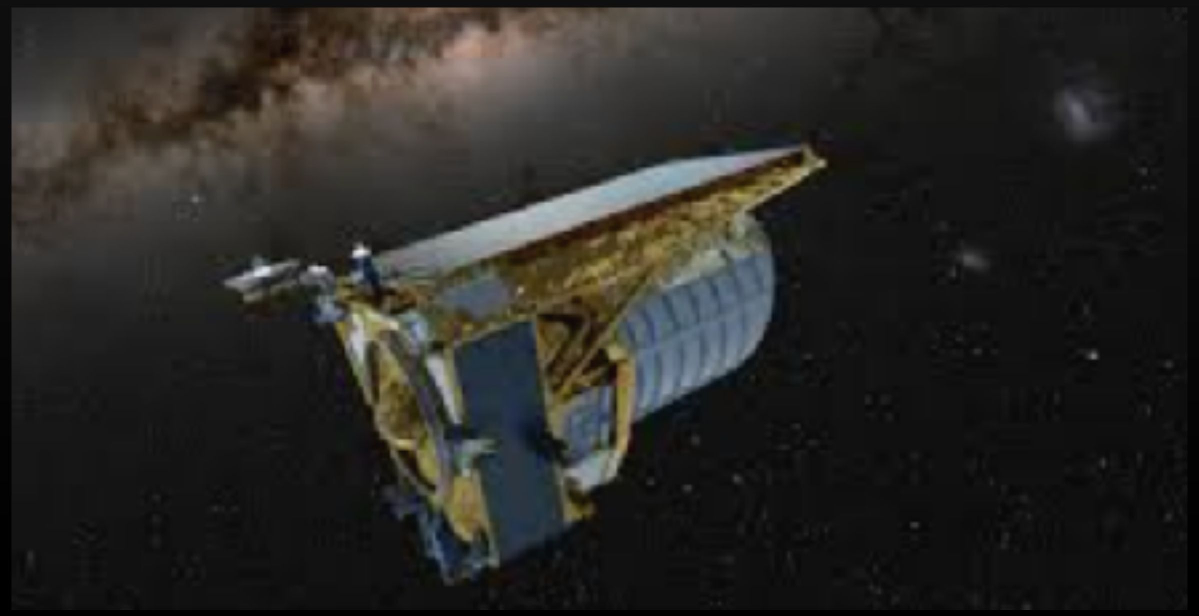
=> SHARP can definitely shed more light at high-z

Moving to high-z/low-Z

Candidates???

LSST

EUCLID



ROMAN

Detection of CC-SNe at z <= 1

Observing in the NIR - CC-SNe at z <= 2-2.5

Optimizing photometric classification tools

Future plans

A Transient search in EUCLID DEEP FIELDS in synergy with LSST

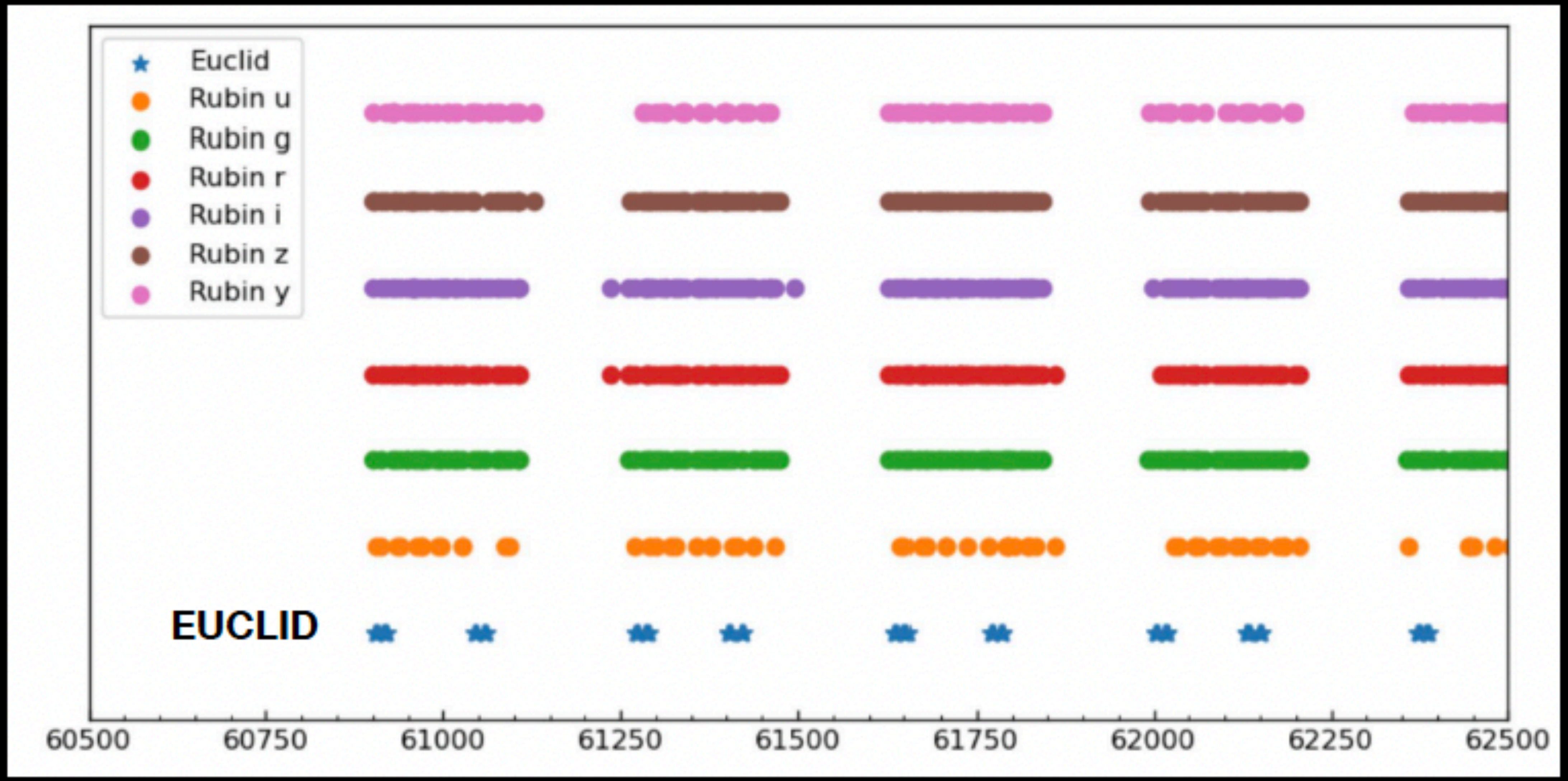
A large statistical sample of SNe with high-quality optical and NIR data

SN Ia cosmology in NIR range

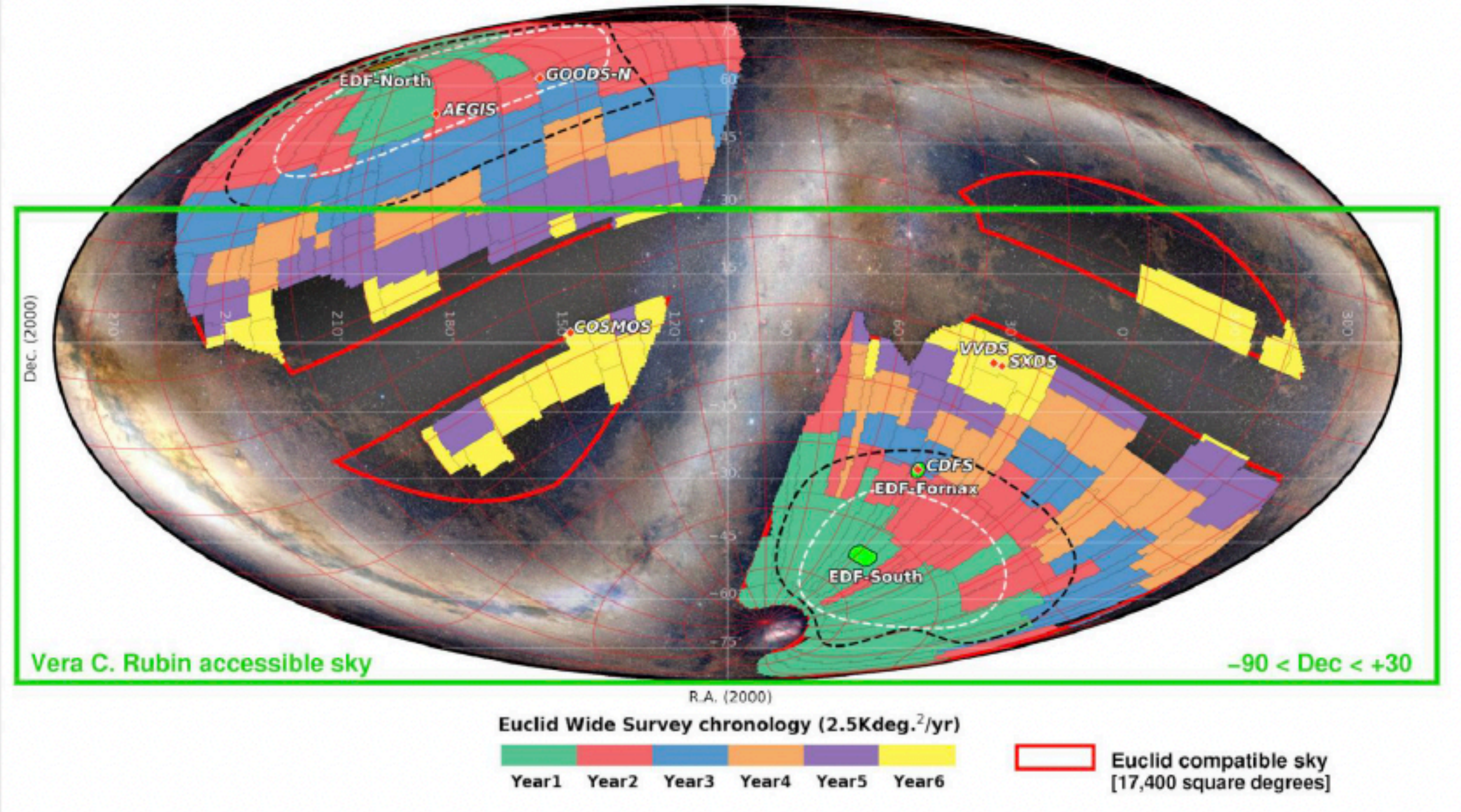
SN rate measurements and fraction of dust obscured SNe

host galaxy properties from combined Euclid LSST datasets

EUCLID Deep Field South

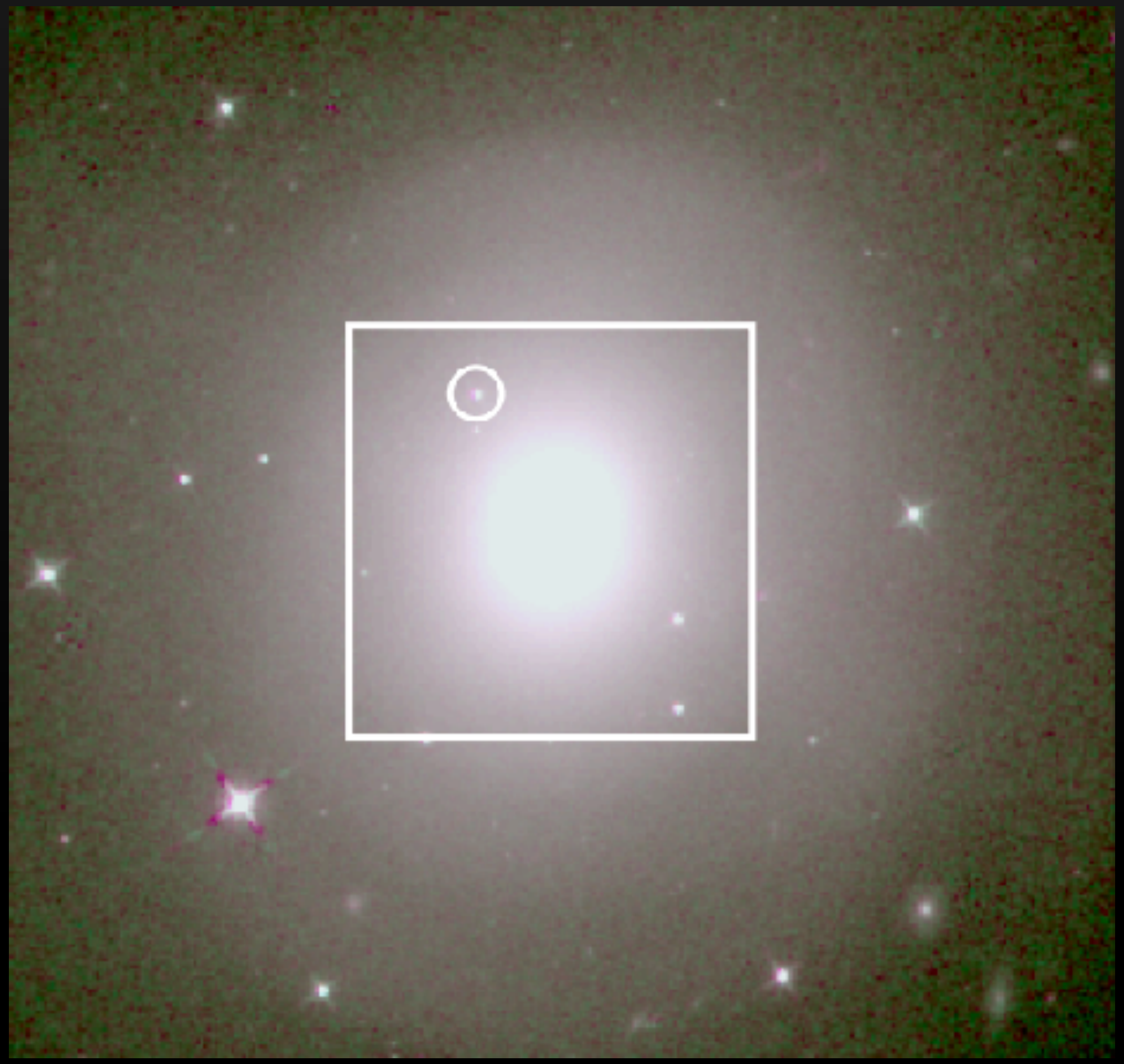


Credits The Rubin-Euclid Derived Data Products Initial recommendations



Kilonovae/short GRB

<u>The case of AT 2017gfo / GW170817</u>

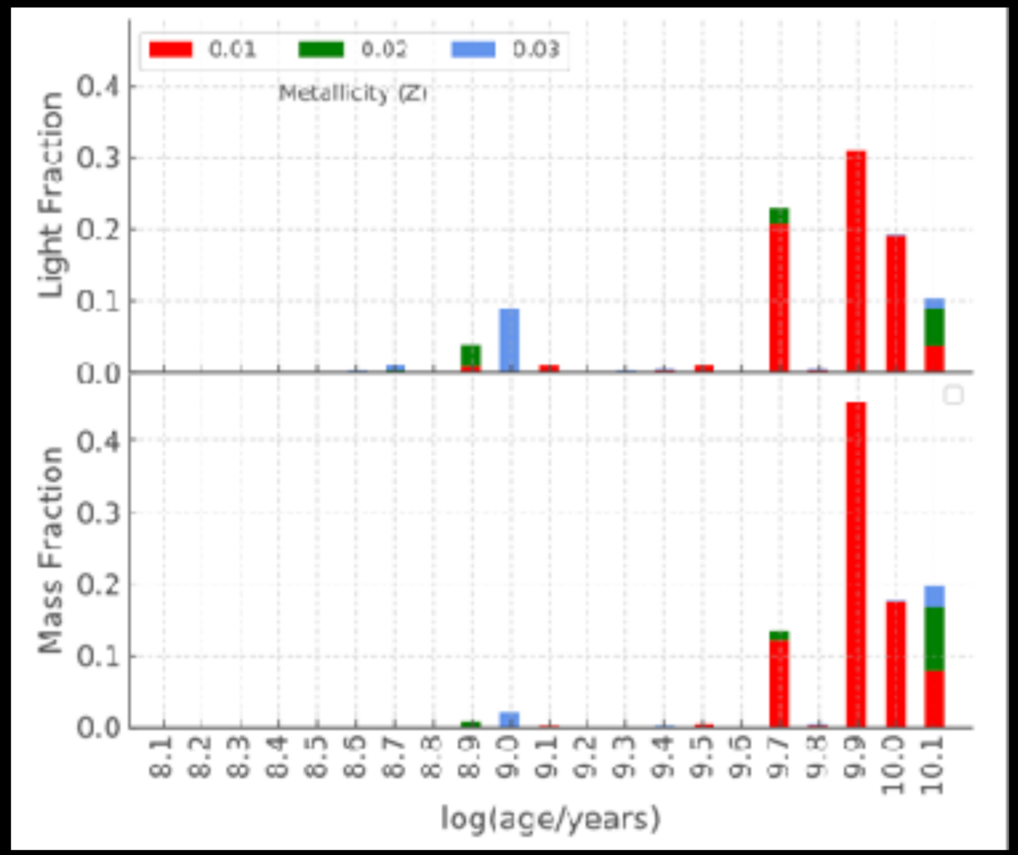


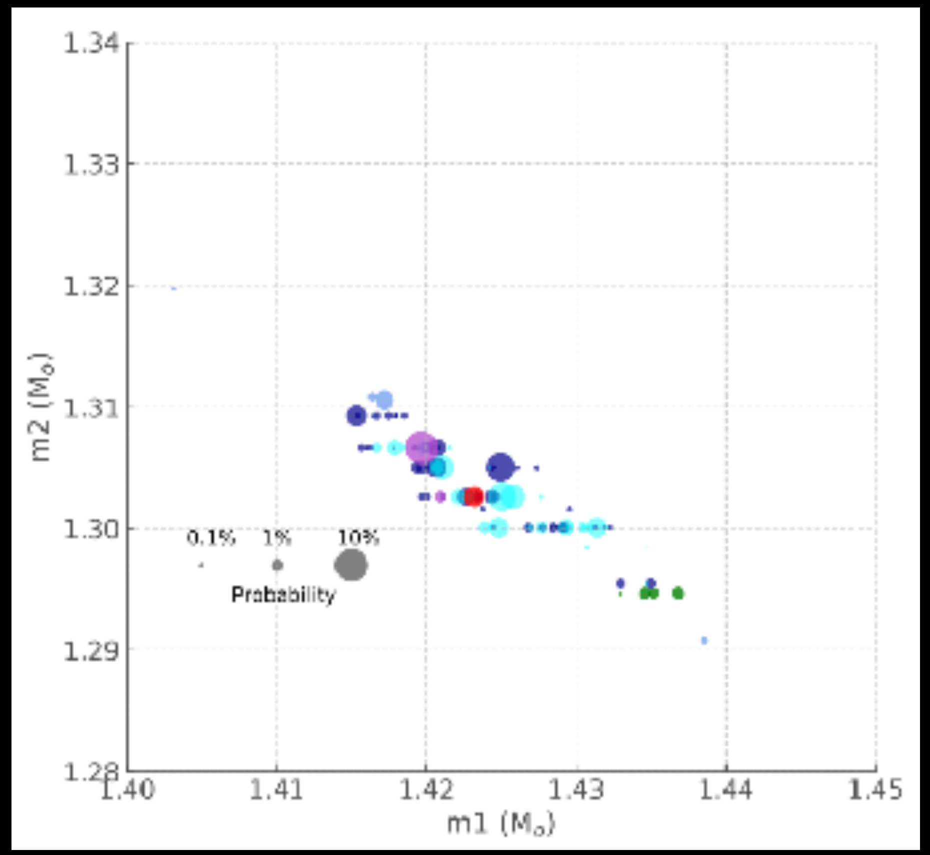
NGC 4993: S0 galaxy with evidences for ~<Gyr merger

Old stellar population at KN position

Binary stellar population codes suggest 5 < age < 12 Gyr and Z = 0.01

<u>Progenitor: massive binary system + CE phases before DNS formation</u>

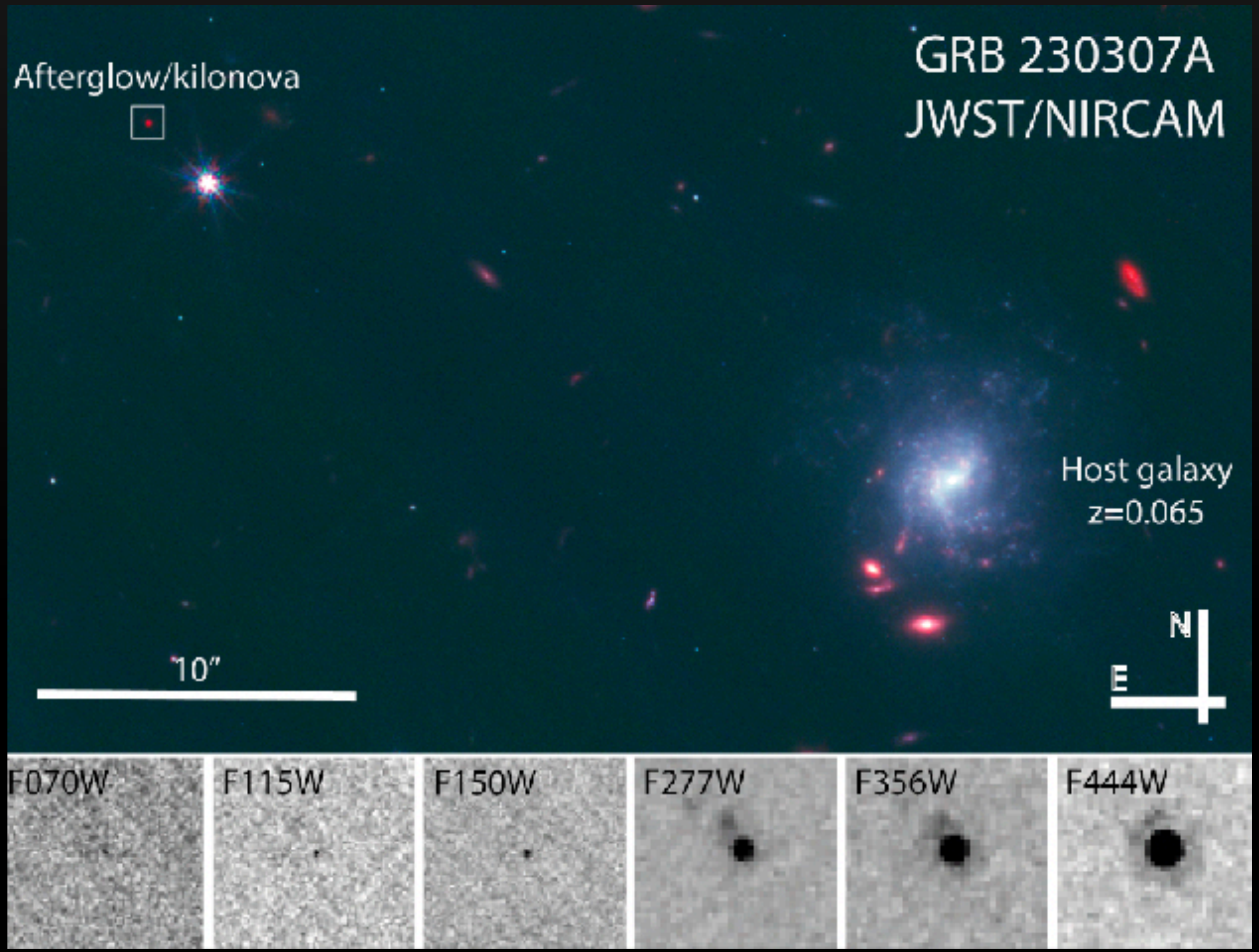




(Levan+ 2017, Stevance+ 2023)

Kilonovae/short GRB

The JWST KN associated with GRB 230307A



Very bright (2nd) GRB associated with a faint red counterpart

faint z=3.87 galaxy found by JWST, but Eiso = 10^{56} erg ...

JWST shows presence for r-process line features at z=0.06

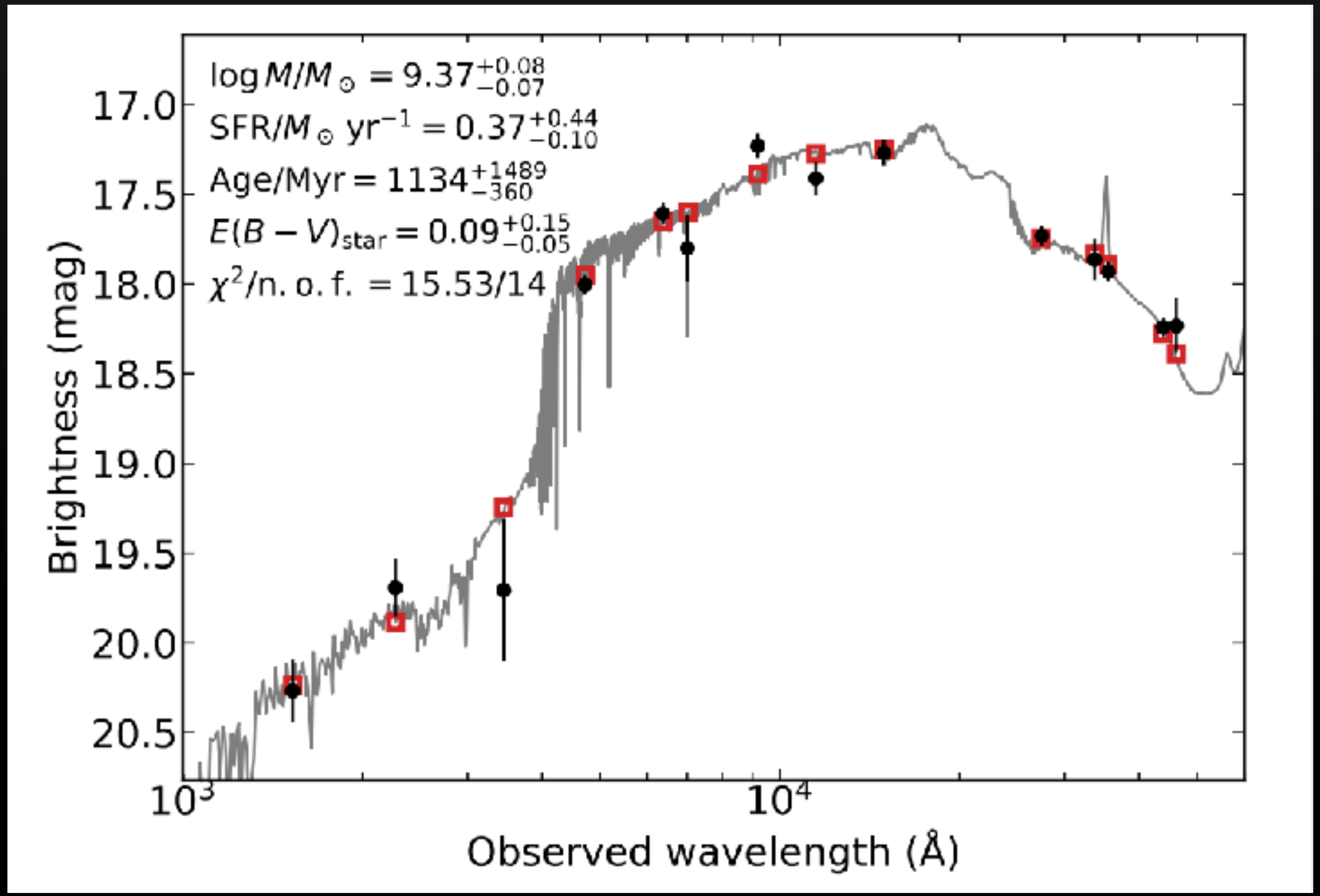
=> consistent with close ~40 kpc galaxy

Still consistent with offset displayed by short GRBs

(Levan+ 2024, Fong+ 2022)

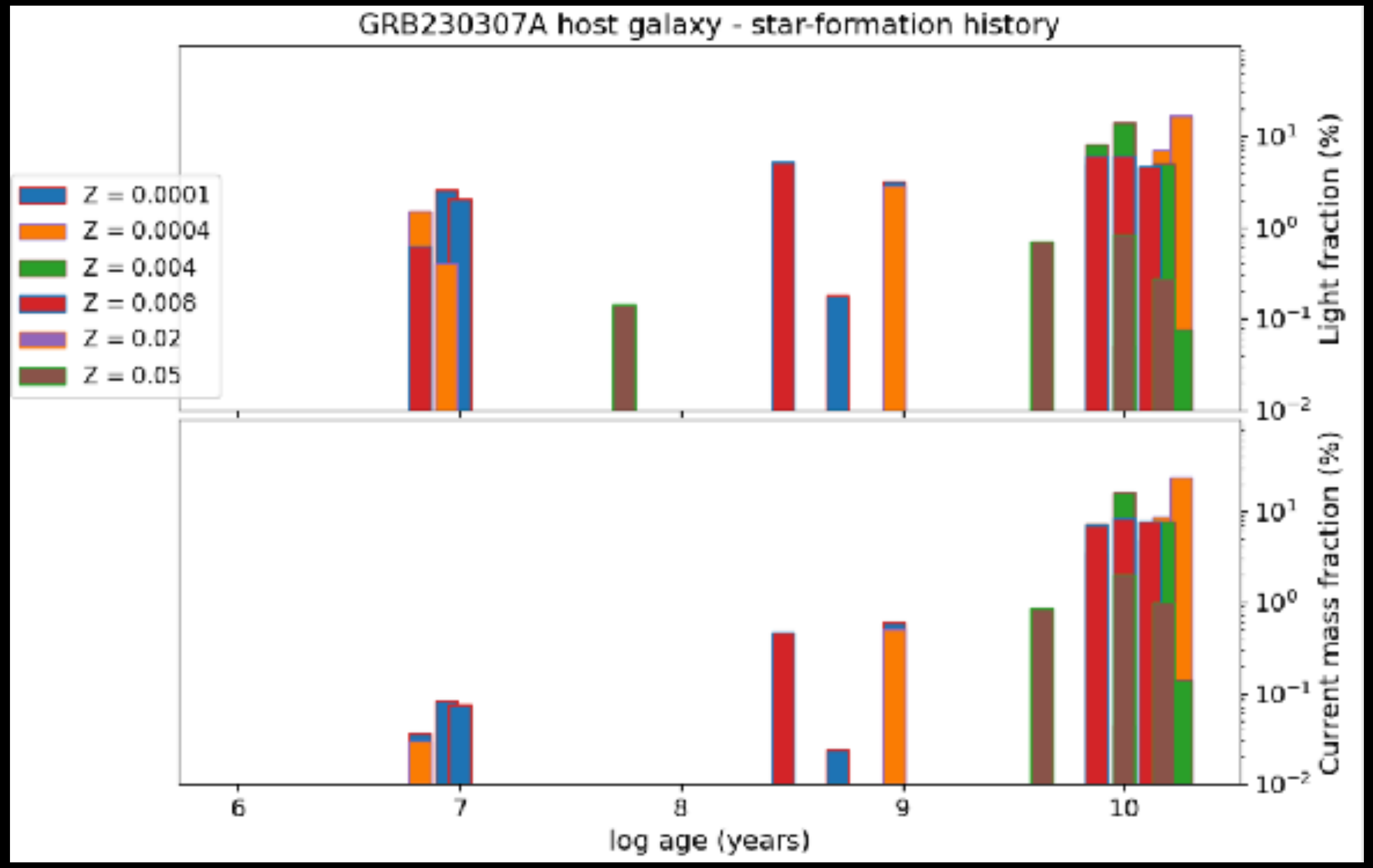
Kilonovae

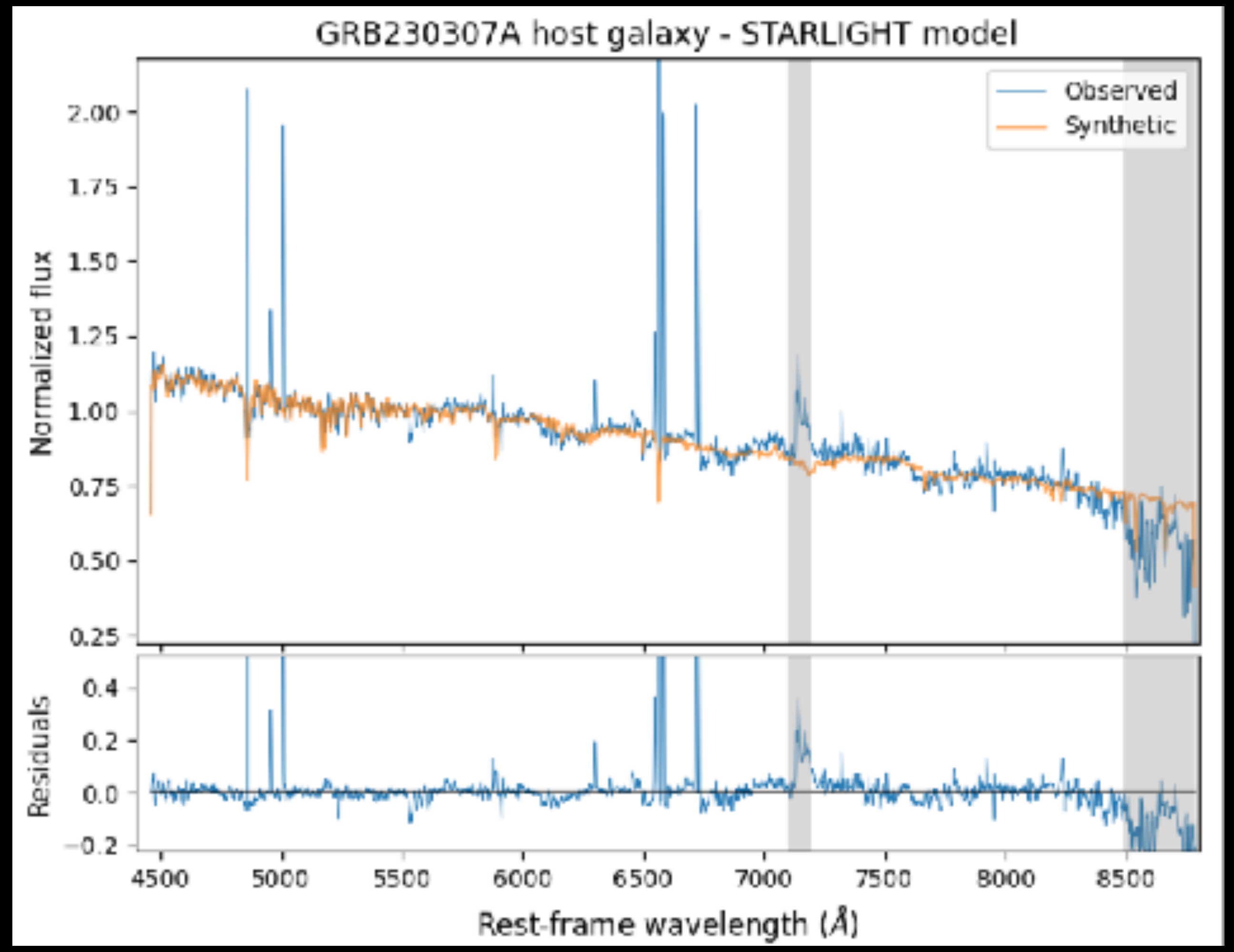
Host galaxy being a relatively low (M* ~ 10^9 MSun) with three main stellar populations



"the galaxy is dominated by an old population with sub-solar metallicity and has a younger component likely originating from inflow/accretion of pristine gas"

<u>KN position (40 kpc) not consistent with young component !!!</u>





(Levan+ 2024)

Conclusions

SHARP/VESPER is ideal to build a targeted sample of spatially-resolved GRB hosts

=> SFR @ $z < 3$ (or using [O II] @ $z < 5 - 5.5$)

=> metallicities at GRB location for a large sample of arcsec-localized GRBs

Host properties for bright peculiar events (SLSNe, PISNe)

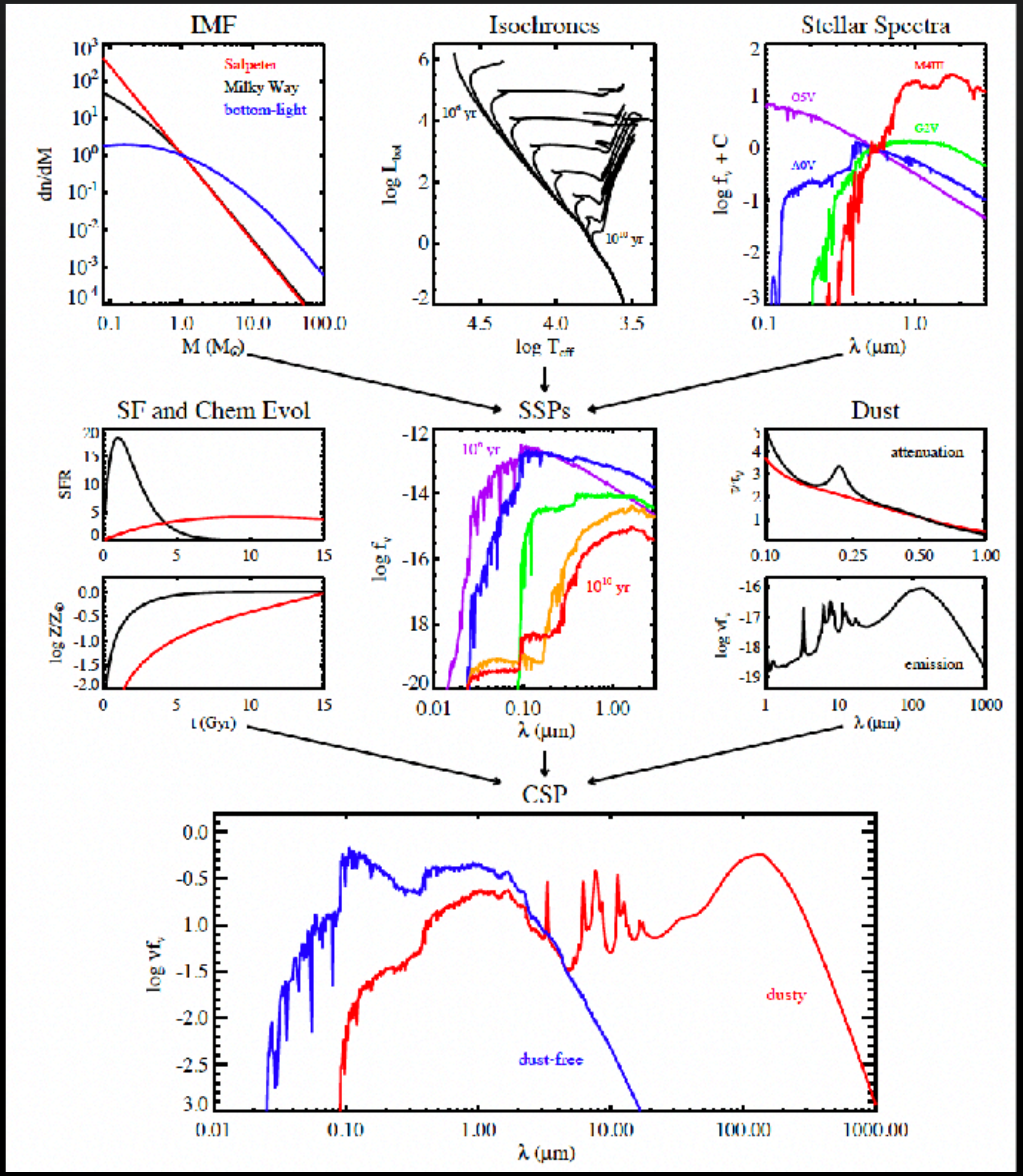
Metallicity evolution @ high-z for relativistic SNe (with or without GRBs)

Providing hosts properties for EUCLID/ROMAN discovered transients

Kilonovae … short GRBs …

Thank you !!!

Stellar populations synthesis



Galaxies SED is the result of several components including multiple stellar populations, gas and dust and their evolution history

Star-formation history, IMF, metallicity & abundances

Building accurate evolutionary tracks is challenging

Composite SP result from SSP with inclusion of multiple stellar population with different SFH and metallicity and include dust

SF episodes can be given as input or inferred from analysis

(Conroy+ 2013, Cid Fernandes+ 2005)

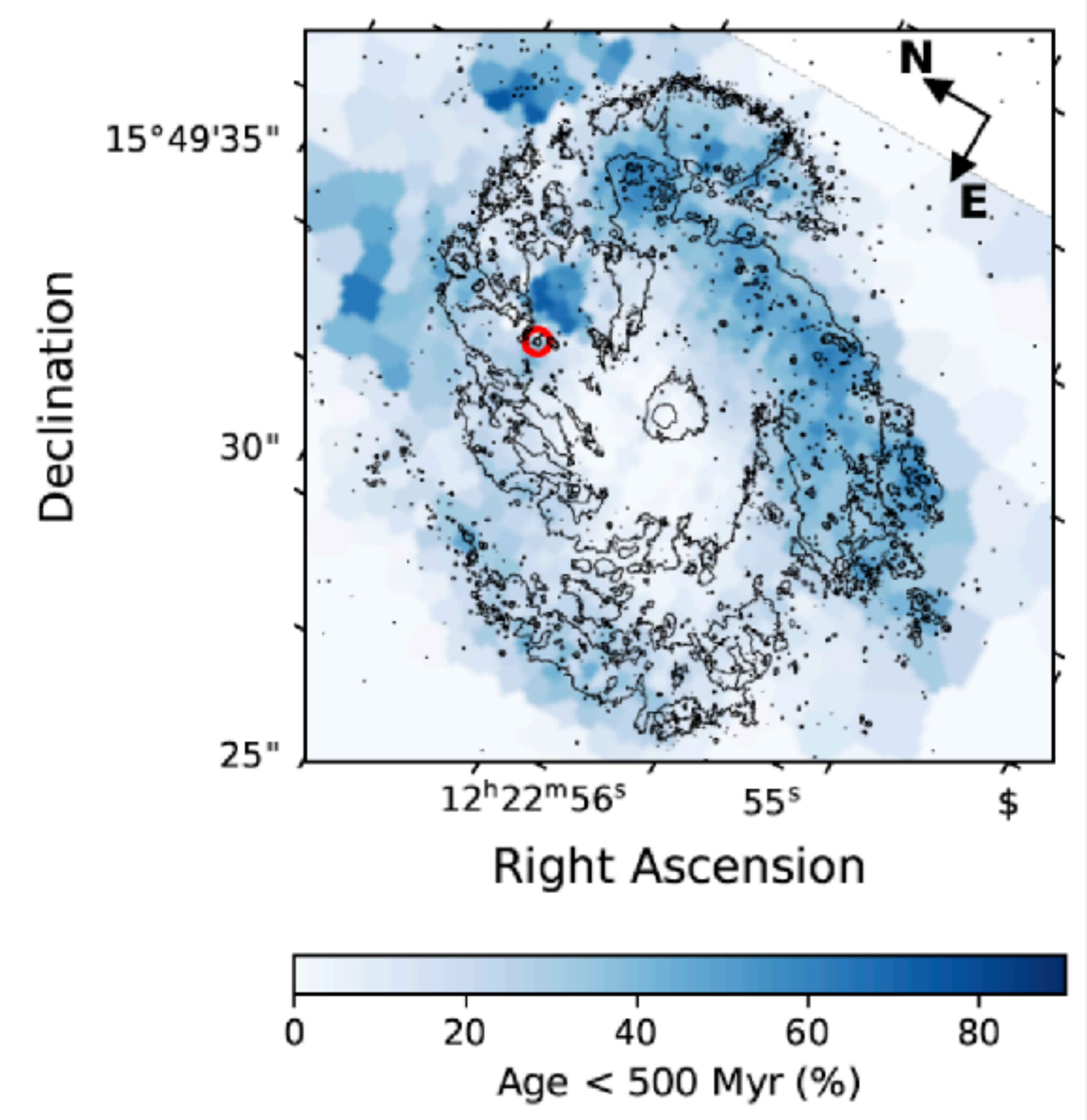
Spatially-resolved analysis

Integral-field spectroscopy represents the best strategy to study environments of transients

Information on the stellar population and ISM at the location of transients

But still biased information:

- Not enough spatial resolution to resolve the SN progenitor environment
- Possible projection effects of the galaxy
- Integrated light along the line of sight can affect estimate of gas properties



(Gagliano, Izzo et al. 2022)

GRB-SNe

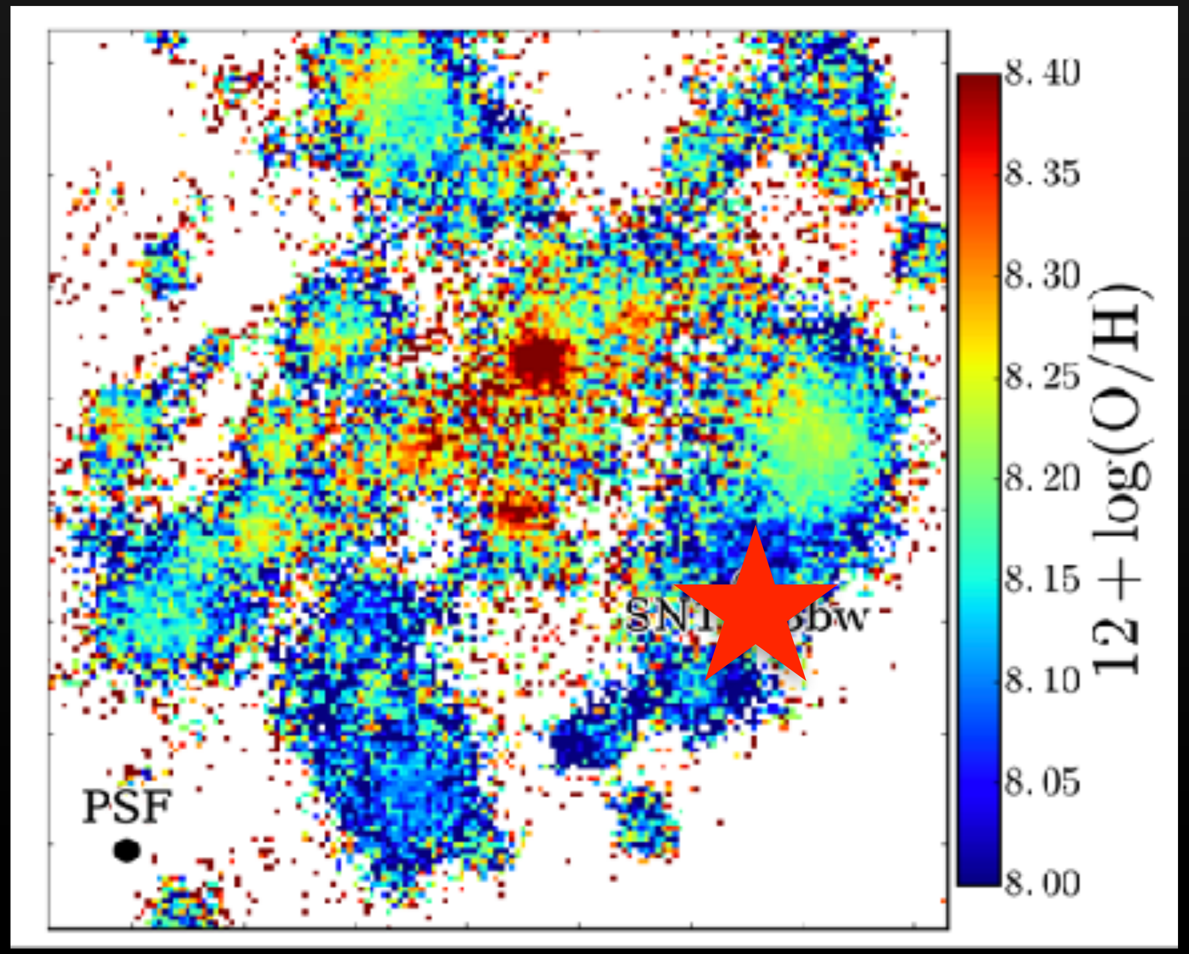
IFU can provide direct information on the metallicity of nearby GRB-SNe progenitors

Use of emission line
Metallicity indicators

Expressed as 12 + log(O/H)

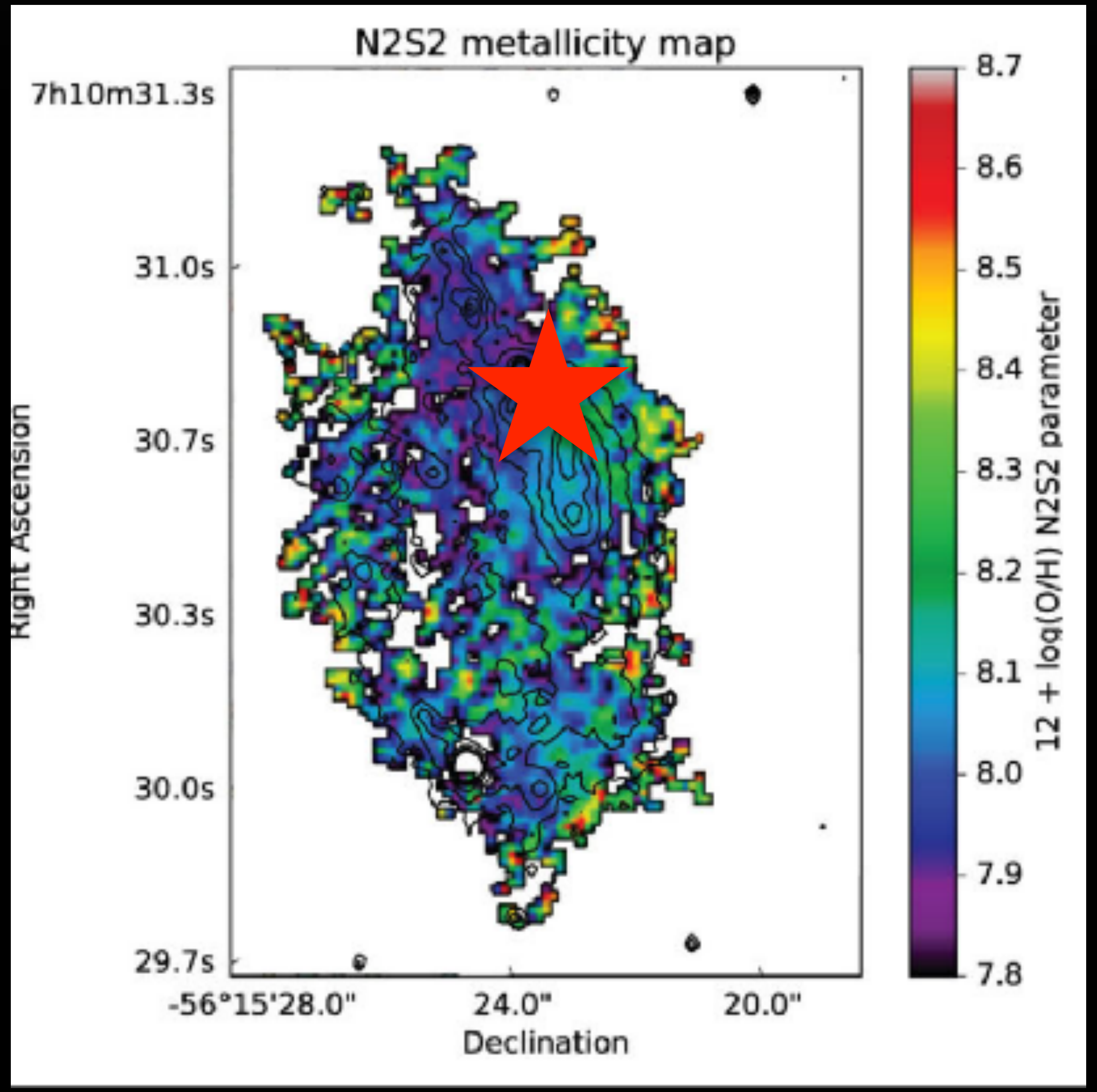
However, strongly dependent on ionization level,
and temperature gradients in the HII region

Low gas metallicity at GRB/SN position
12 + log(O/H) ~ 8.0-8.5



GRB 980425

(Kruhler+ 2017)



GRB 100316D

(Izzo+ 2017)

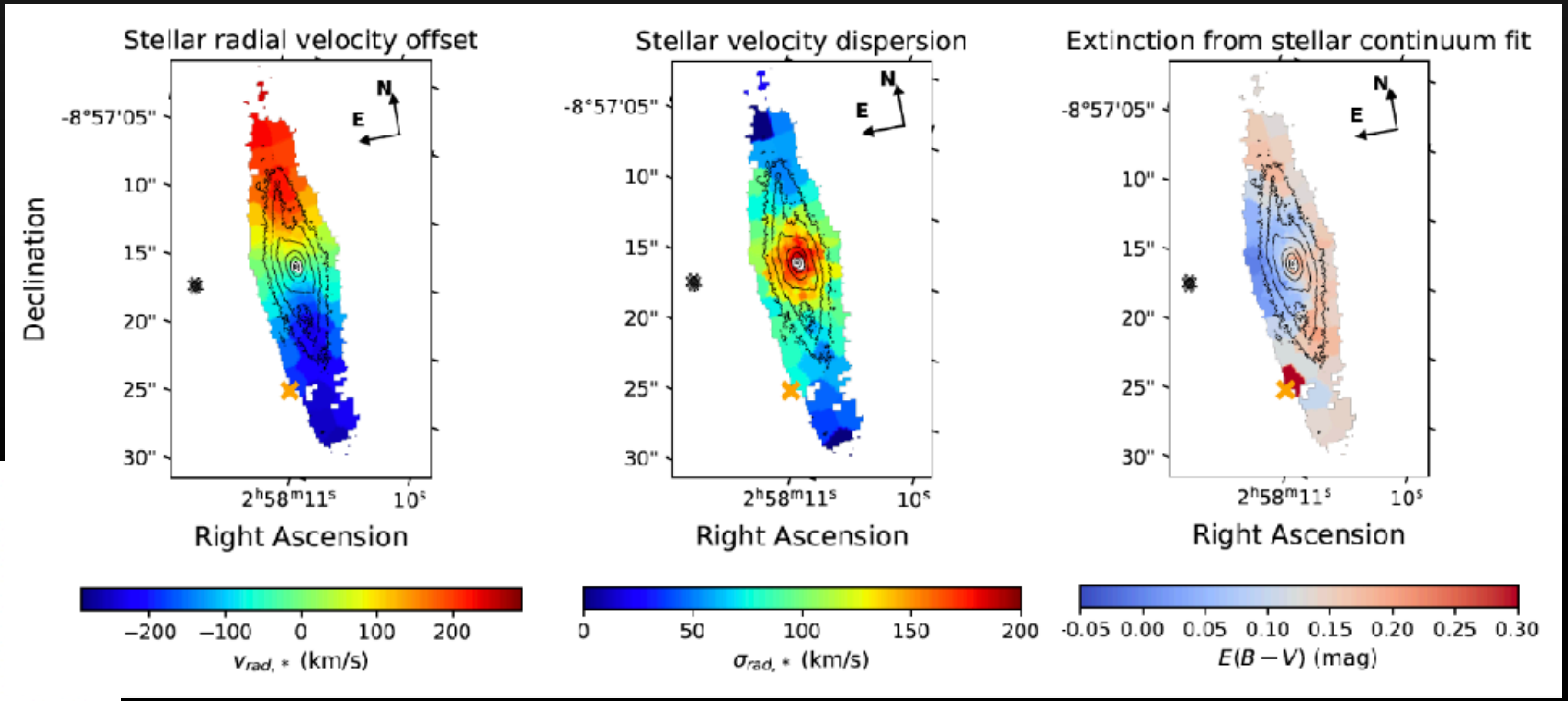
GRB-SNe

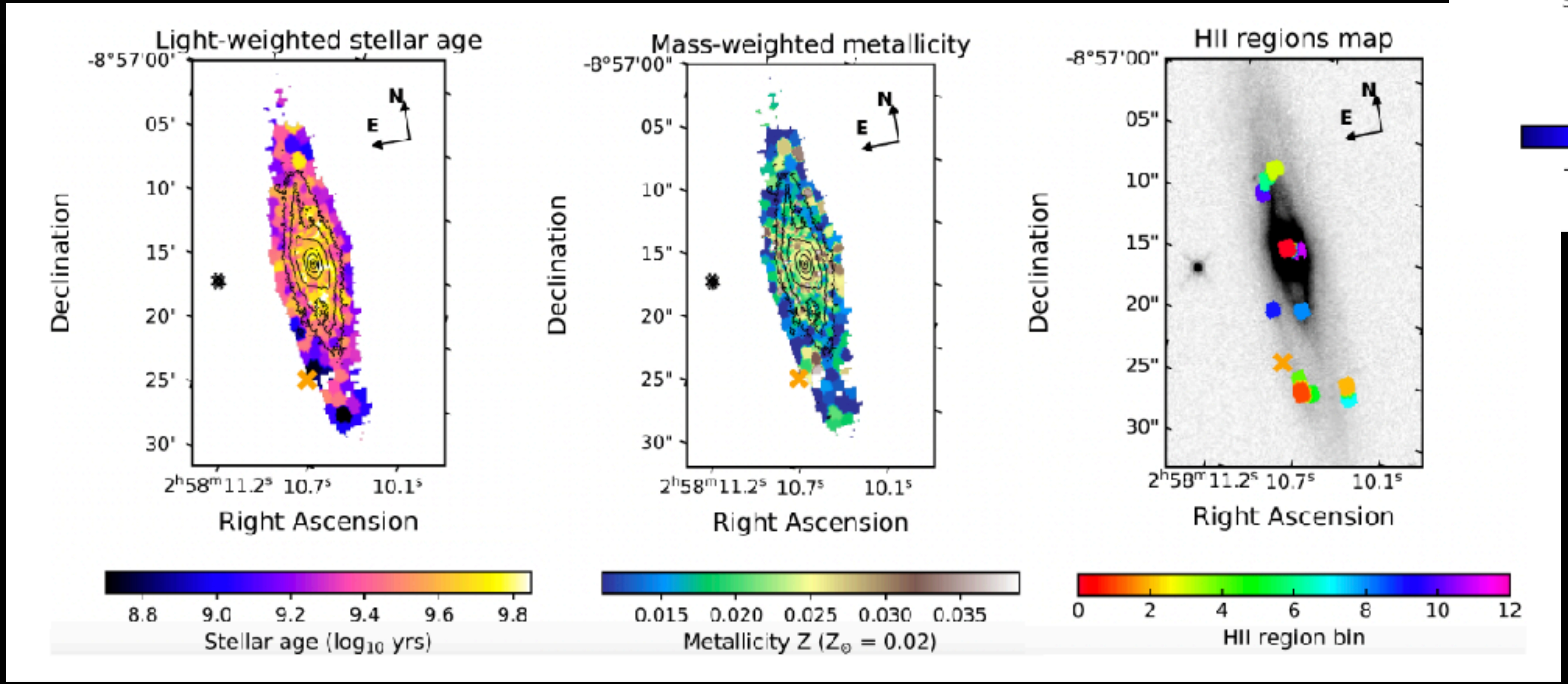
Spatially-resolved information on several physical properties of the stellar population

Stellar age and metallicity

+

HII region distribution





Radial velocity & extinction

(from stars & gas)

(Izzo+ TBS)

Ic BL SNe w/o GRBs

Survey of Ic-BL host galaxies using PMAS/PPAK @ 3.5m telescope in Calar Alto

With or without jet observing program:
Goal: sample of 30 (19 observed) Ic-BL host galaxies

Mrk 1309 - SN 2014ad

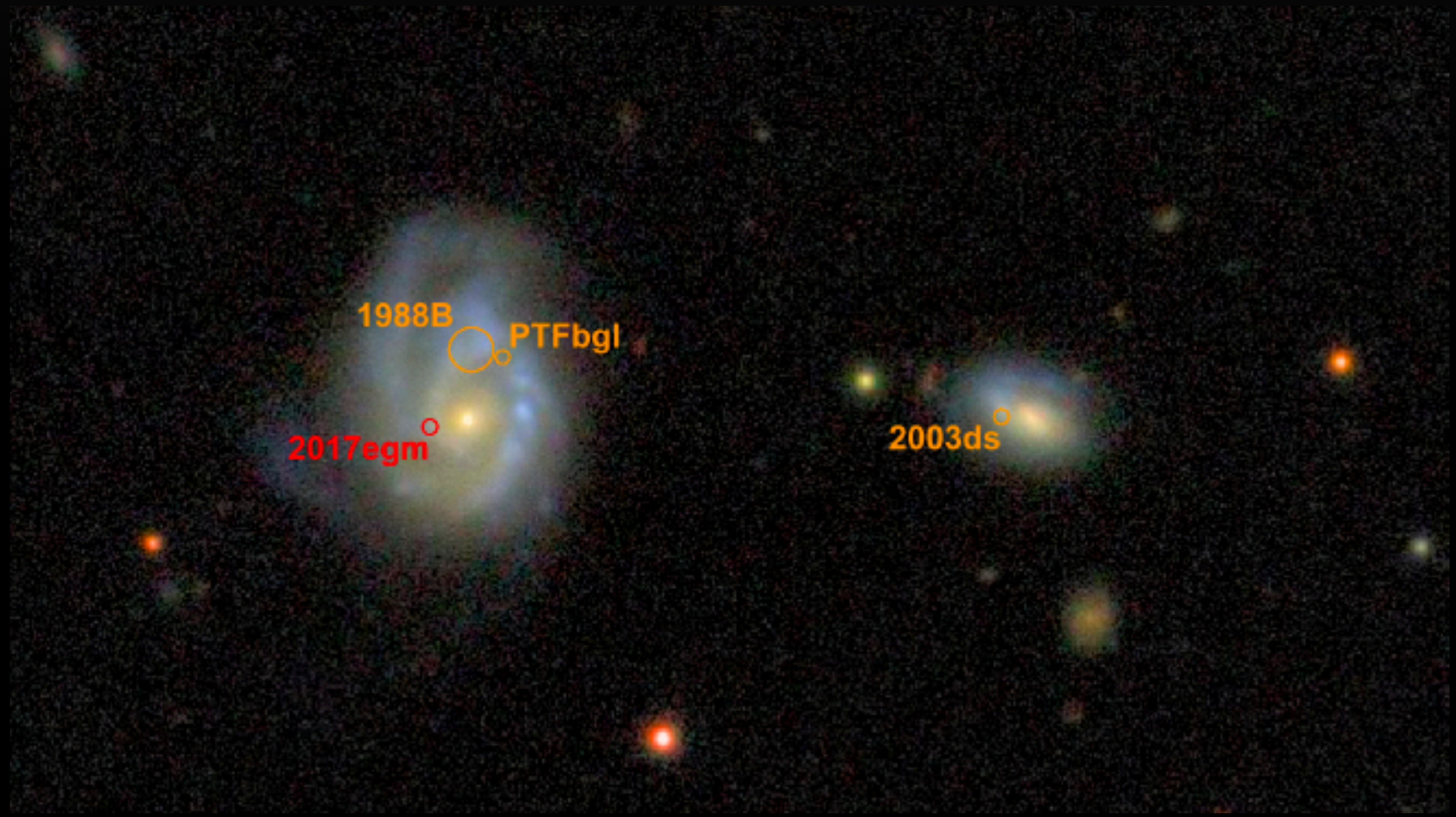
(PI: Gallego-Cano, Izzo)

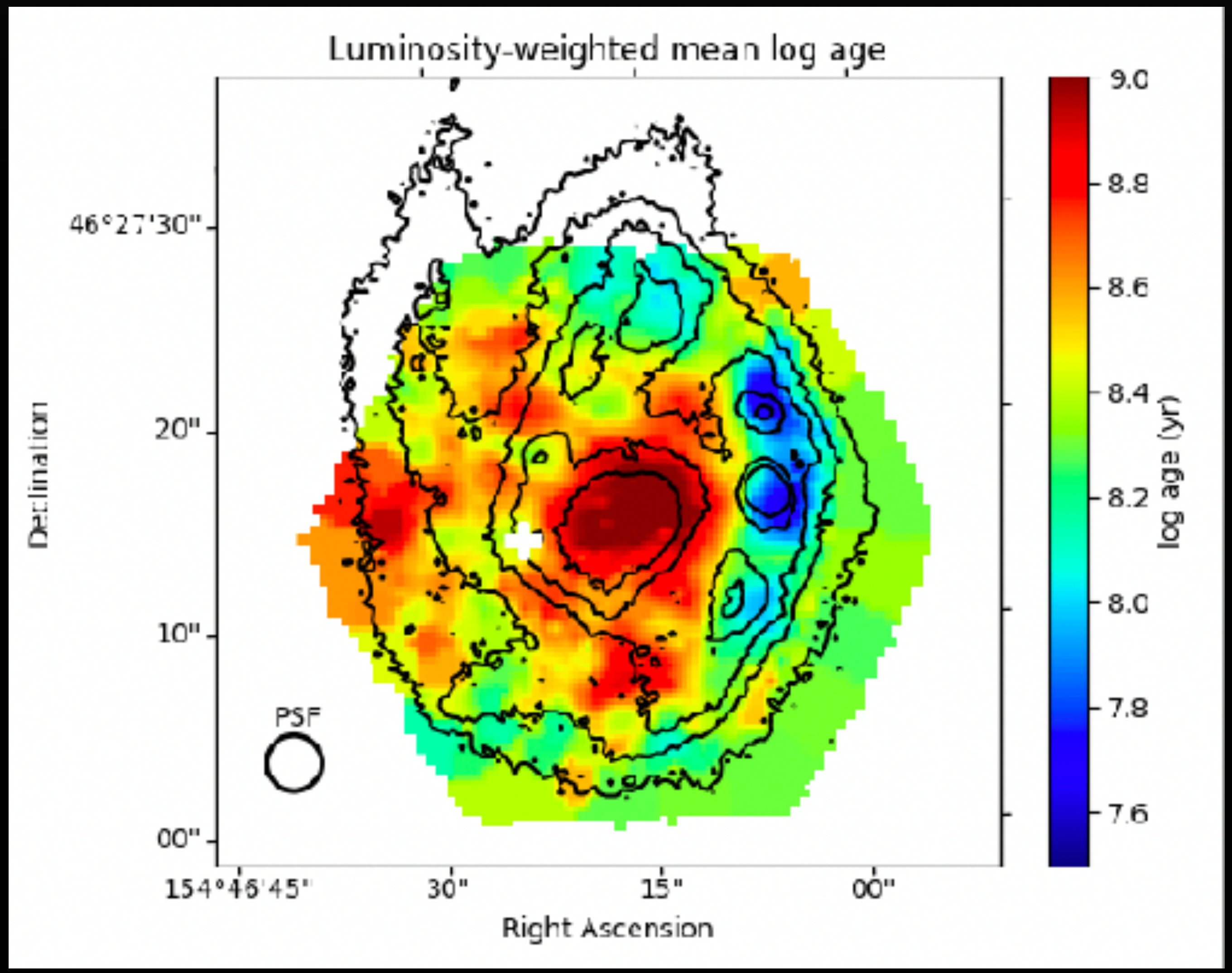
Super-Luminous SNe

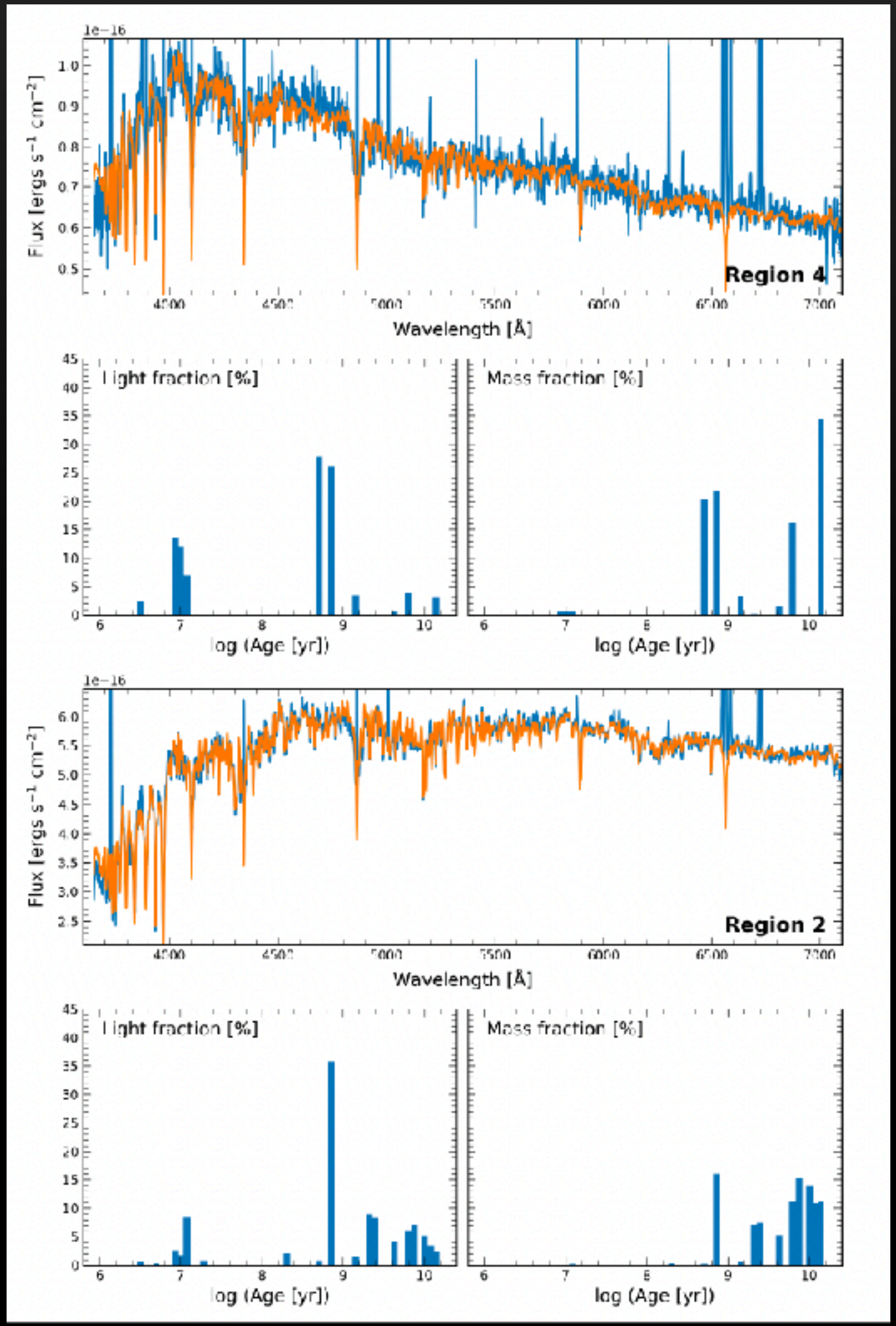
Nearby SLSN 2017egm in high-Z NGC 3191

STARLIGHT => two dominant SP components
1) 2-10 Myr with low-Z (SLSN progenitor) ; 2) older ~Gyr one

Kinematics & SPS shows evidence for interaction with companion
=> recent SF burst, young stars and low-Z gas component







(Izzo+ 2018)