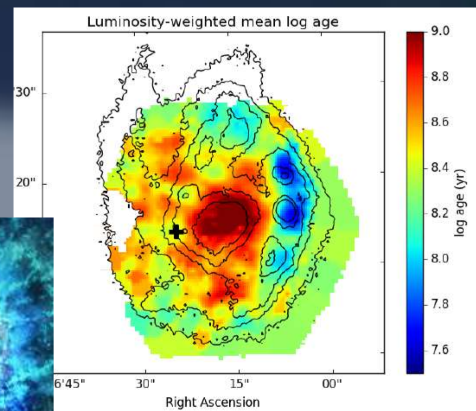
LAM Seminar @ LAM!
Dec. 6, 2021



THE PROGENITORS AND HOSTS OF STELLAR EXPLOSIONS

Christina C. Thöne
(IAA-CSIC/HETH, Granada)

High Energy Transients & their Hosts

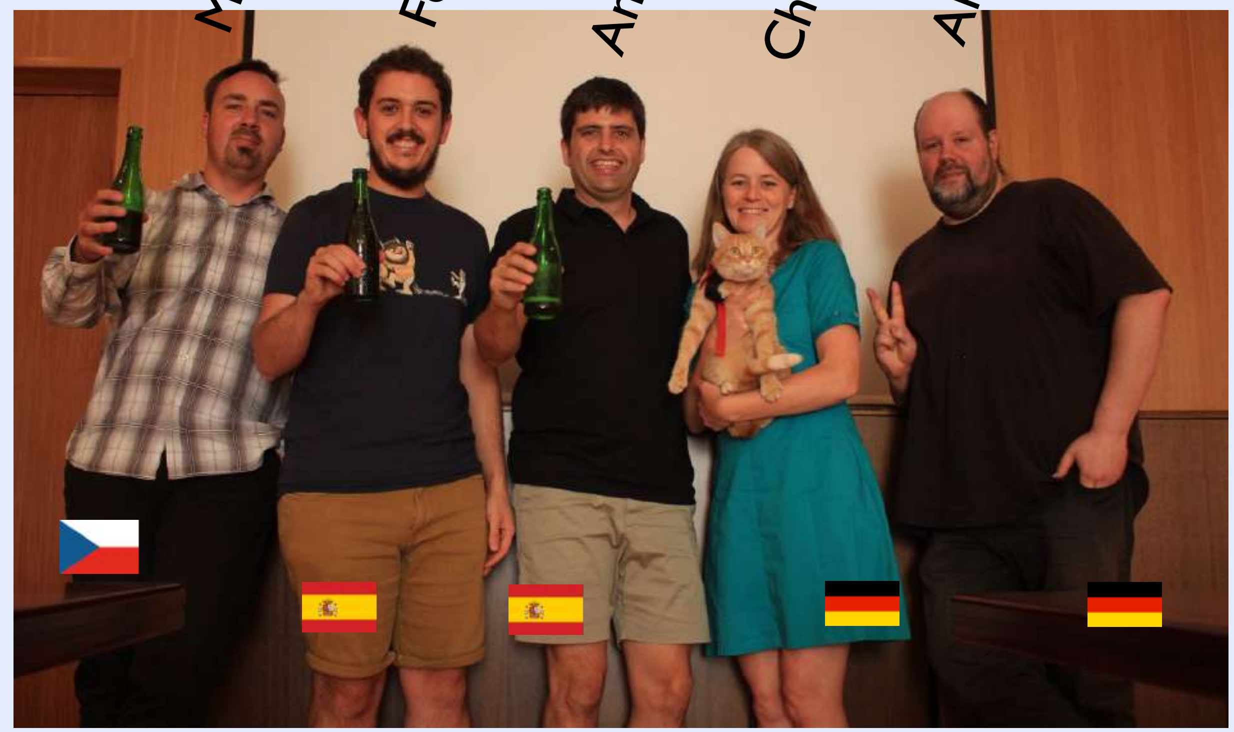
Founded in 2012

<u>Funding:</u>
2 Ramon y Cajal fellows
1 junior PI grant
3 (4) Juan de la Cierva fellows
1 PTA, 2 PhD grants

<u>156 refereed Publications</u>
9900 Citations
„h-index“ 48

Closing on Dec. 15, 2021 ;-(

Martin Blazek
Feli Agüí
Antonio de Ugarte
Christina Thöne
Alex Kann



PTA (technical postdoc)
PhD student
co-PI ↓ OCA Nice
PI ↓ ??
AYA-JIN (junior leader)

Kasia Bensch

PhD student/ data scientist

Former members

↓ Univ. Potsdam

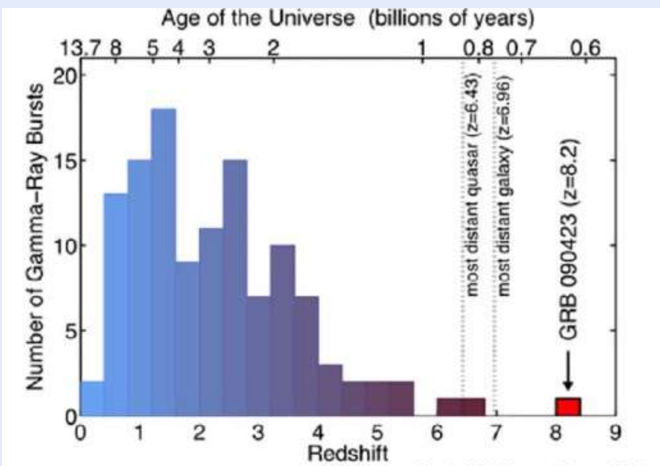
↓ DARK, Copenhagen

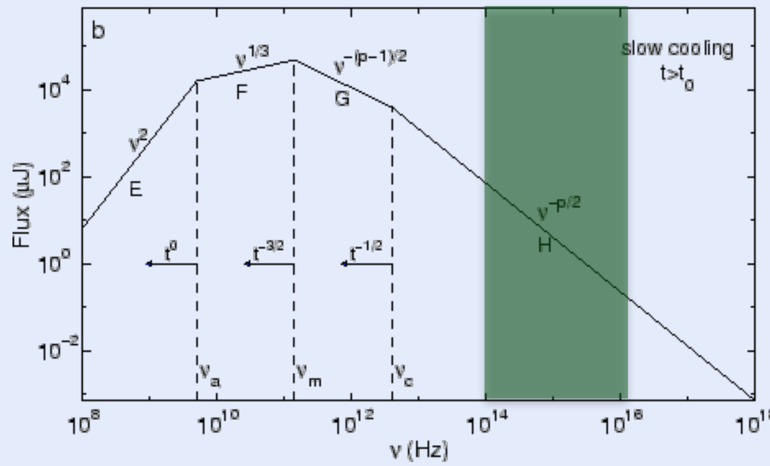
IAA ↖ ↓ INAF/OA Rome

↓ NOT ↘ Stockholm

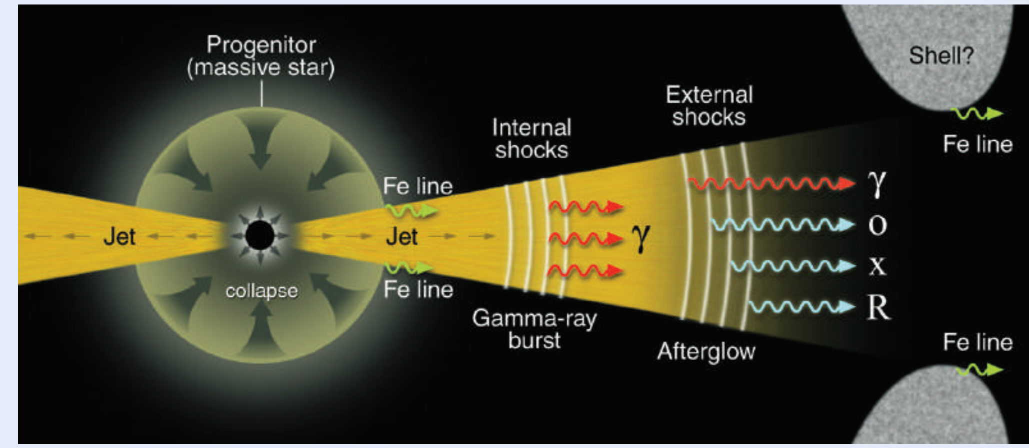
↓ Left academia

Stellar explosions: GRBs





Synchrotron spectrum



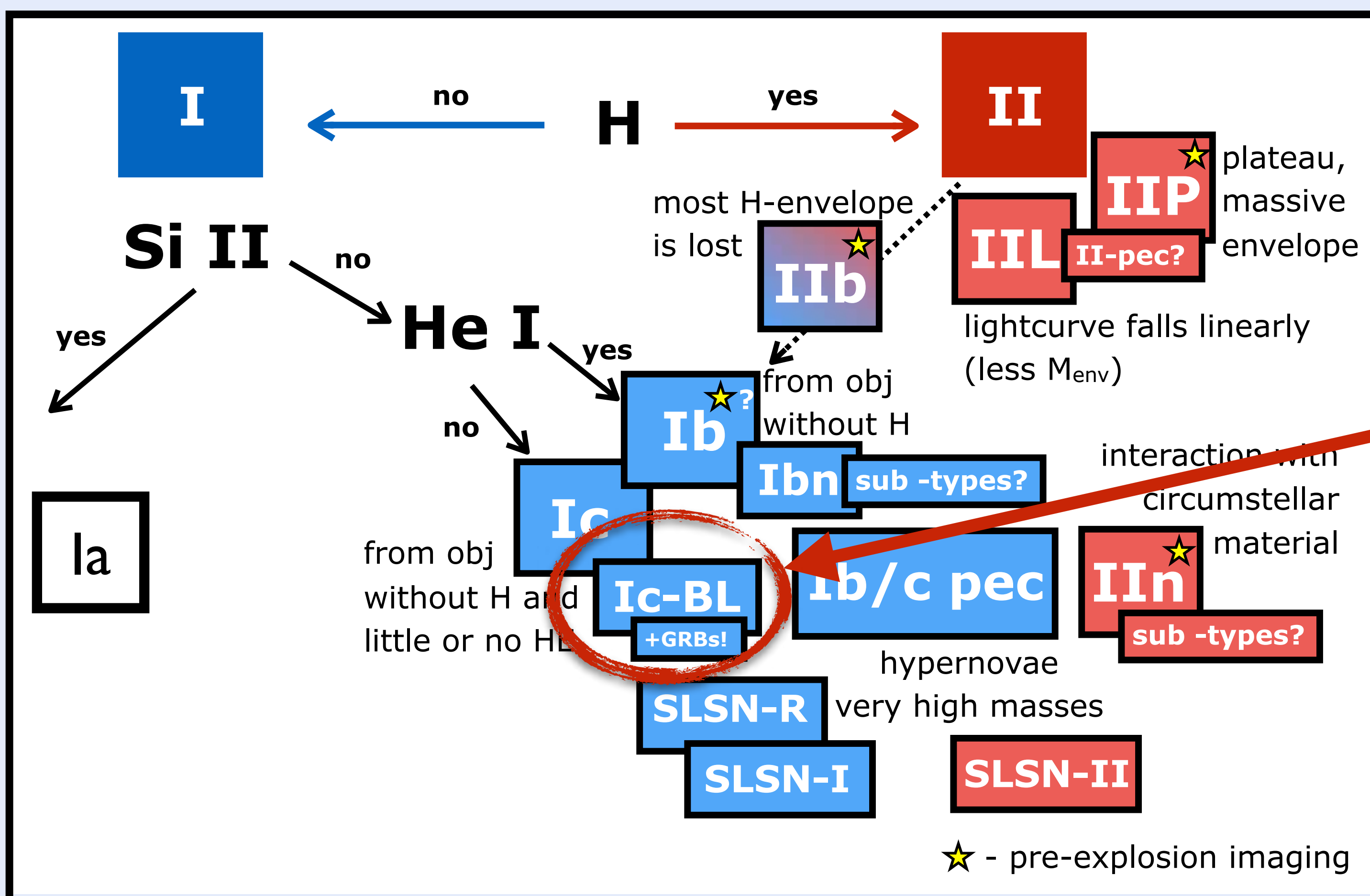
Long/soft GRB
$T_{90} > 2s$

BL-Ic SN
star-forming
host

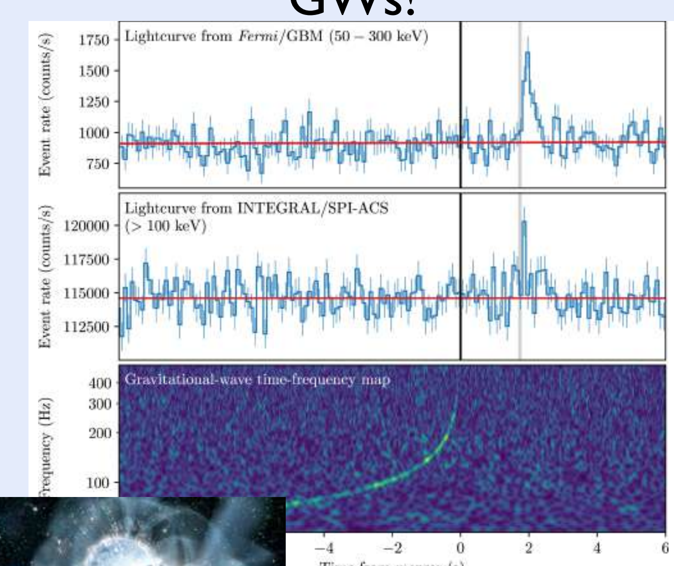
Short/hard GRB
$T_{90} < 2s$

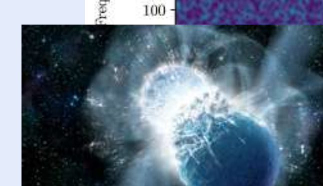
kilonova
young+old hosts

GWs!



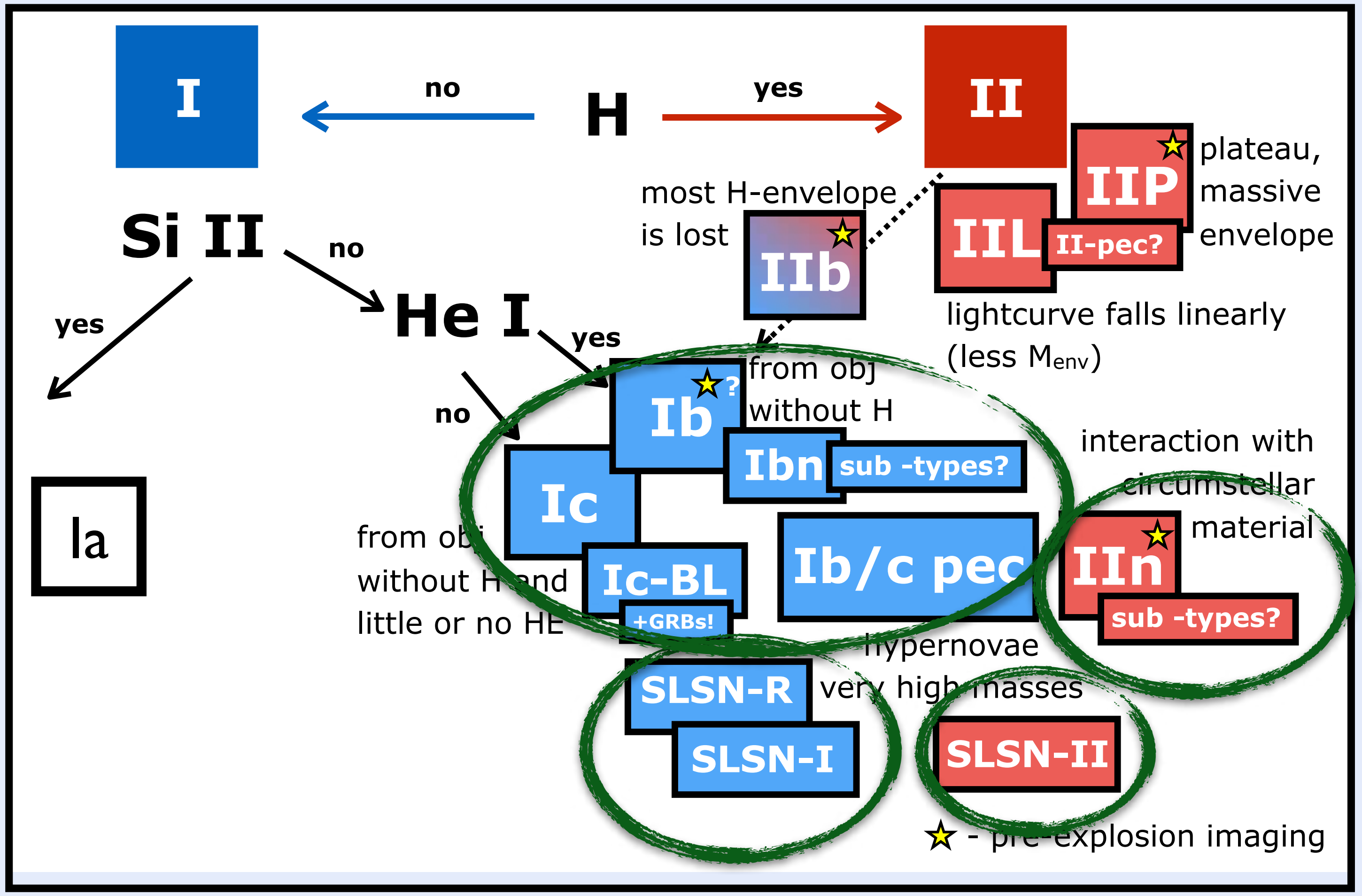
Collapsar
(massive star)



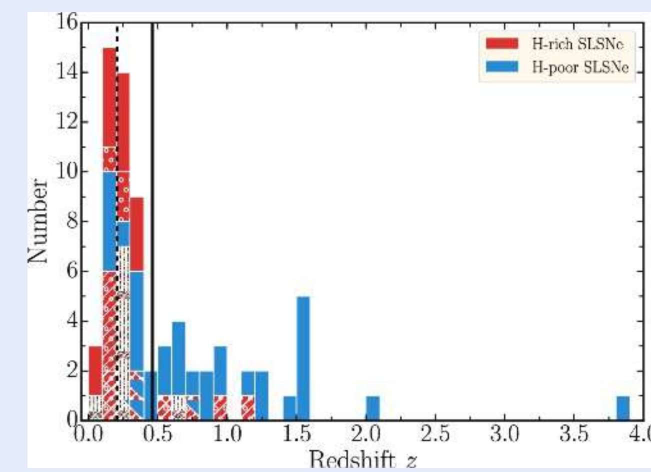


NS merger

Stellar explosions: supernovae

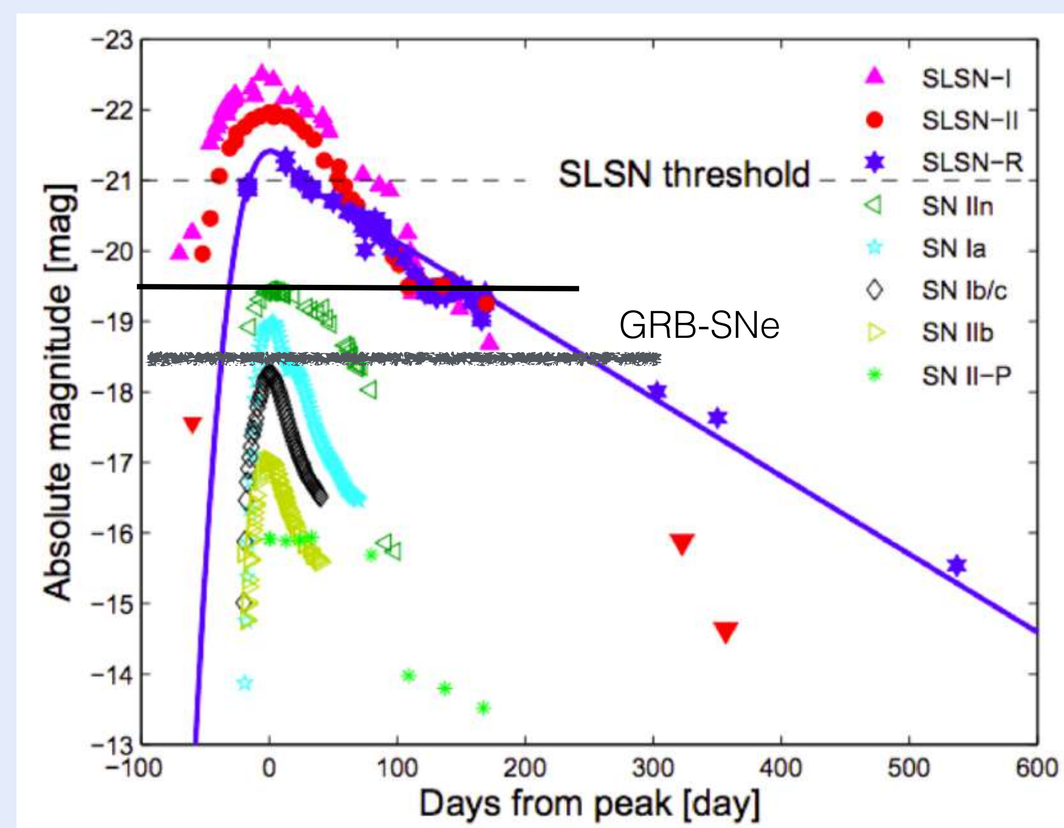


- SLSN-I: very massive stars
- SLSN-II: luminous IIn SNe? (CSM interaction)
- Powered by magnetars….?!
- Related to FRBs?!



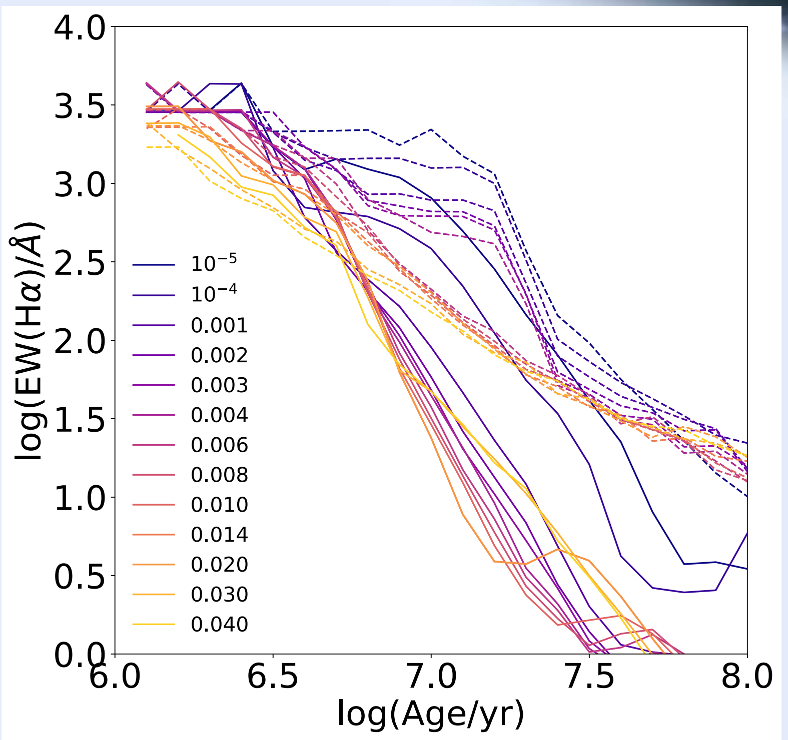
Other luminous SNe and progenitors:

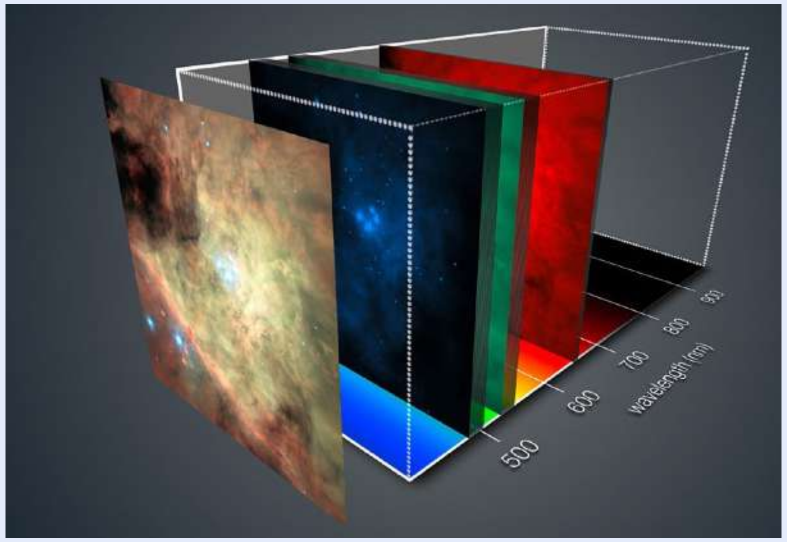
- IIn (interaction with CSM)
- Ib/c without GRB (stripped envelope stars)



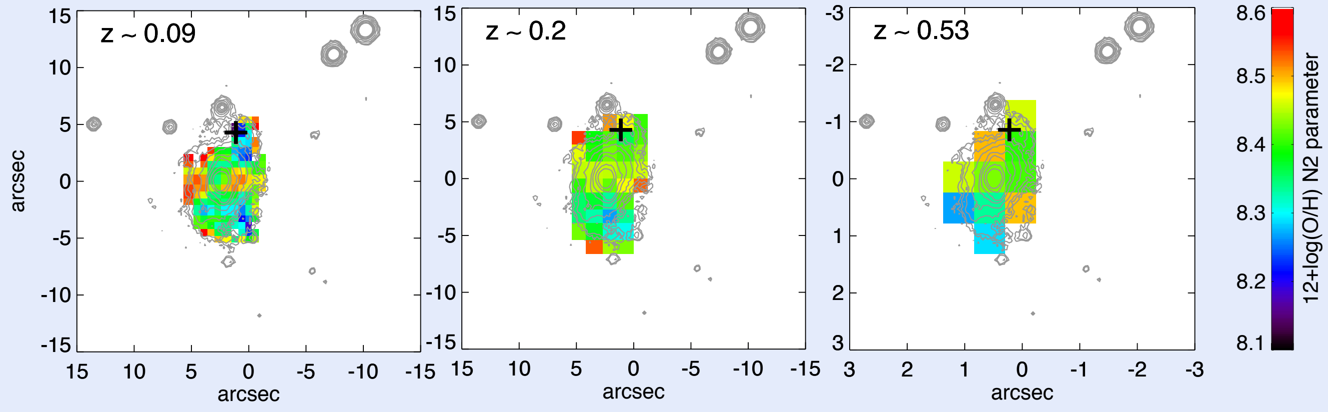
Progenitor properties from the environment

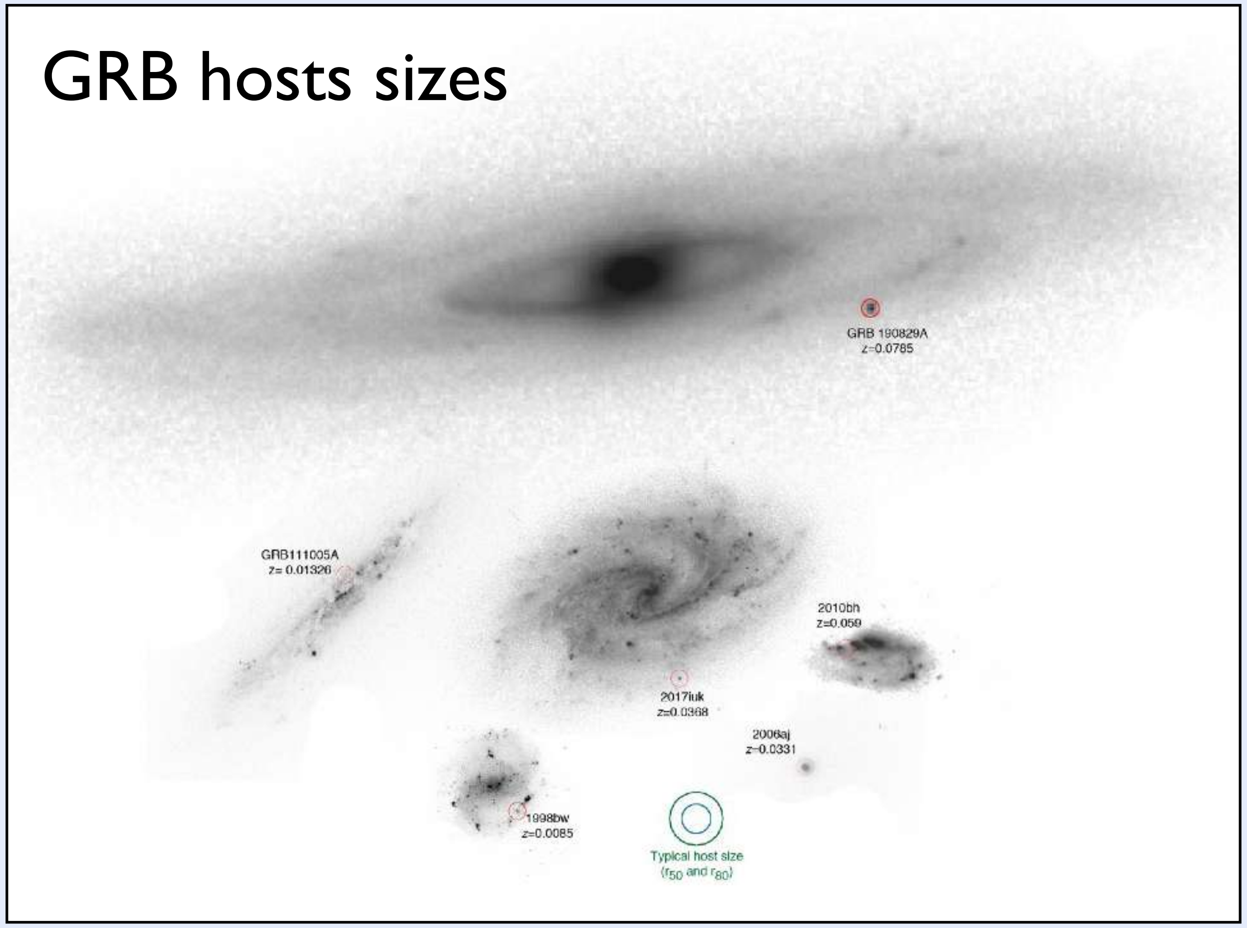
- Progenitor imaging tricky (anything beyond >50 Mpc): infer mass, Z, age from environment
- Problem1: most GRB hosts far & unresolved: <z>= 2.1 -> 8 kpc / arcsec!
- Problem 2: low-z GRB and SLSN hosts dwarf galaxies





Careful with resolution issues (simulation, Thöne et al. 14)



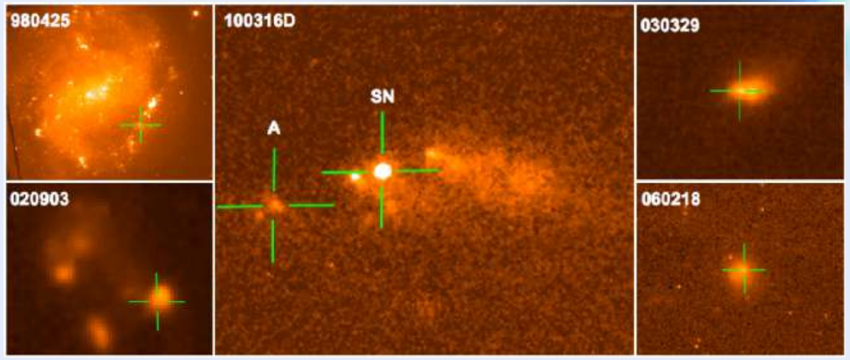


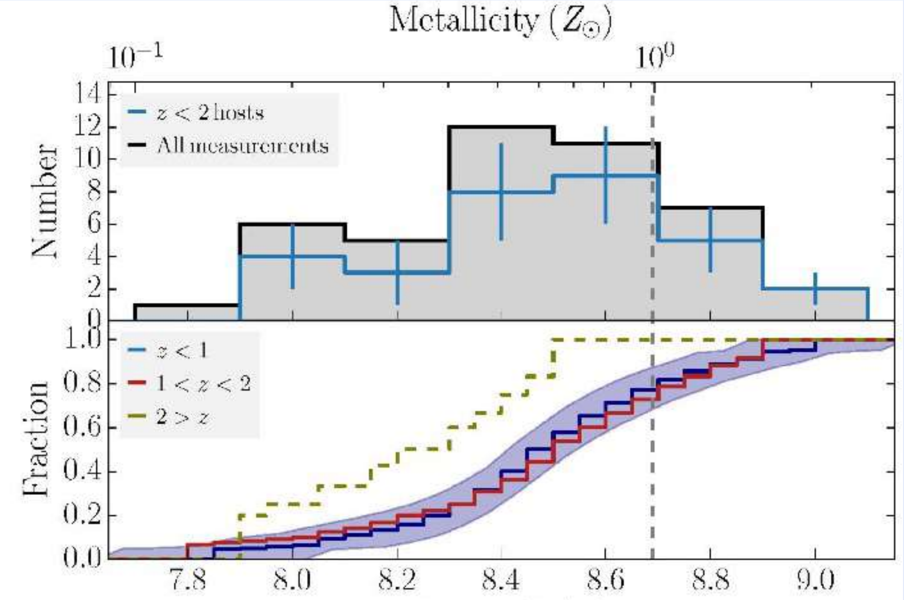
GRB hosts - resolved and unresolved

Long GRB hosts

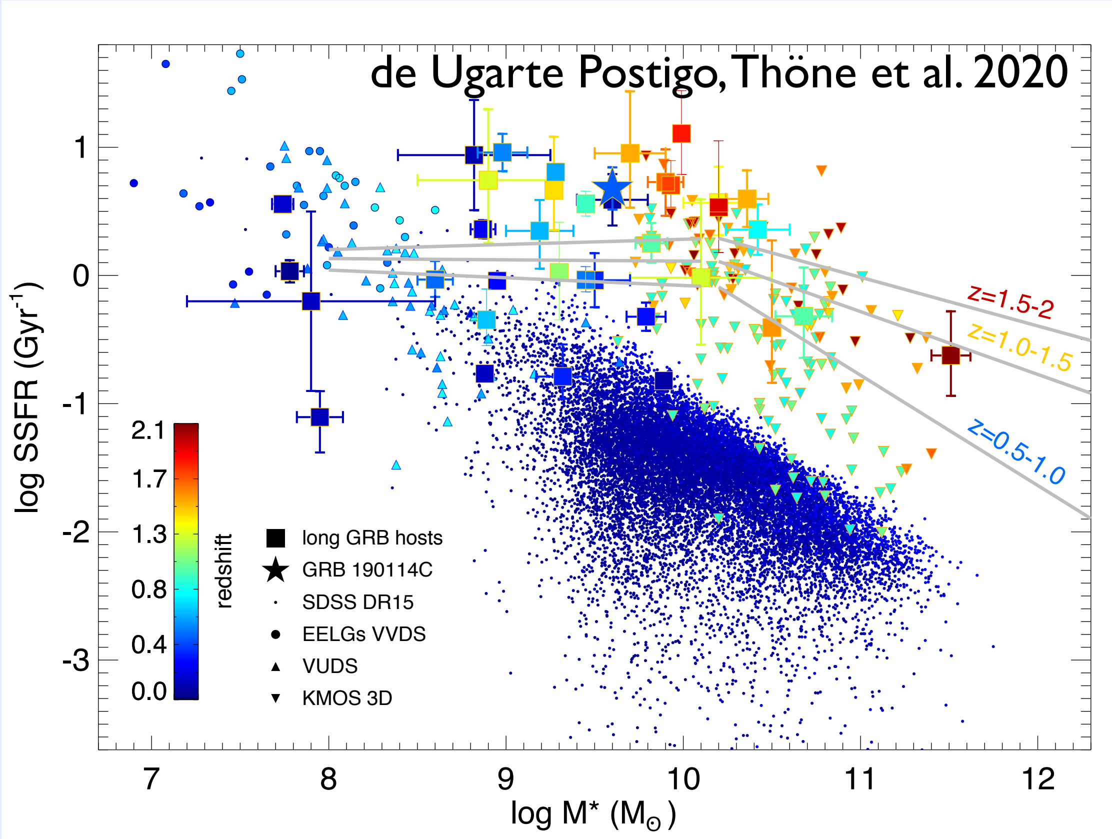
- GRB hosts
  z <1, mostly dwarfs (log M < 9 M*)
  z>2 ~10 M*
- lowish metallicity (<0.5 solar)
- high specific SFR

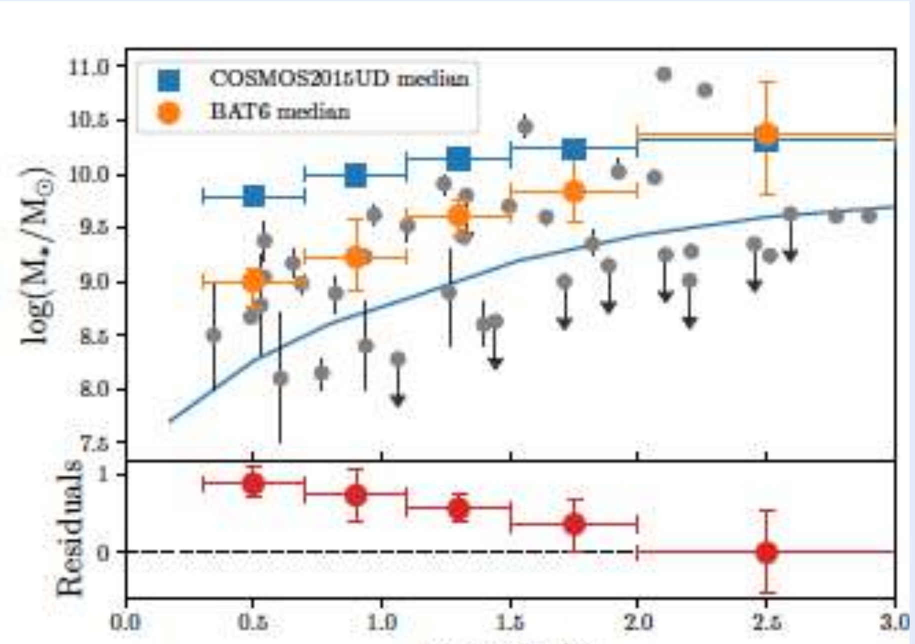
HST images of GRB hosts





Krühler et al. 2015

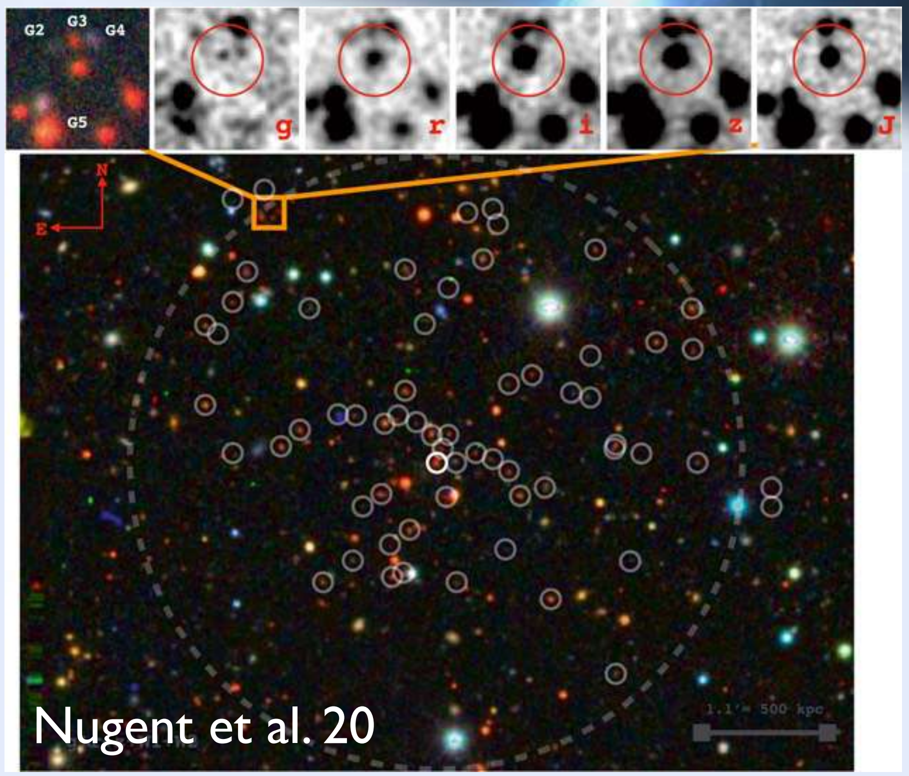




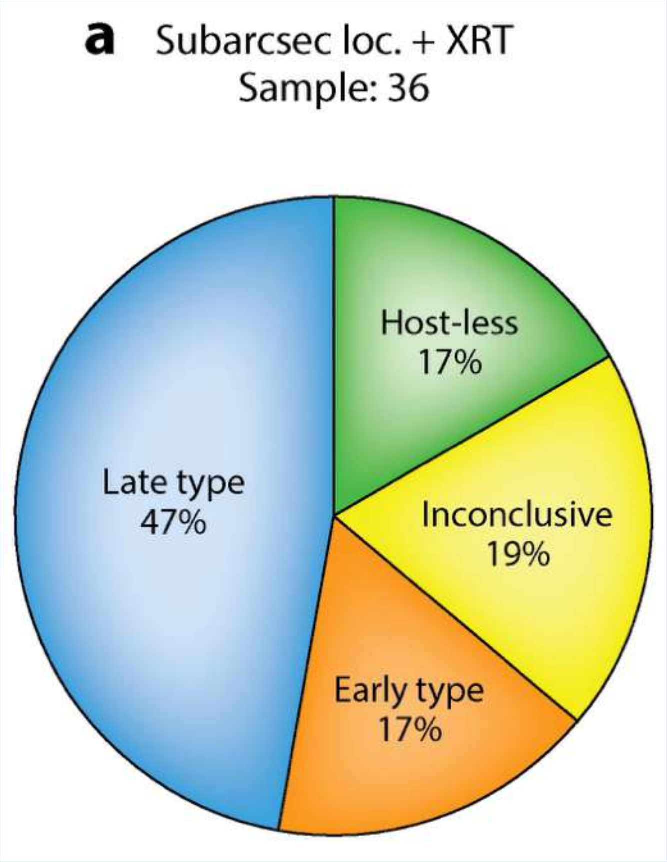
Palmerio et al. 2019

Short GRB hosts

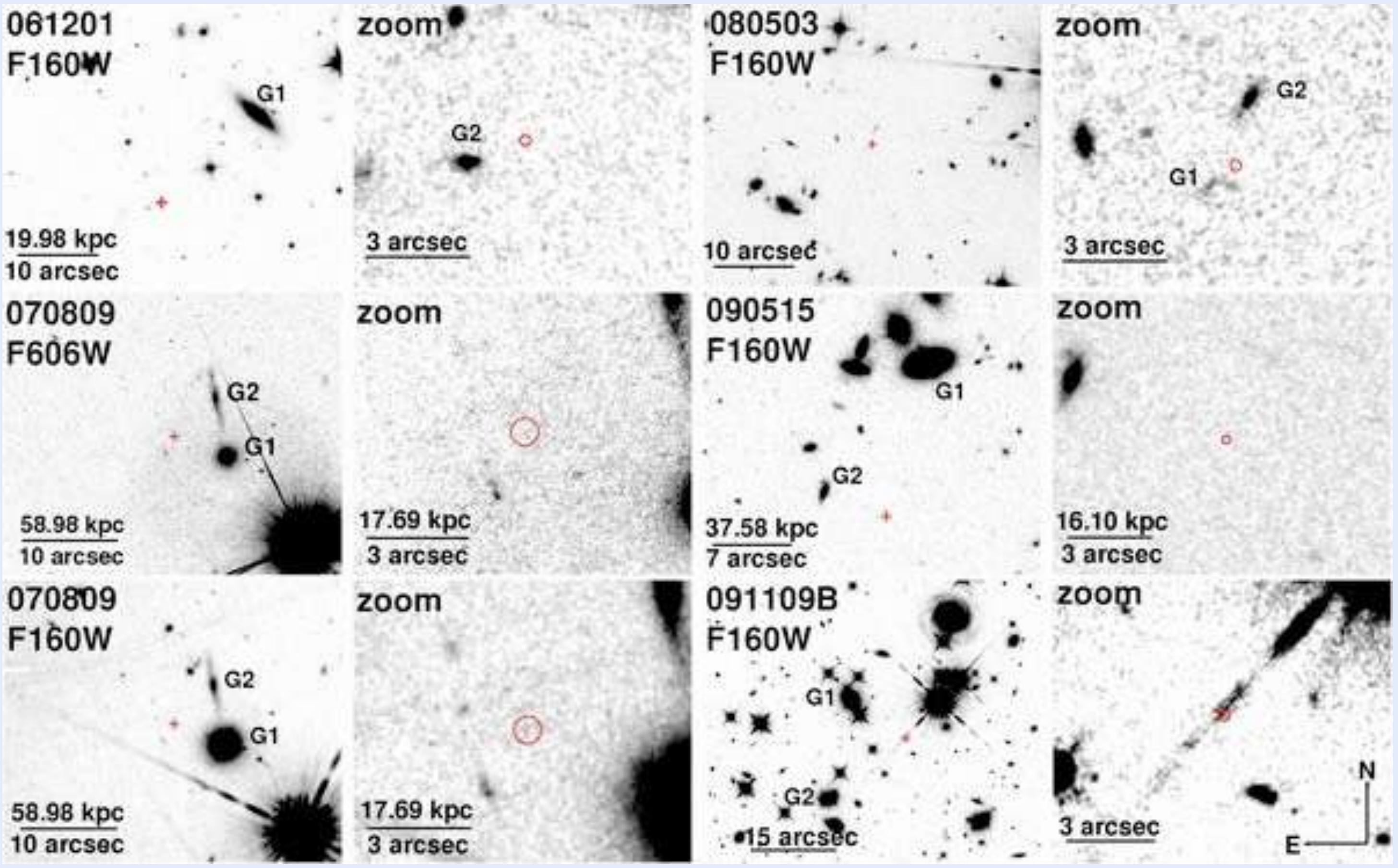
- only ~20% early type hosts!
- Many insecure host identifications, some revised later
- Only 4 afterglow spectra so far
- Very few hosts in galaxy clusters



Nugent et al. 20



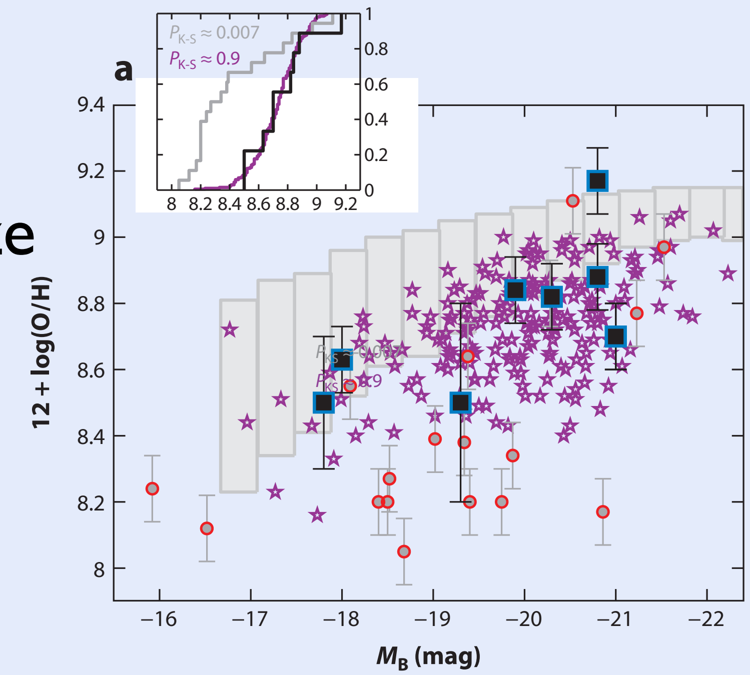
Berger 14

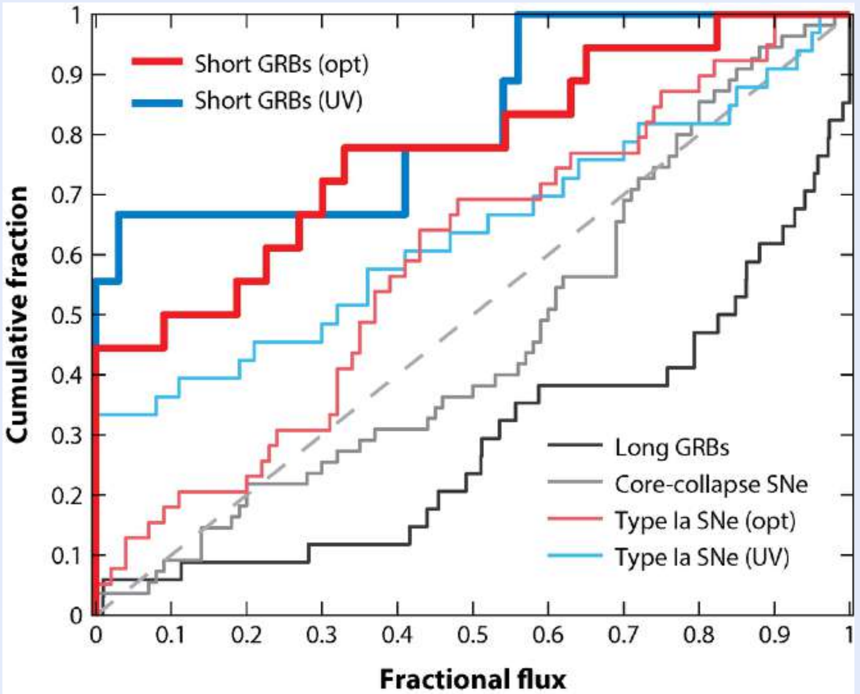


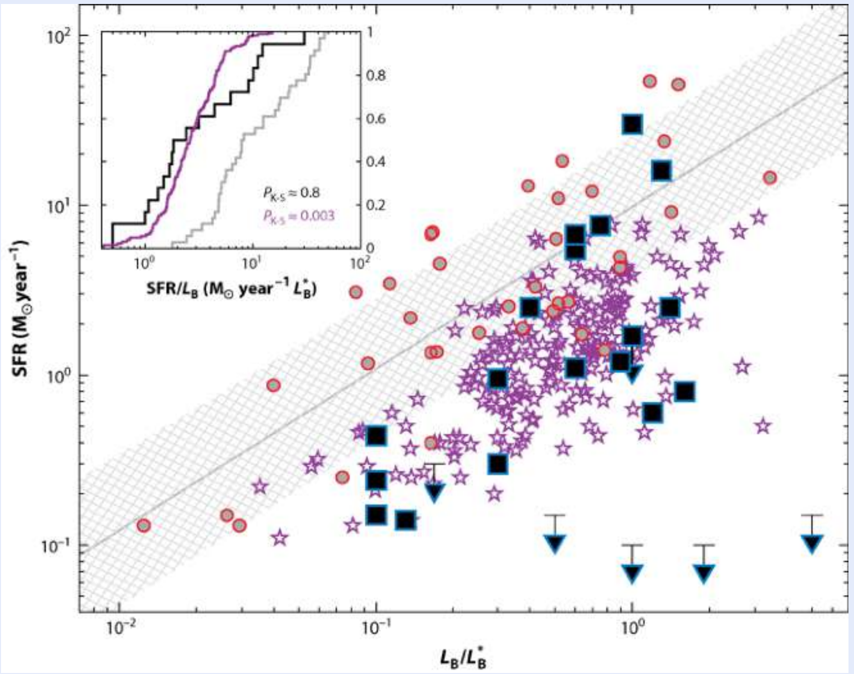
Fong & Berger 13

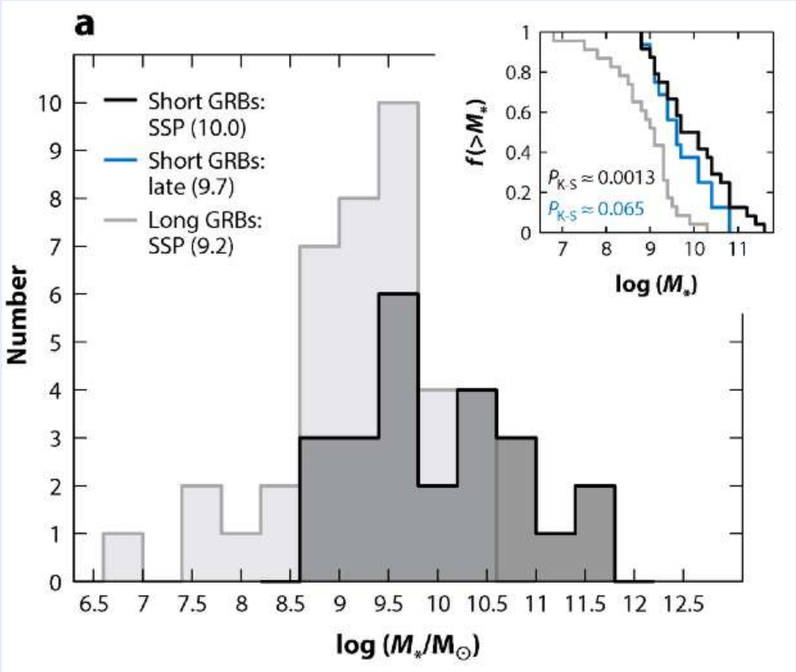
Short vs. long hosts

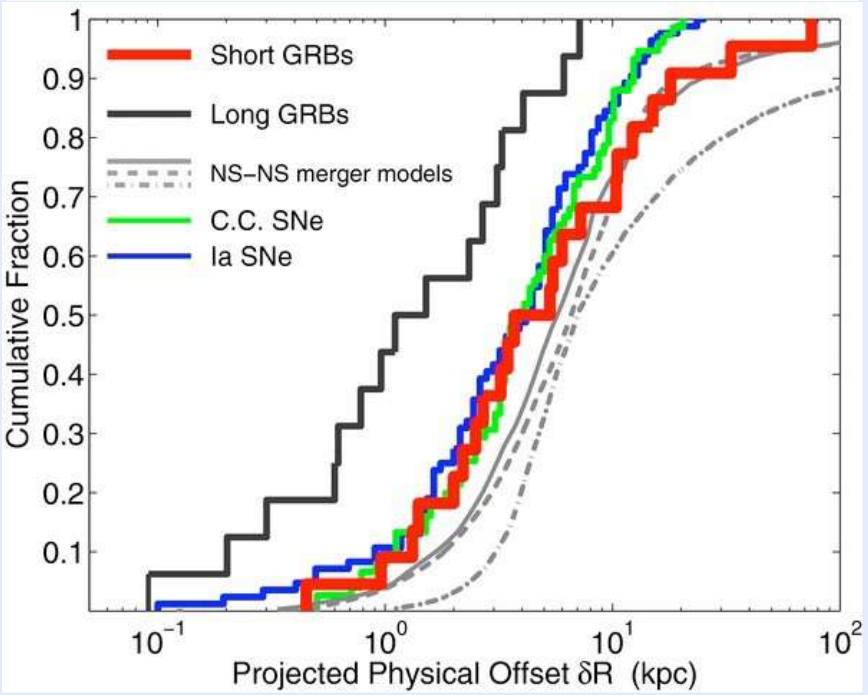
- Short hosts typically more massive
- Less SFR/luminosity
- higher metallicity?!
- Offset ~5x larger
  1.5x normalized to galaxy size
- No correlation with bright (=star-forming) regions like for long GRB hosts



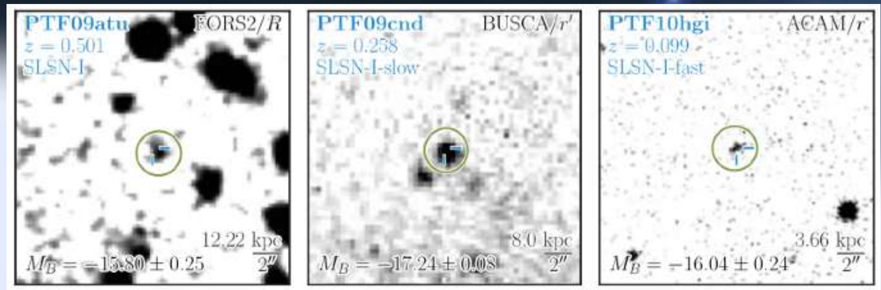




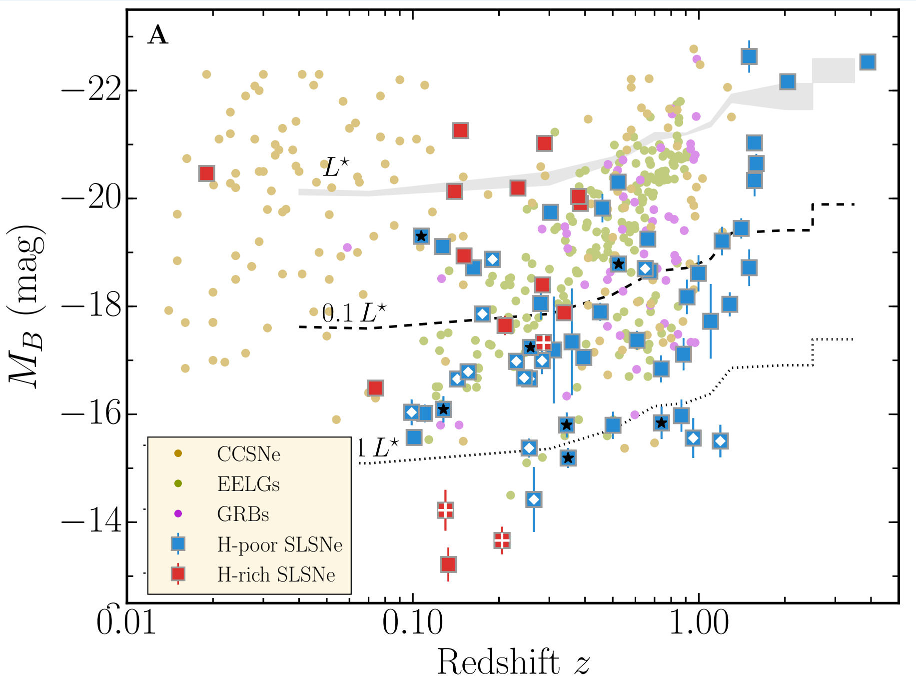




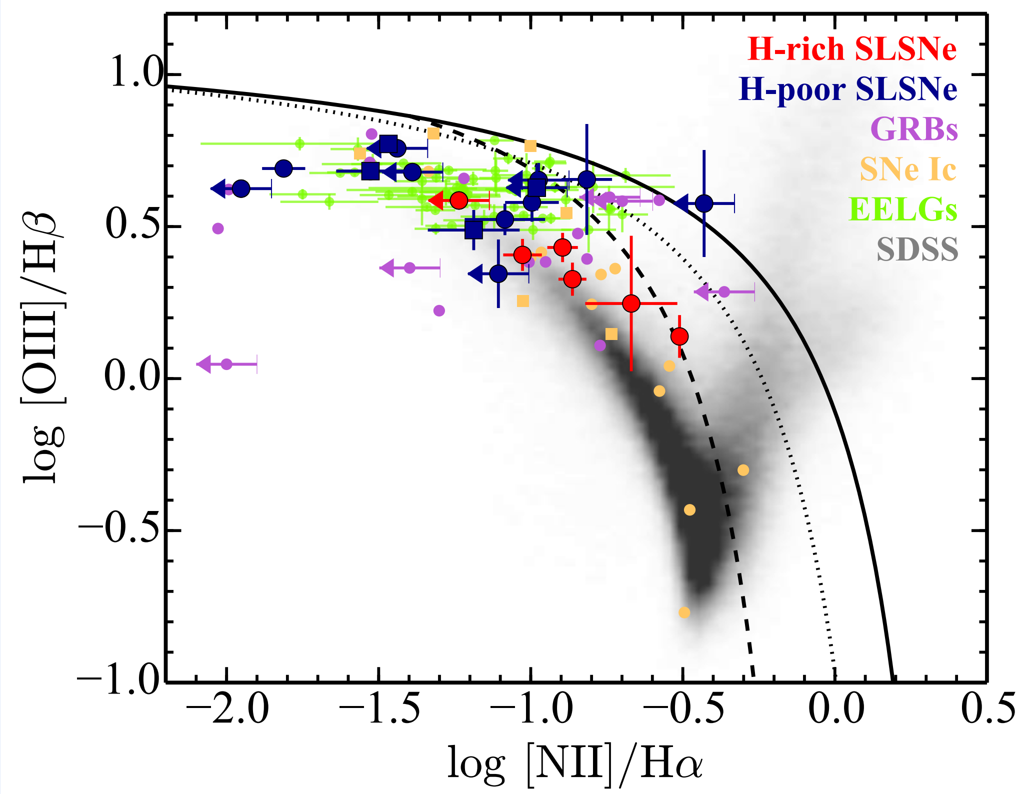
SLSN hosts

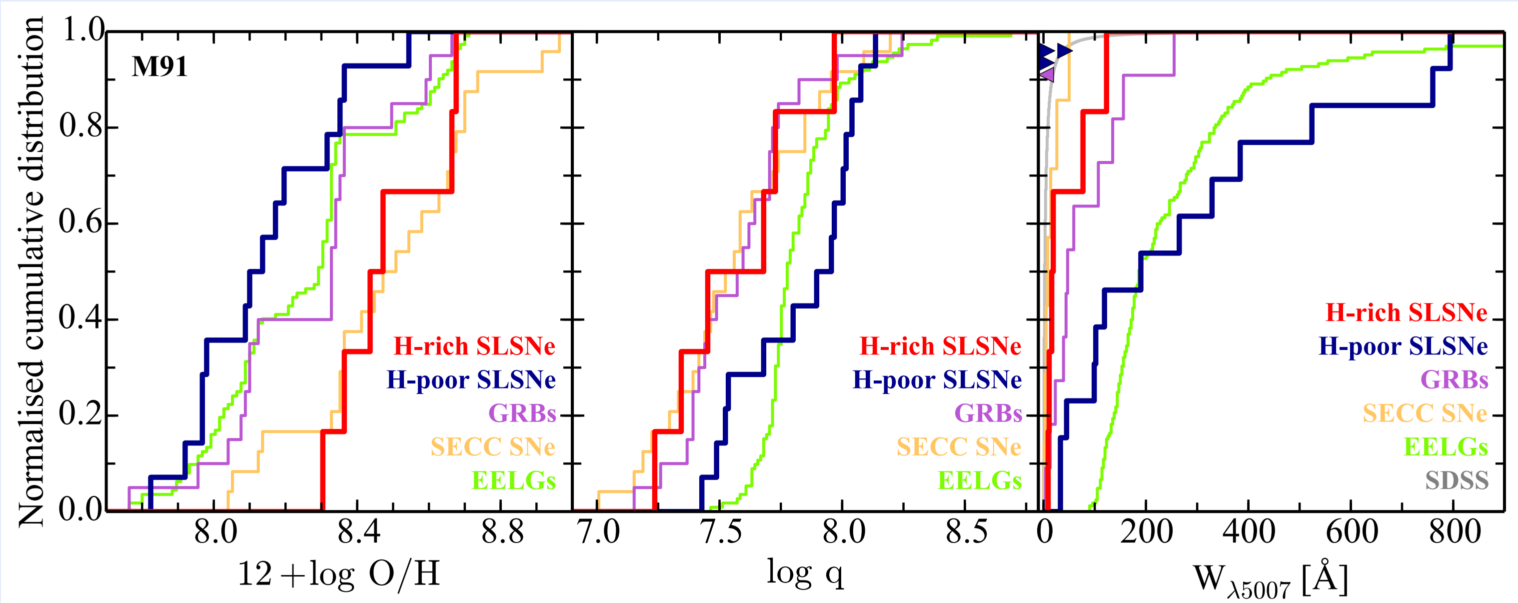


Schulze et al. 2018



- SLSN-I (mostly) in compact dwarfs with low metallicity
- SLSN-II hosts more massive & metal-rich
- 50% SLSN-I are EELGs
  -> more extreme galaxies than GRB hosts?

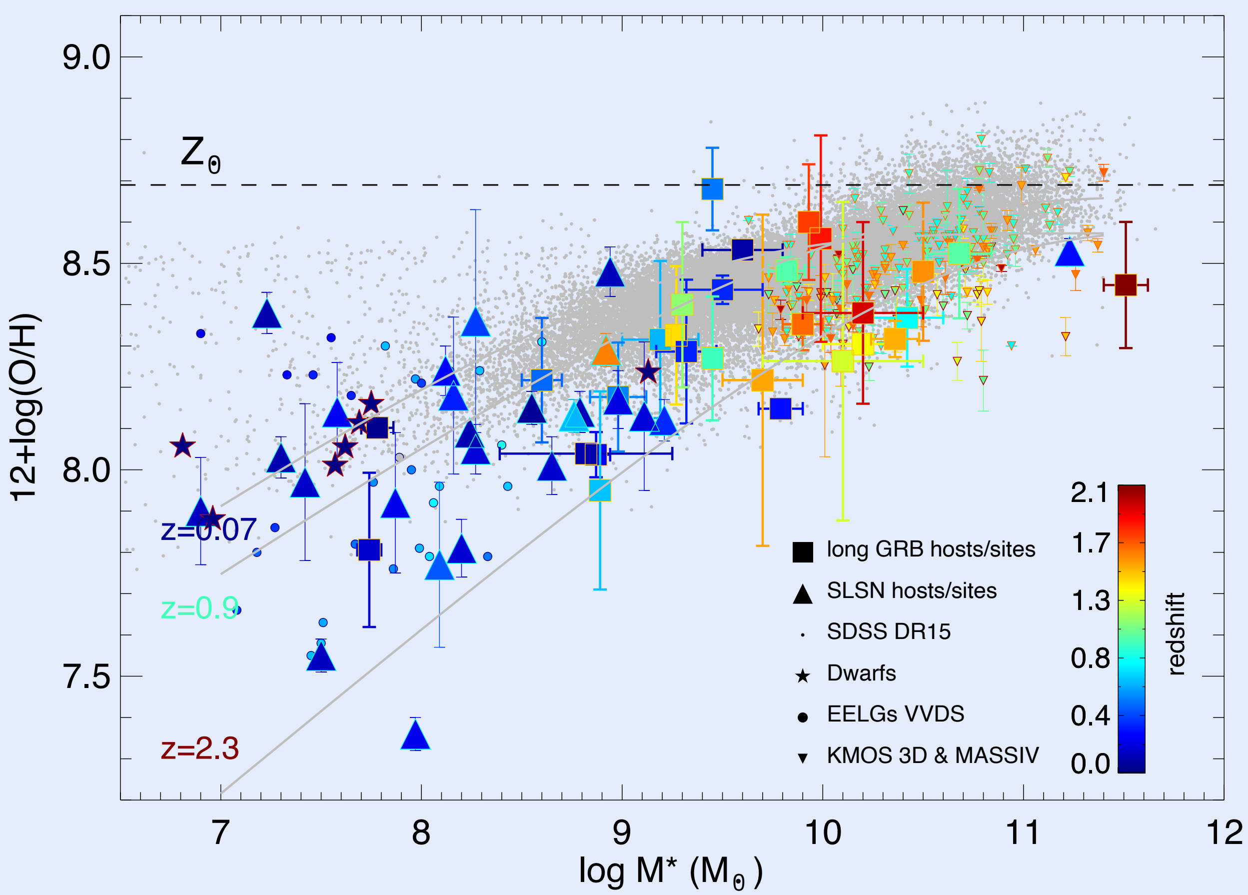


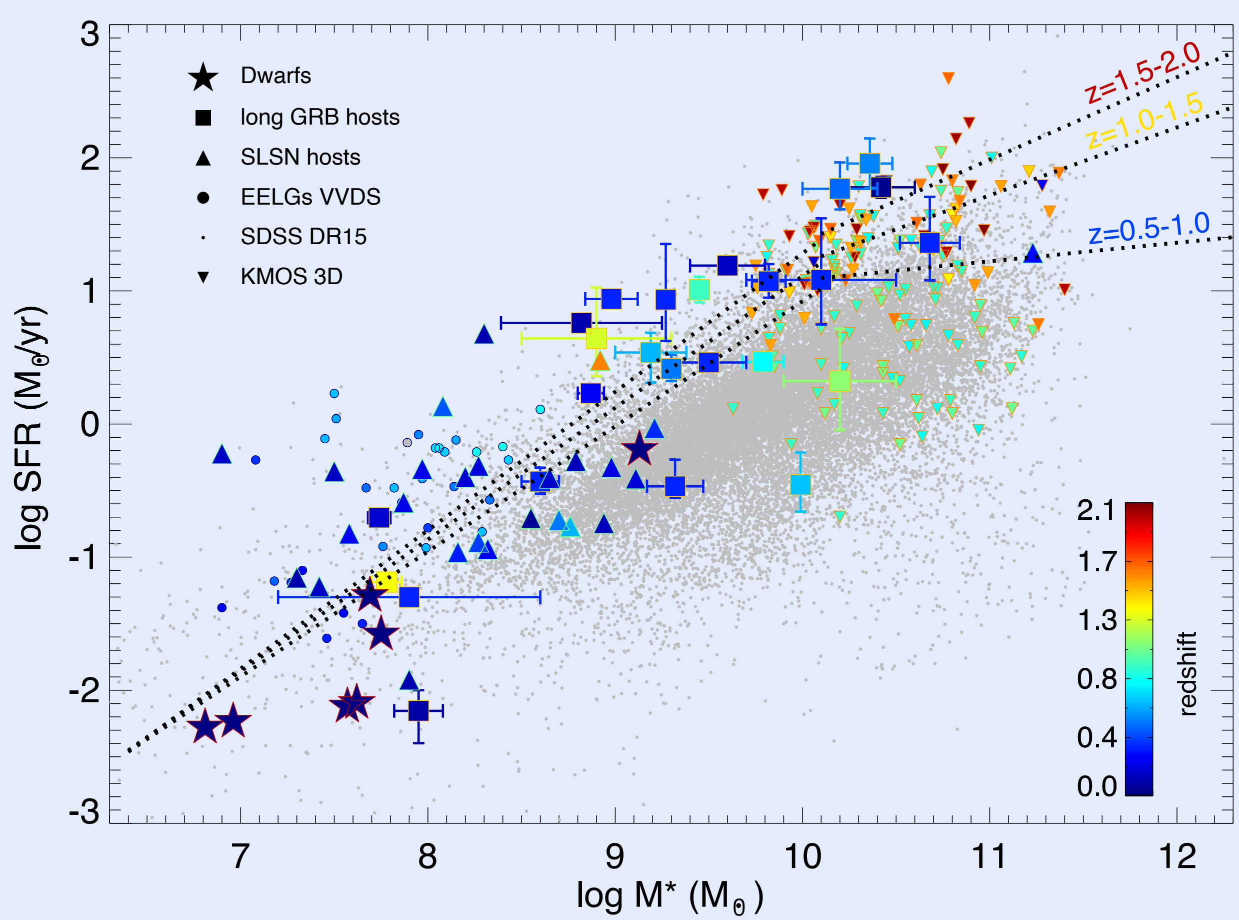


Leloudas et al. 2015

Long GRB vs. SLSN hosts

- SLSN hosts more metal poor and less mass than GRB hosts
- Redshift evolution for GRB hosts, not enough data yet for SLSN hosts
- metal poor, young, star-forming dwarfs not overlapping
- GRB site has usually lower metallicity then host, not much difference for SLSNe?



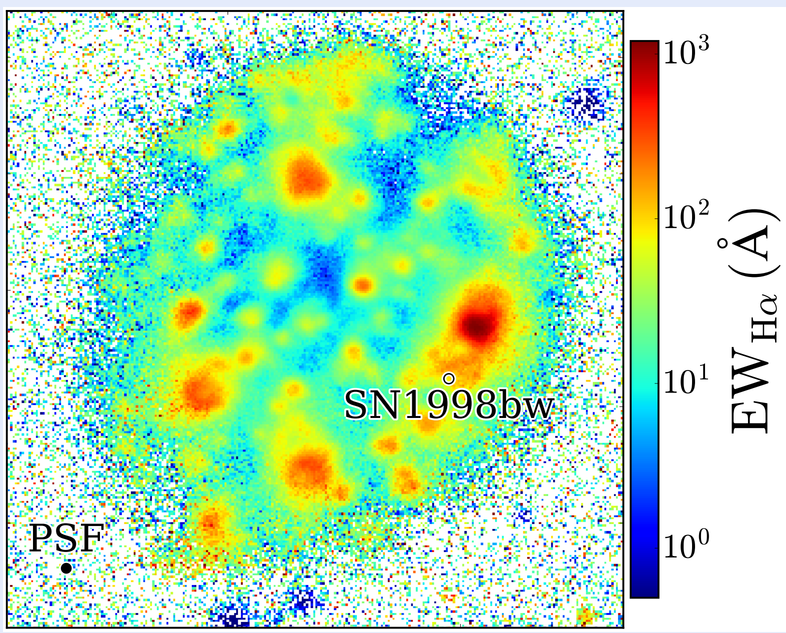


Bensch, Thöne et al. in prep.

GRB hosts resolved

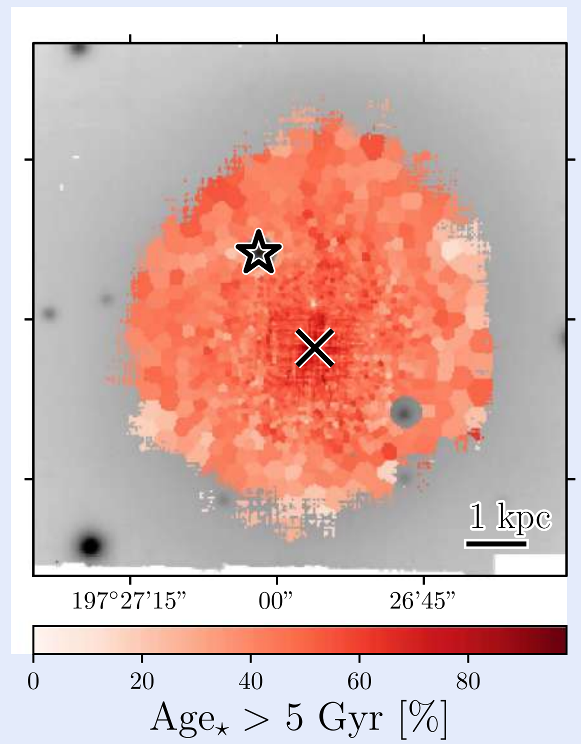
GRB-SN 980425, dwarf spiral

(Christensen et al. 08, Krühler et al. 17)



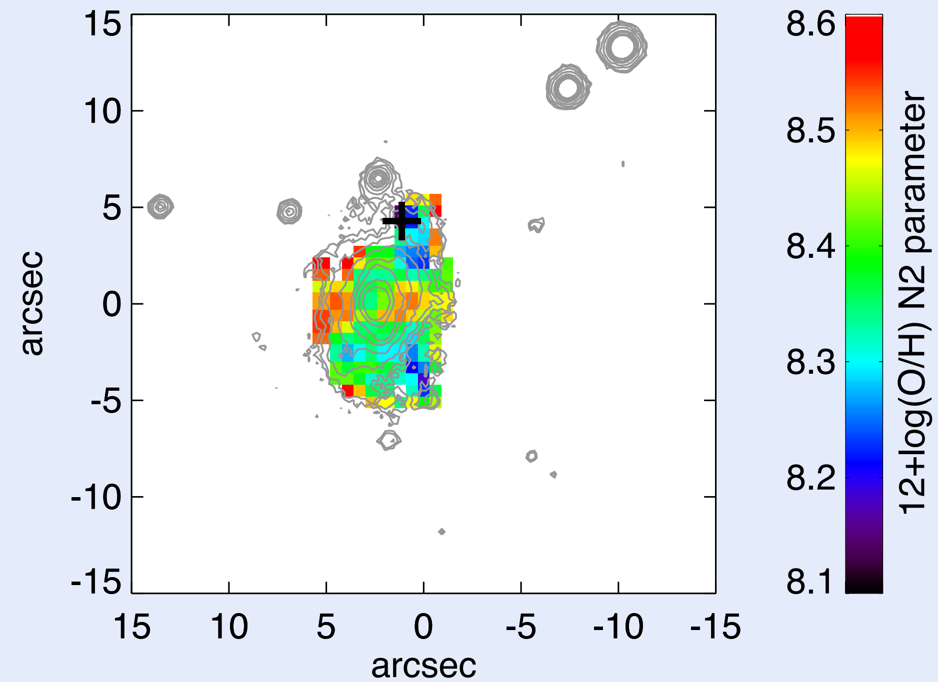
GRB 170817, short, elliptical

(Levan et al. 17)



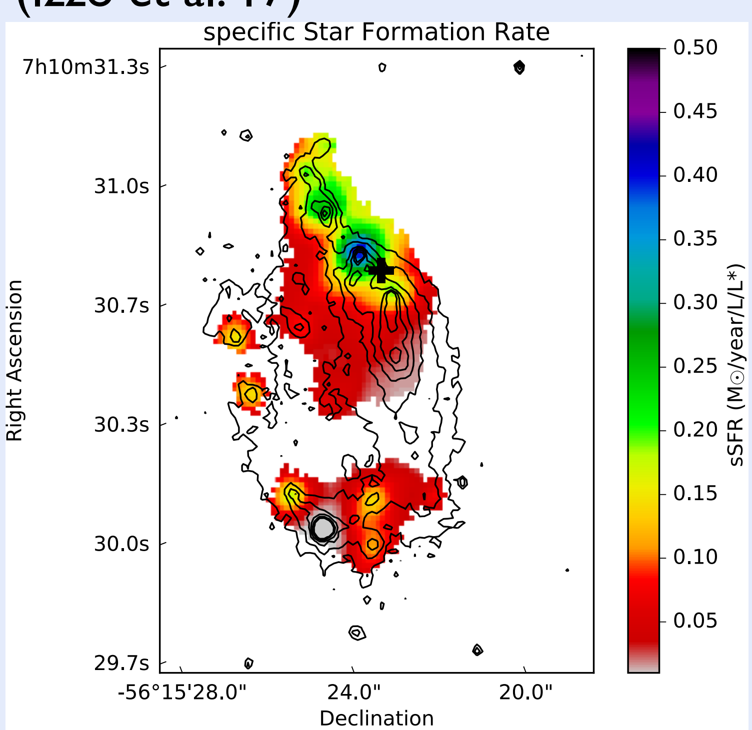
GRB 060505, SN-less

(Thöne et al. 14)



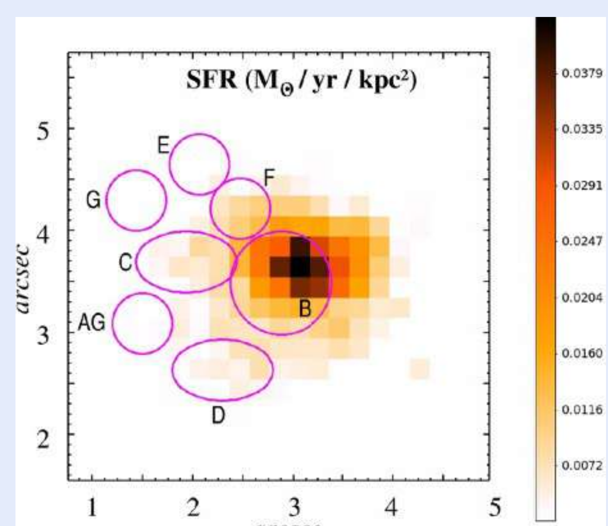
GRB-SN 100316D, dwarf

(Izzo et al. 17)



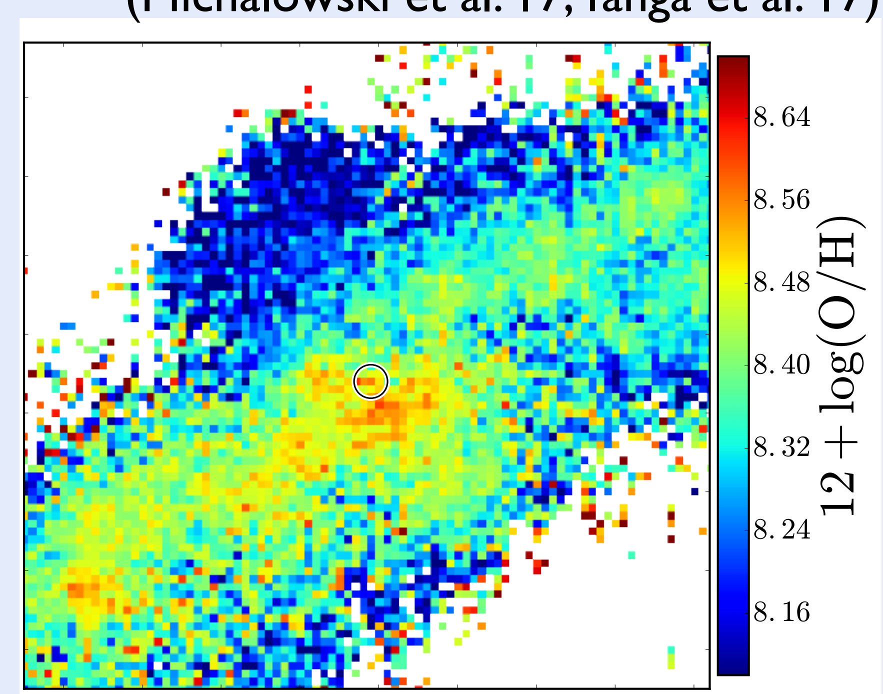
GRB 050709, short, dwarf

(Nicuesa-Guelbenzu et al. 21)



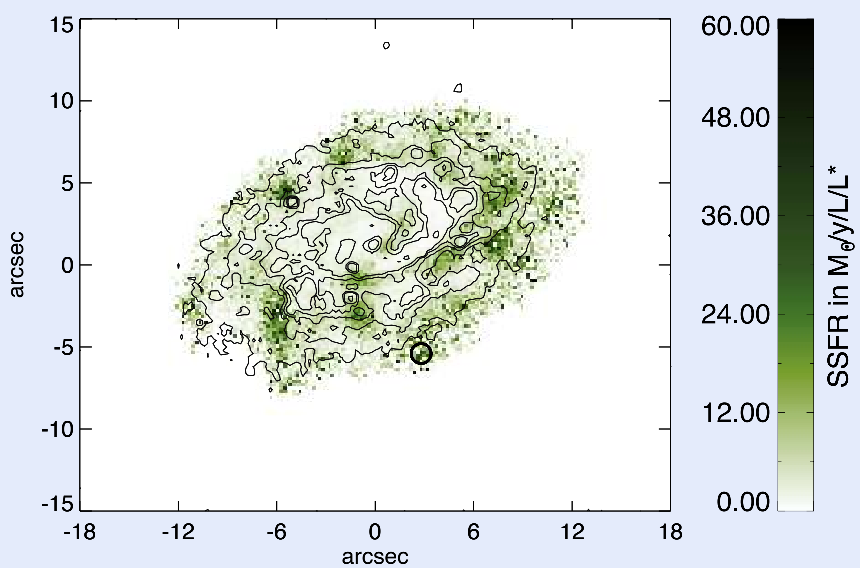
GRB 111005A, SN-less

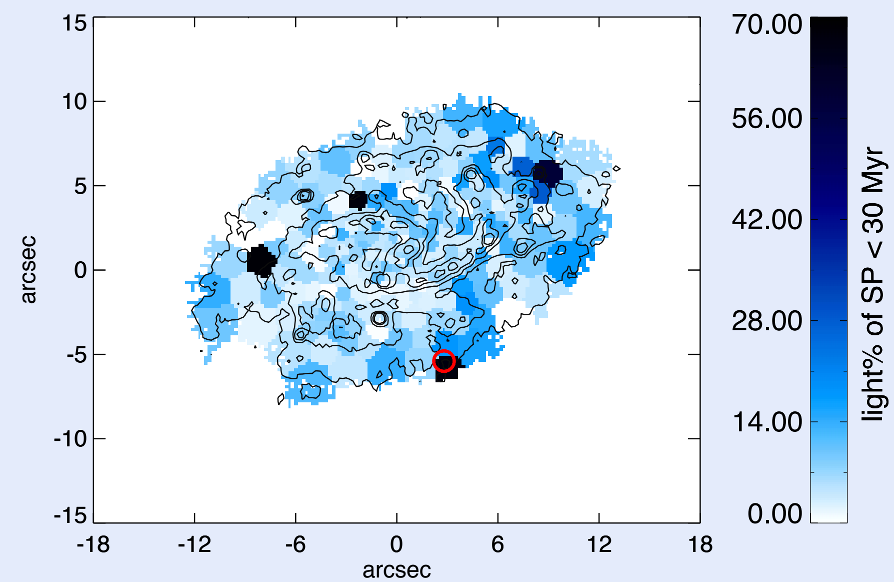
(Michalowski et al. 17, Tanga et al. 17)

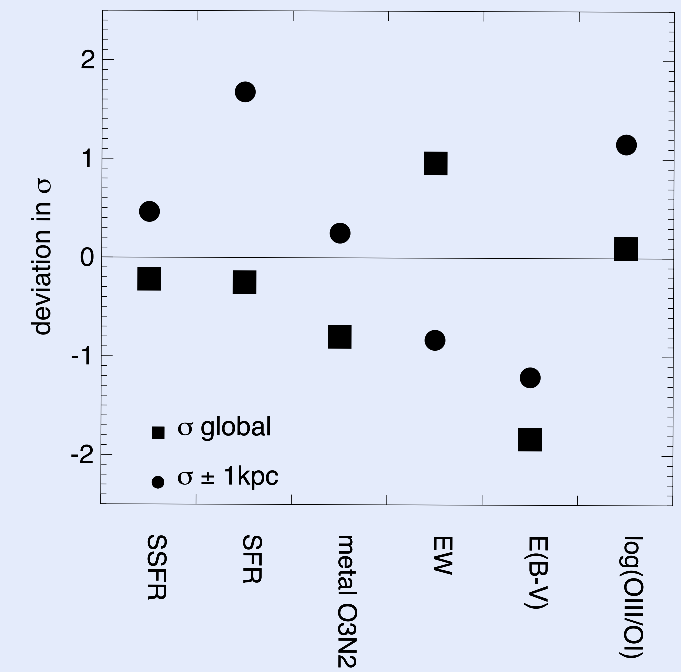


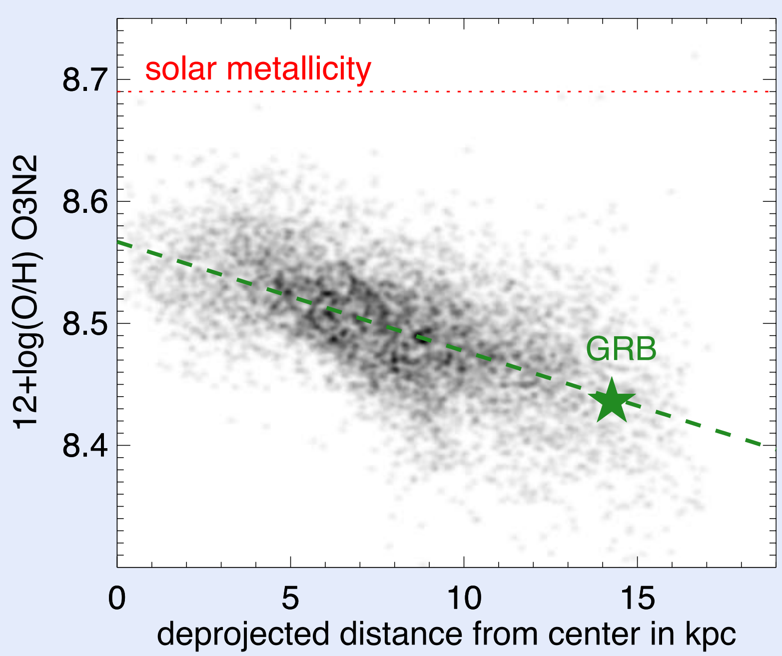
GRB 171205A

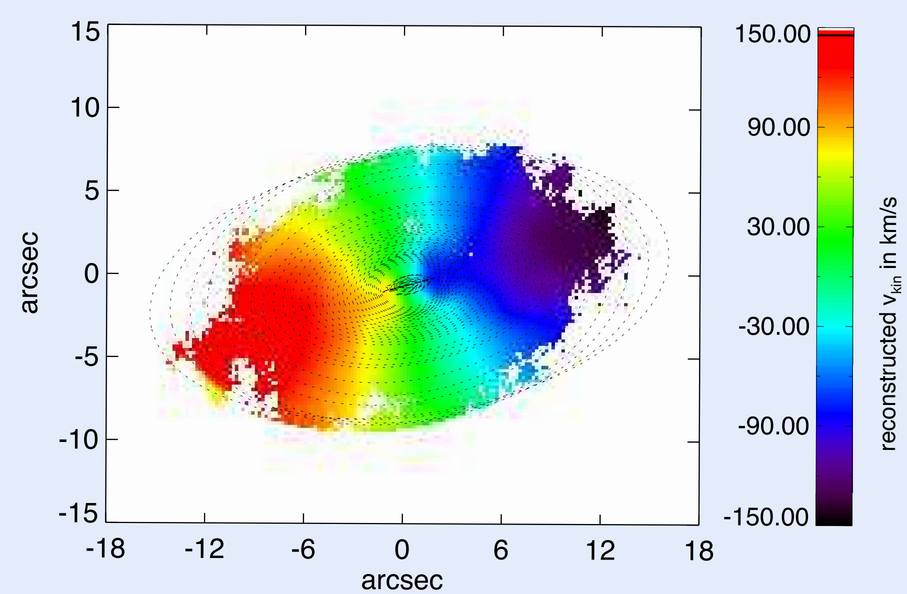
- Grand-design spiral, 163 Mpc
- High SSFR, low Z, low age at GRB site, but otherwise not too special
- no SF trigger indication from (optical) rotation field

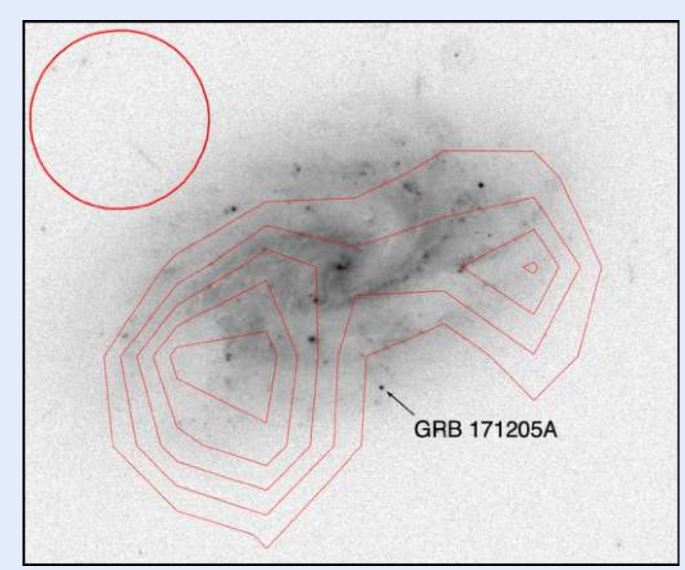




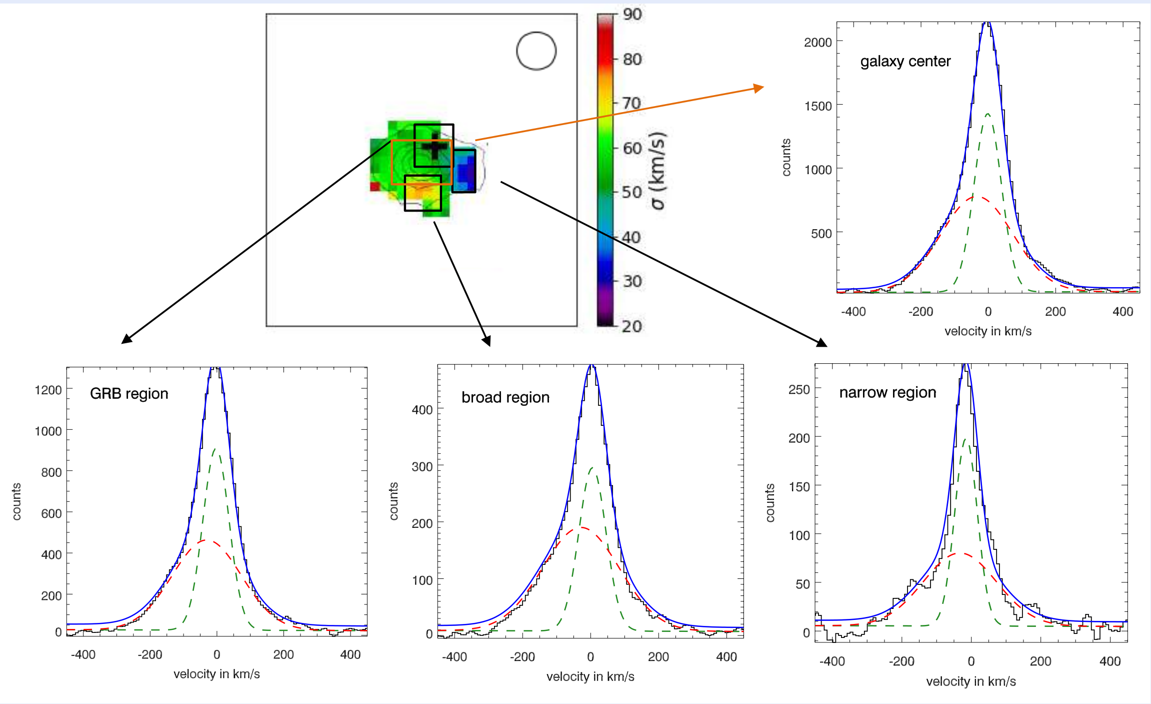




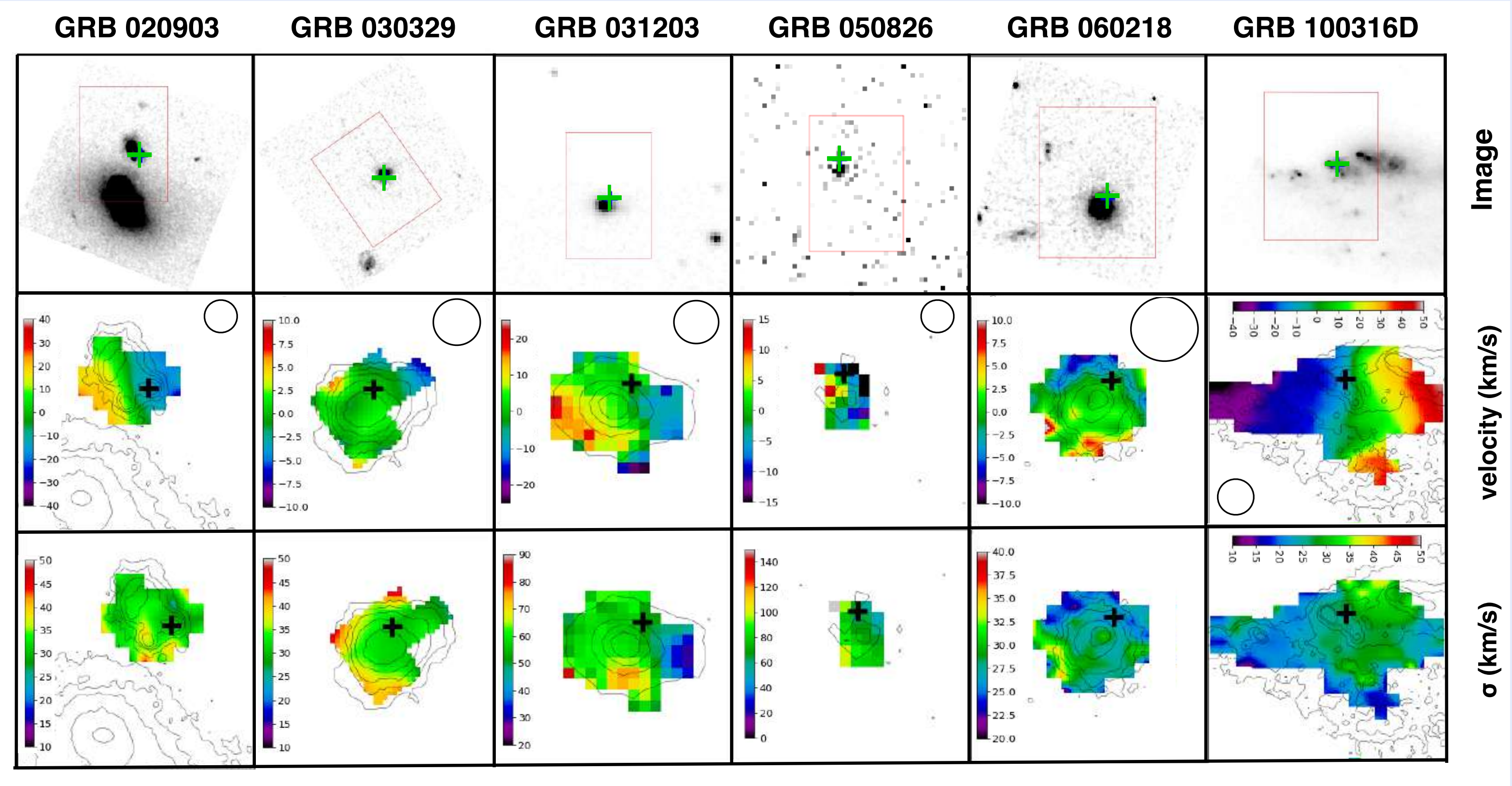




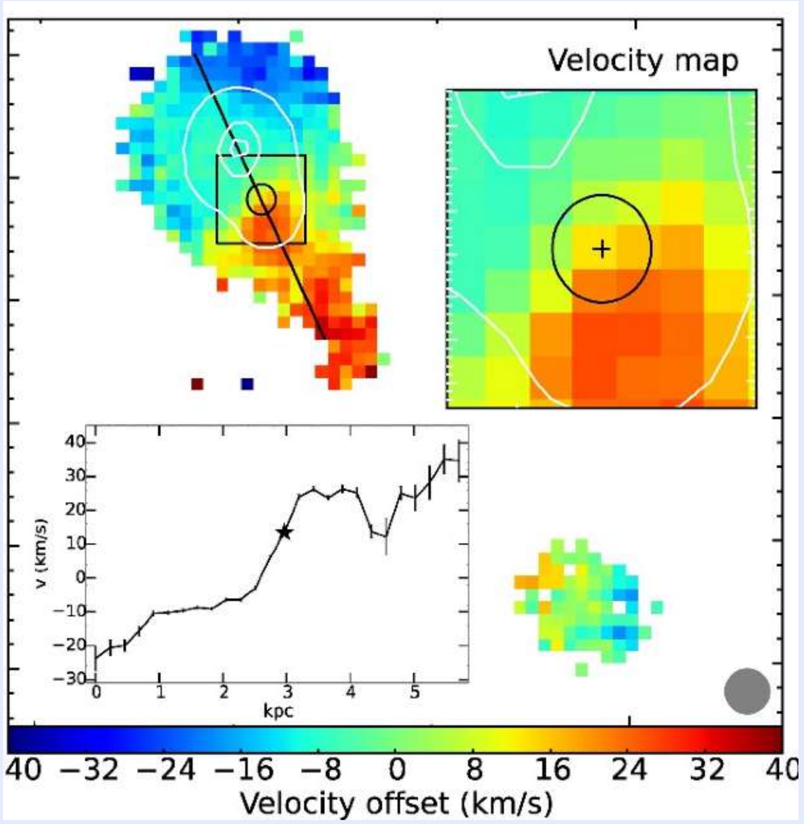
GRB host kinematics



- Only some low-z GRB hosts show a disk-like rotation, some double components (mergers??)
- Powerful winds/outflows correlated with SF
- Still lacking studies for SLSN hosts



PTF11hrq (Cikota et al. 2017)

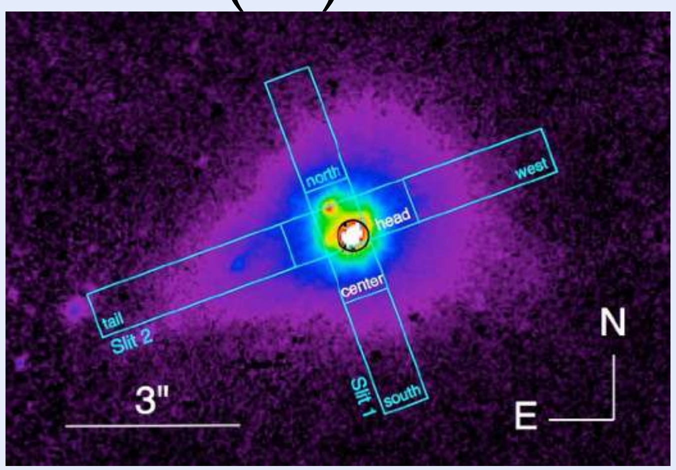


Resolved SLSN hosts

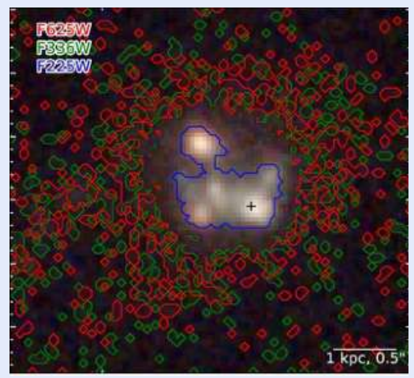
PTF12dam: A very young stellar population

Thöne et al. 2015

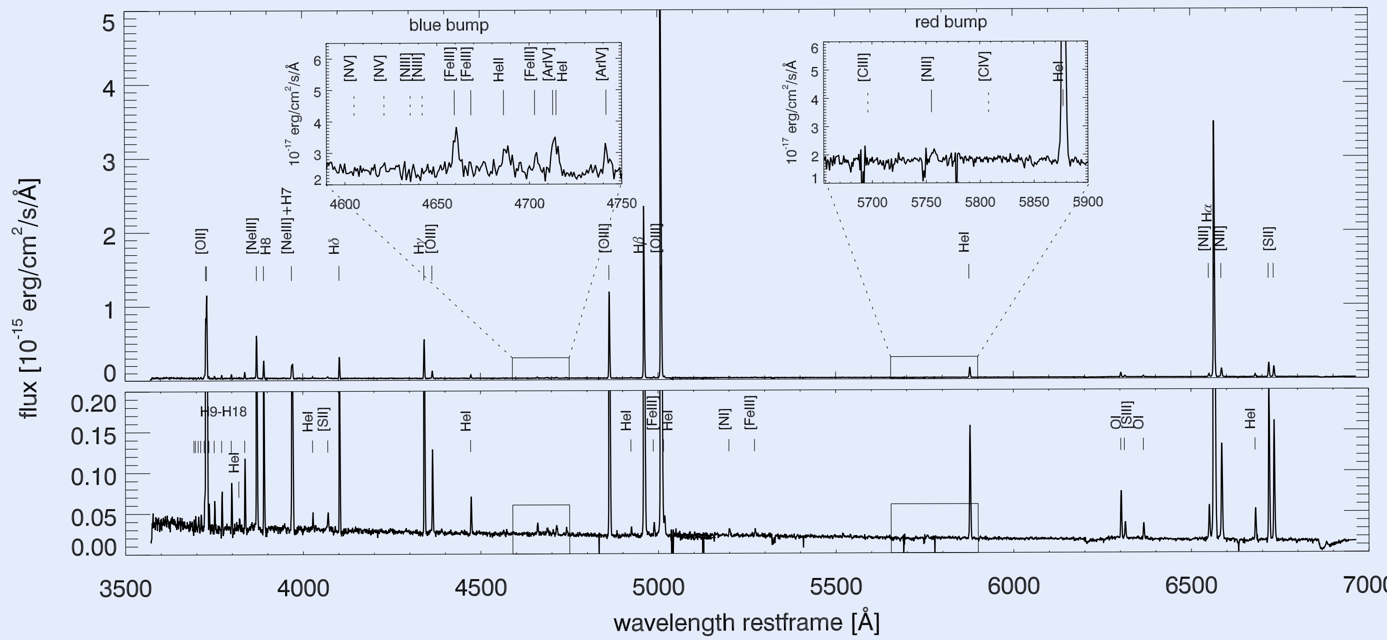
OSIRIS (slit)



HST

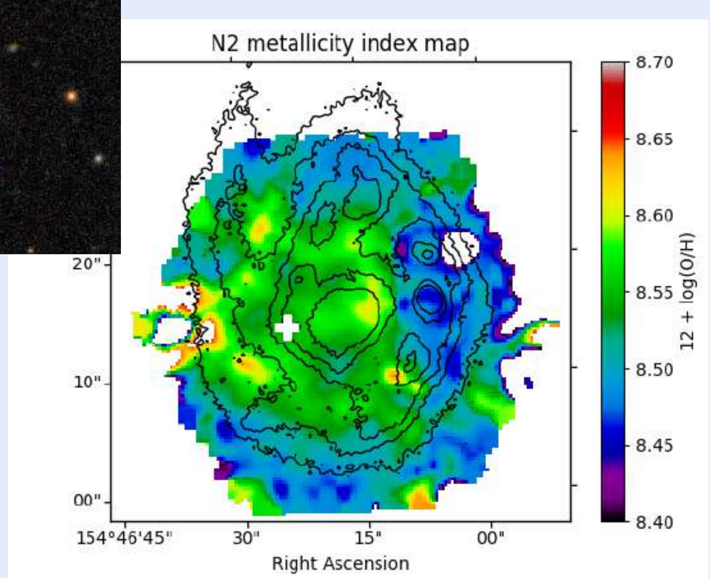


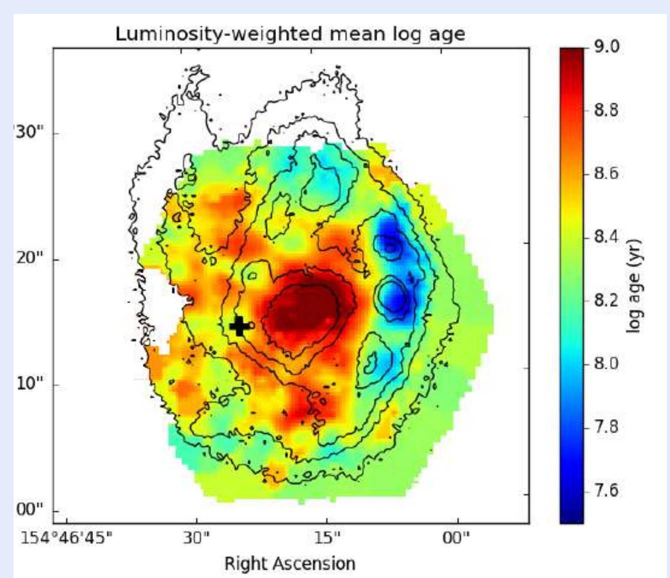
Cikota et al. 2017

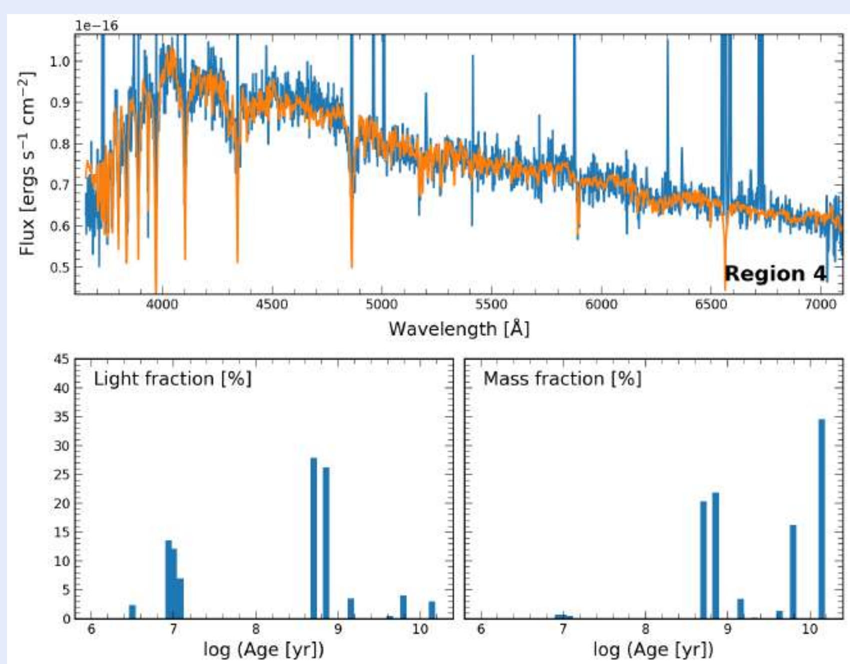


SN 2017egm: A SLSN-I in a solar host but with two populations at the SN site

Izzo, Thöne et al. 2017



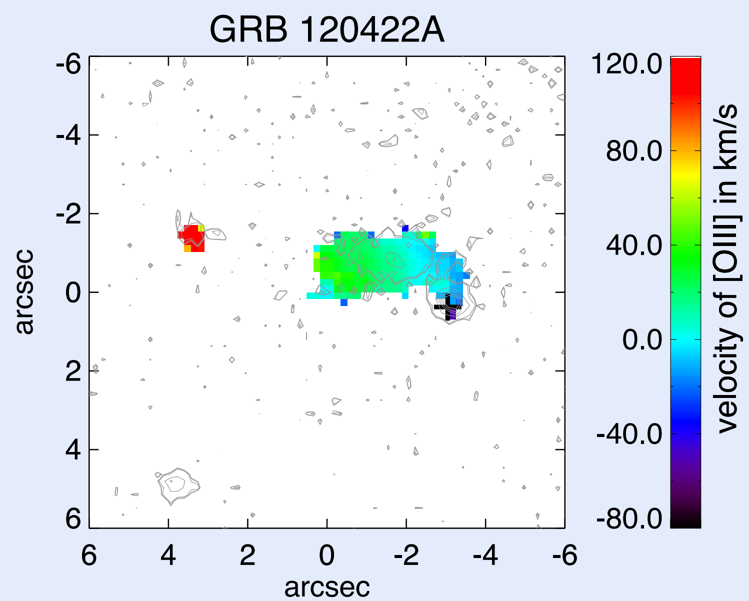


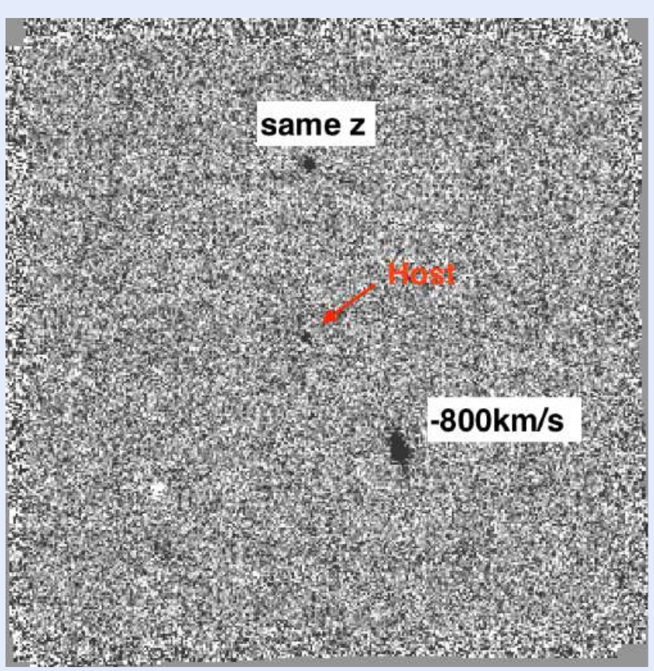


Thöne et al. in prep.

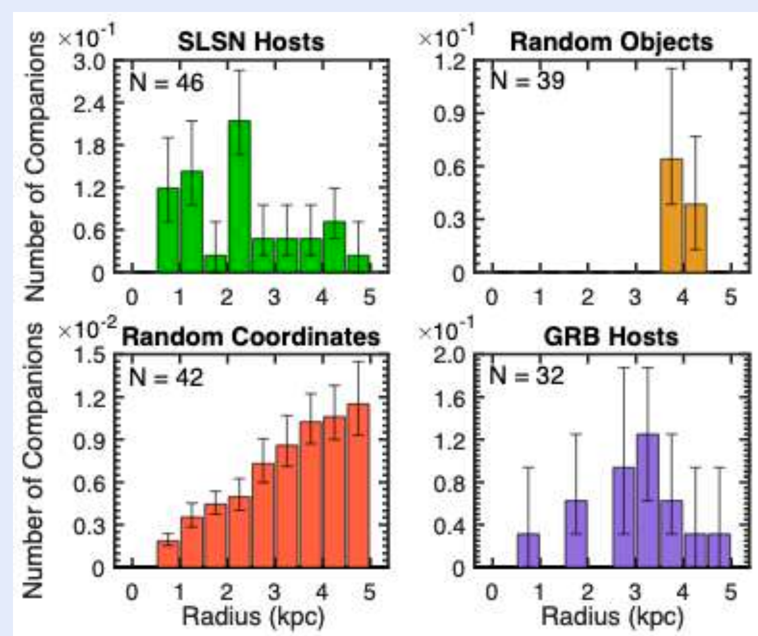
Influence of the environment?

- Ideal with MUSE (large FOV)
- GRBs: Only 2/11 have a nearby galaxy, only one obviously interacting
- SLSN hosts: ~50 % have a neighbour at +/- 300 km/s

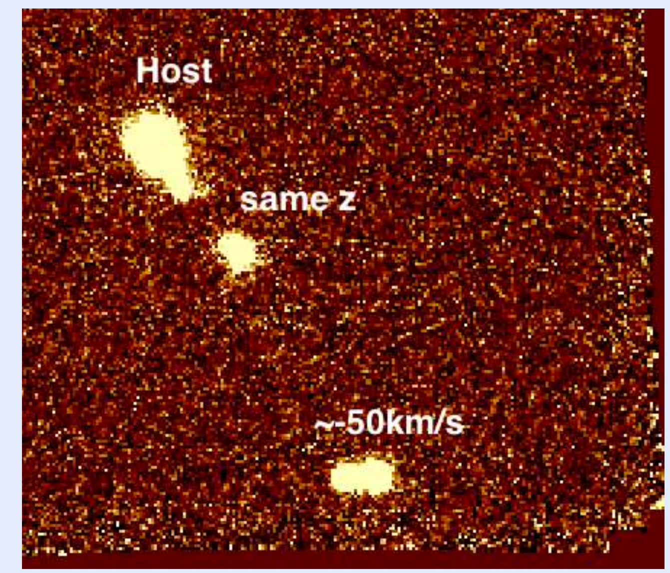


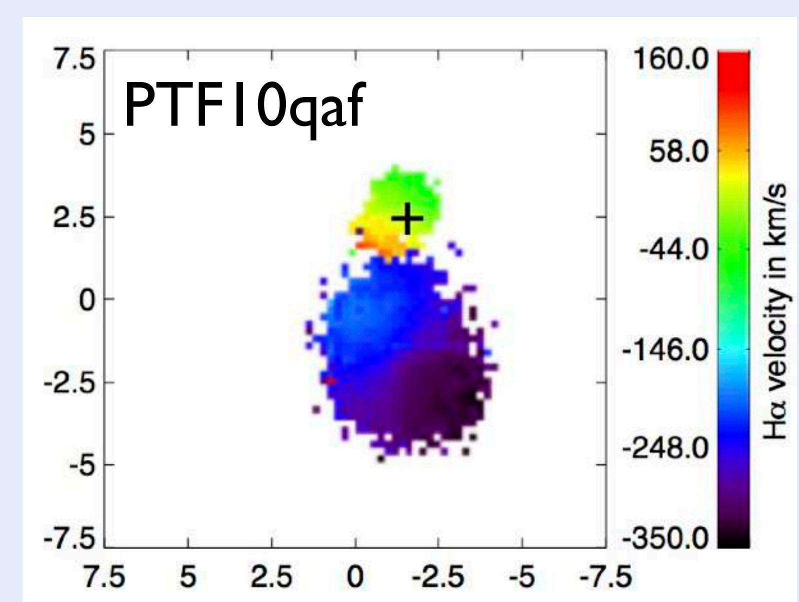


Ørum et al 2020 (HST):
~50% of SLSN hosts have an object within 5kpc
Only ~25% for GRB hosts
Smaller offsets for SLSN hosts



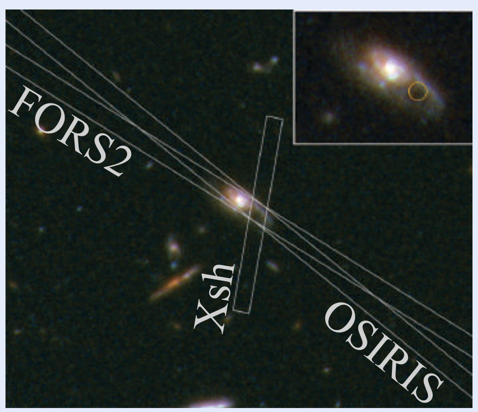
PTF11hrq

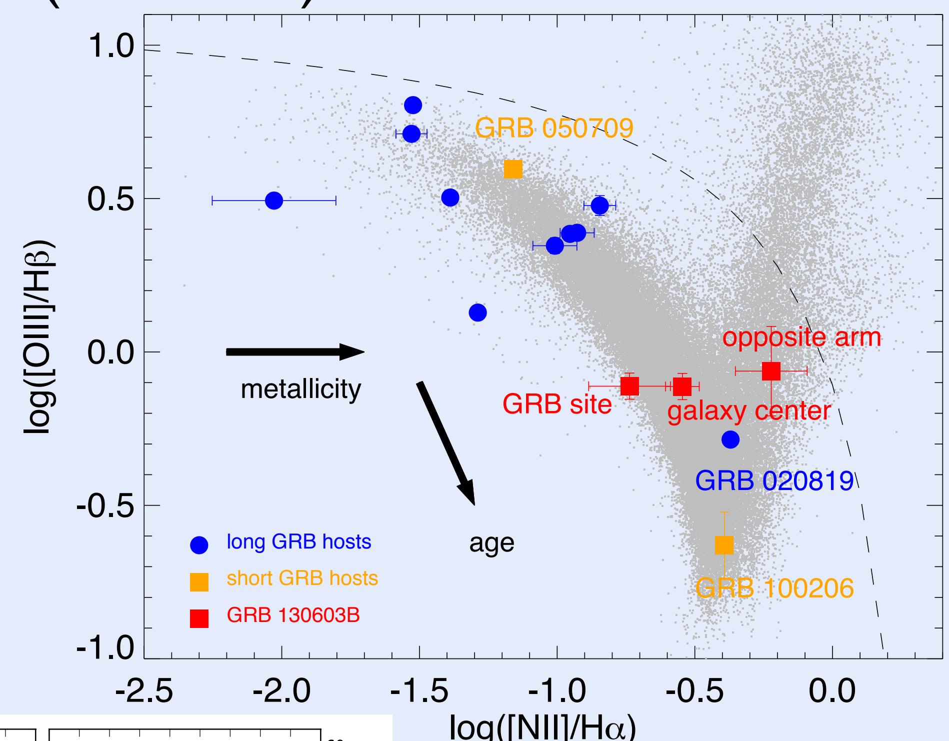


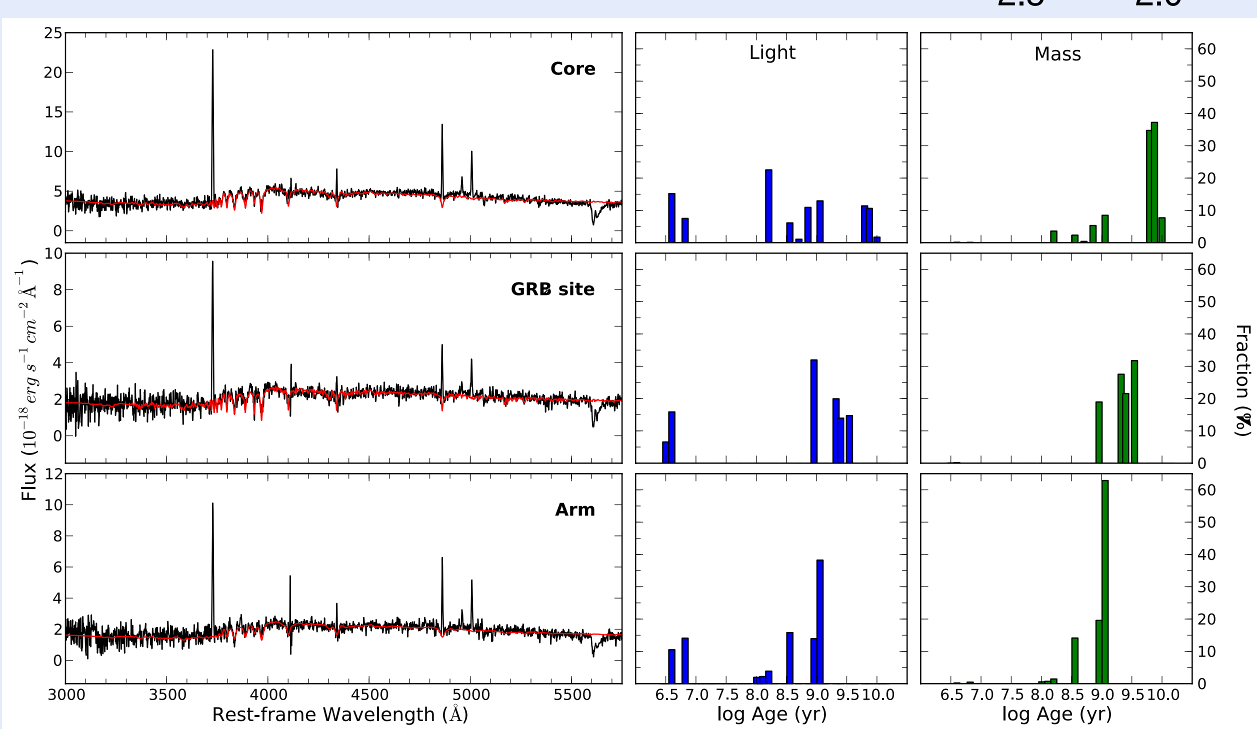


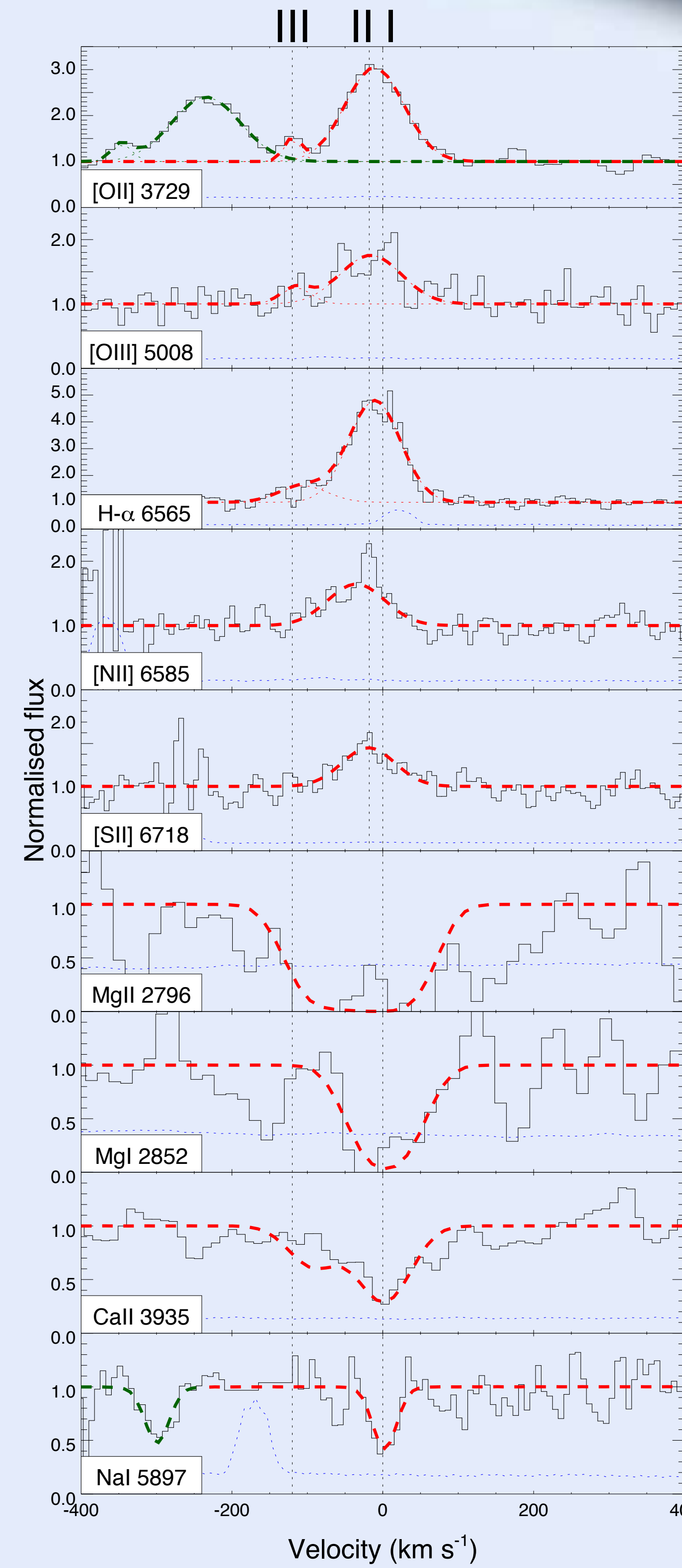
Short GRB 130603B

- Late type (tidally disturbed?) host
- SFR ~4.8 M$_\odot$/y, Z~0.5 solar (GRB site)
- Both old and young (<10 Myr) population



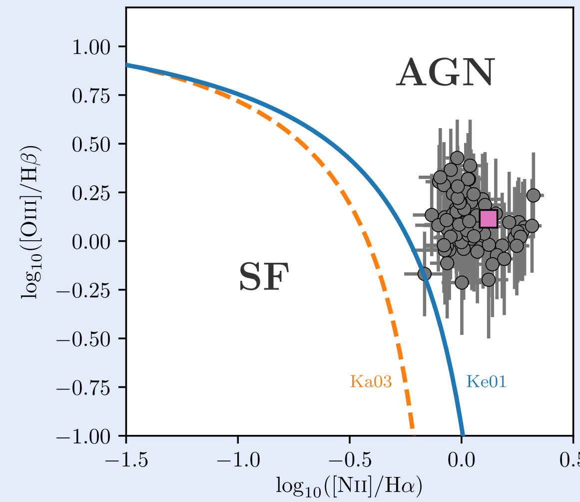


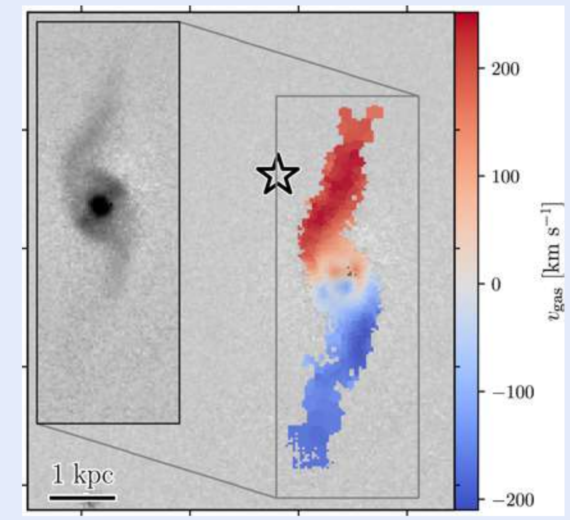


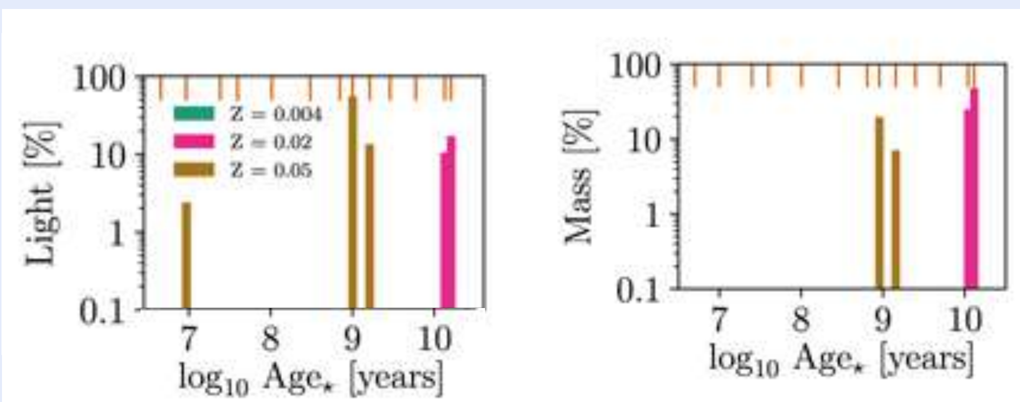


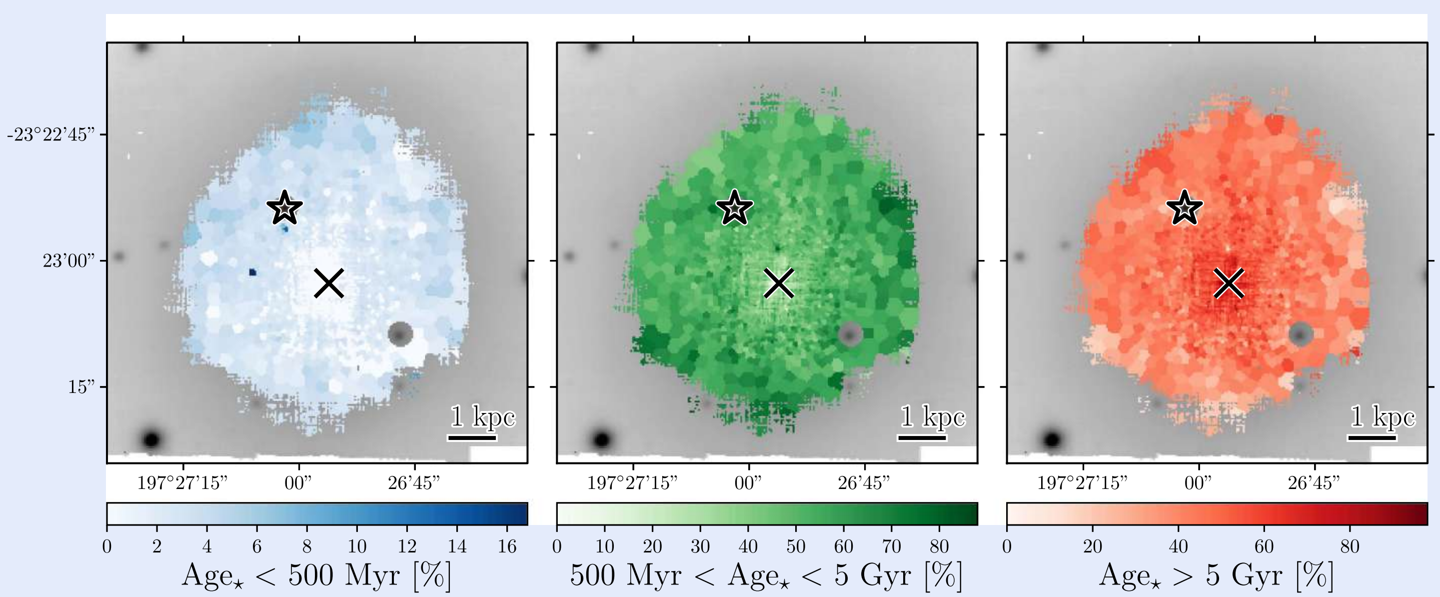
Short hosts: GW170817

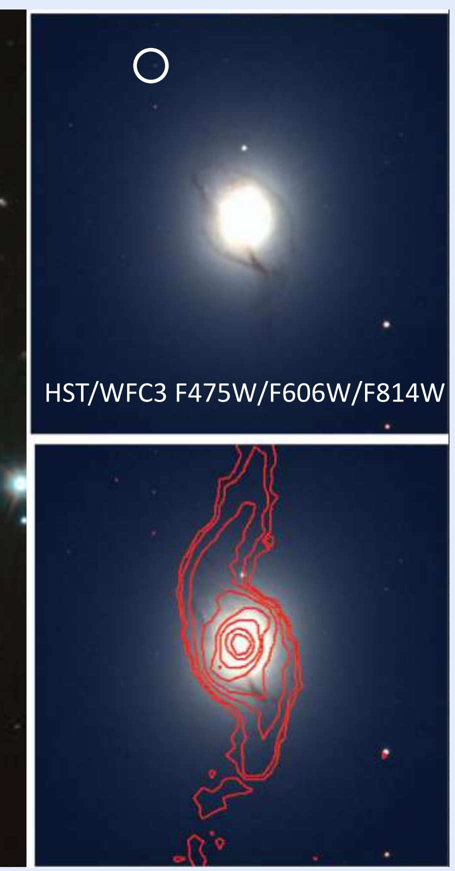
- S0 galaxy with 1.4x10^{11} $M_\odot$/y
- hosts an AGN
- dust lanes in [NII], dry merger (?)
- mostly old stellar population









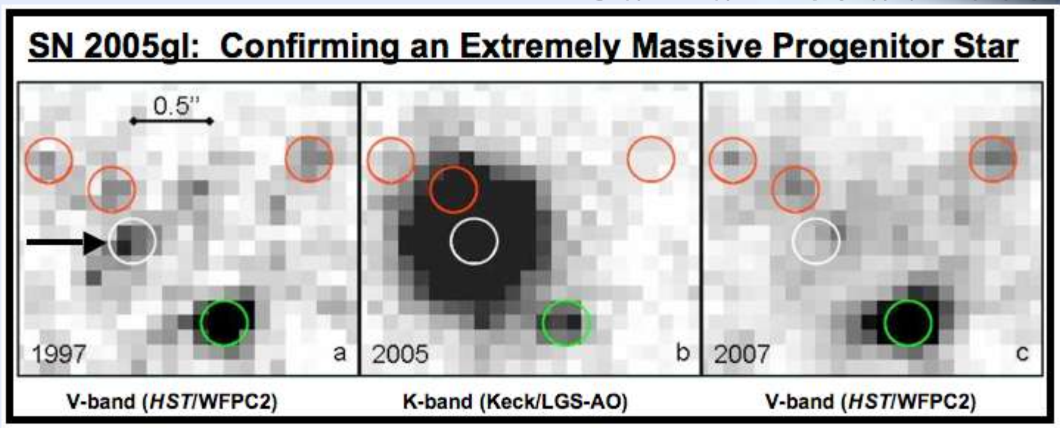


SN progenitors

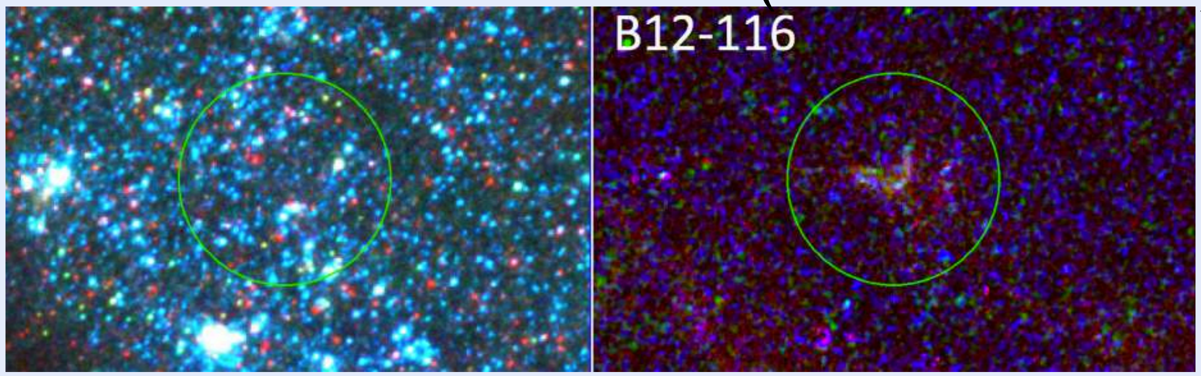
SN progenitor detections

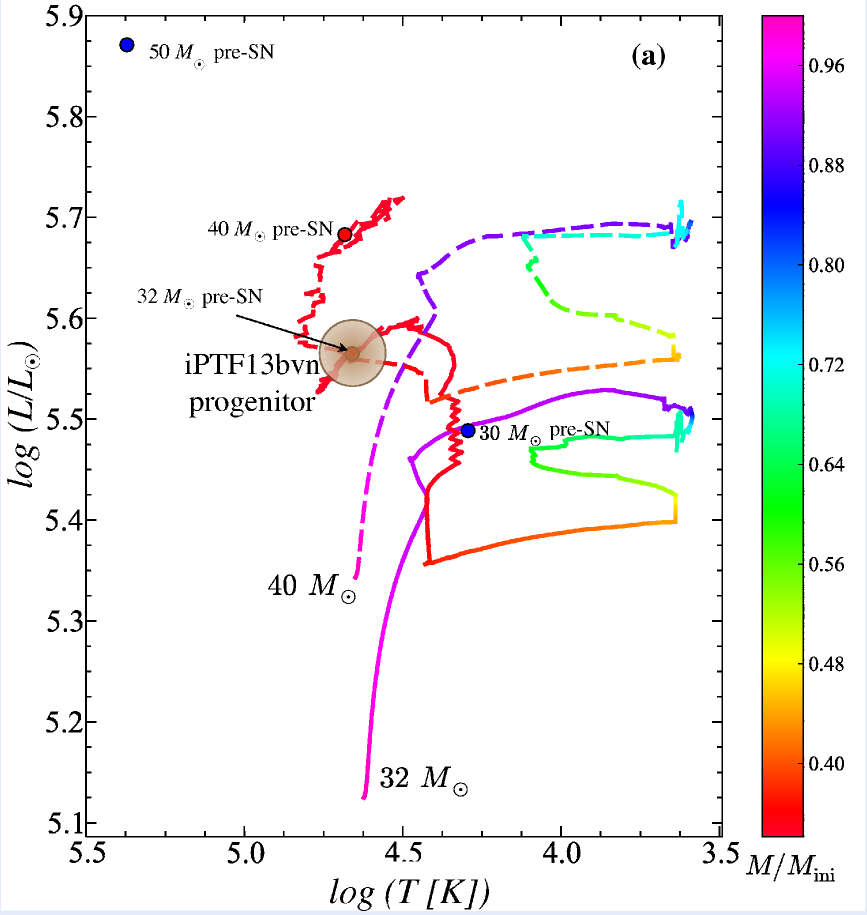
- II-P/IIn least massive
- IIn LBVs?
- Ib/c only candidates (binaries?!)
- rest still elusive
- Indirect determination of the SP

Gal-Yam et al. 2005

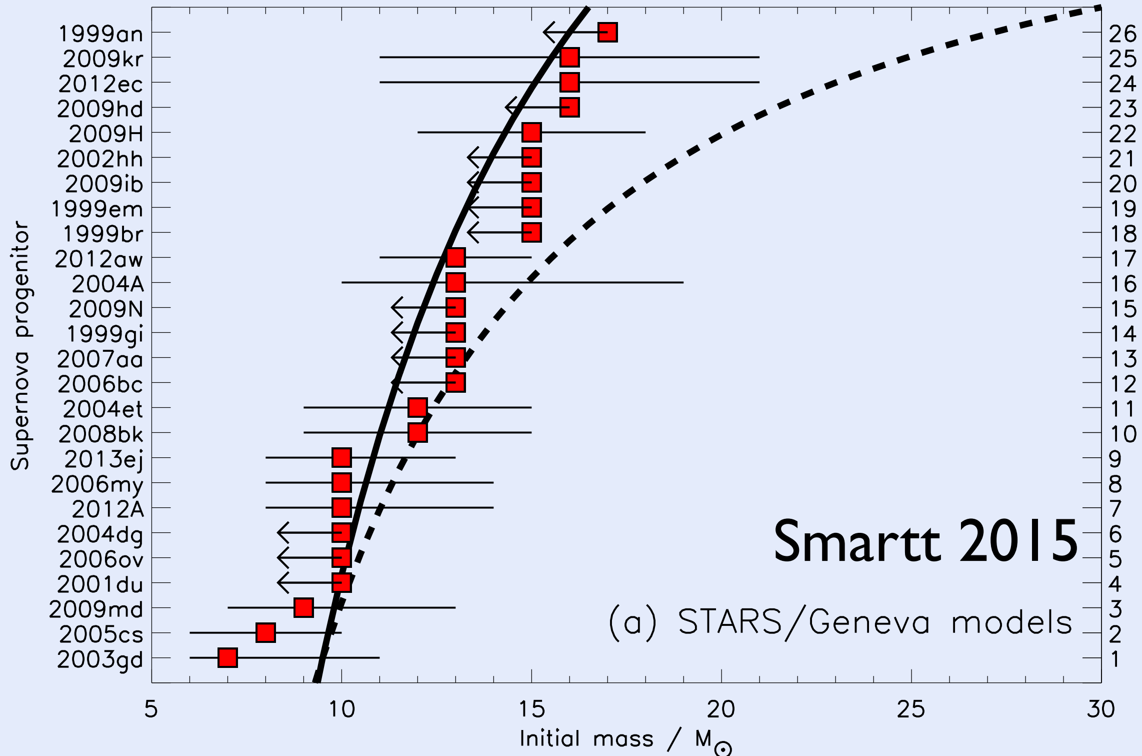


SPs near SN remnants in M83 (Williams et al. 19)





Groh et al. 2015

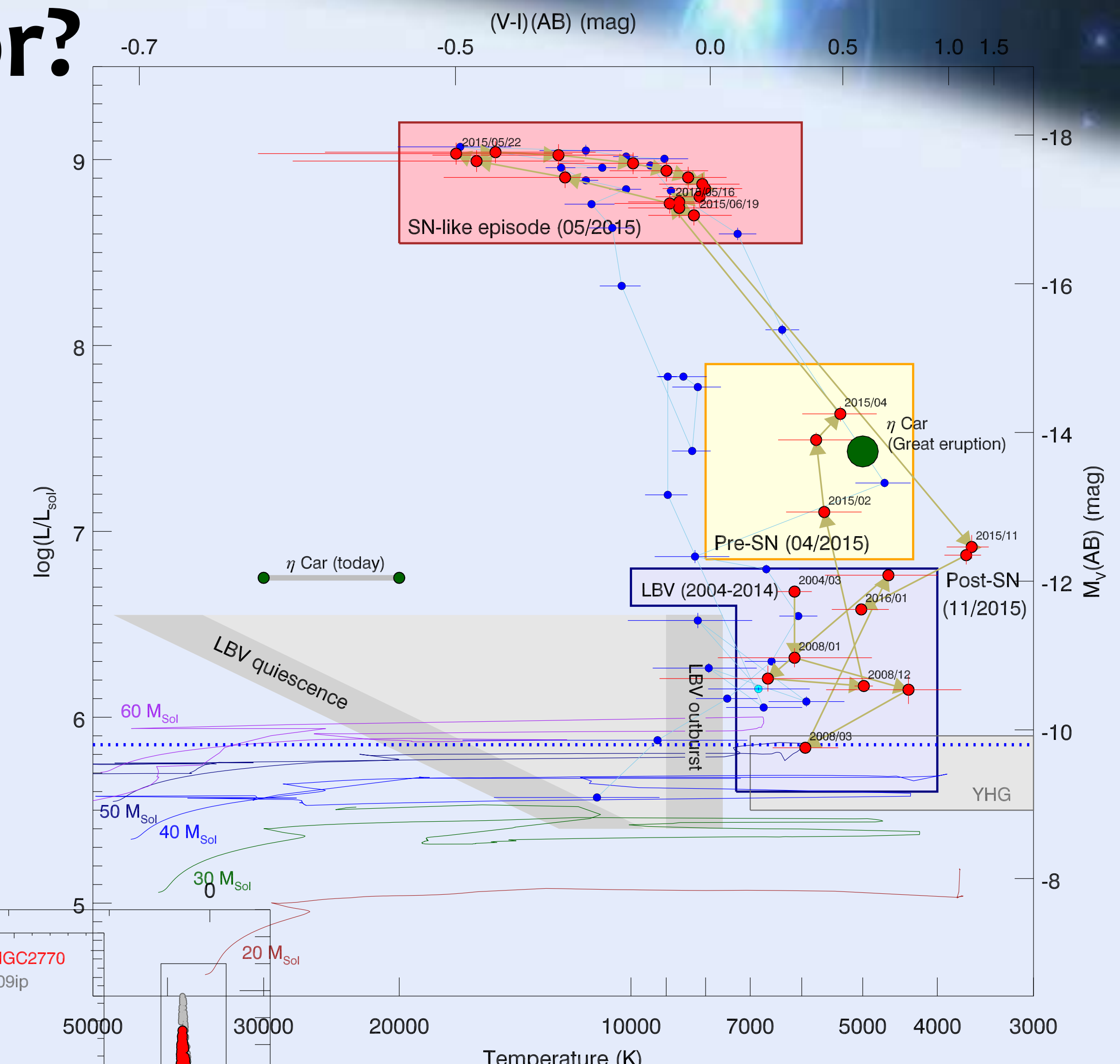


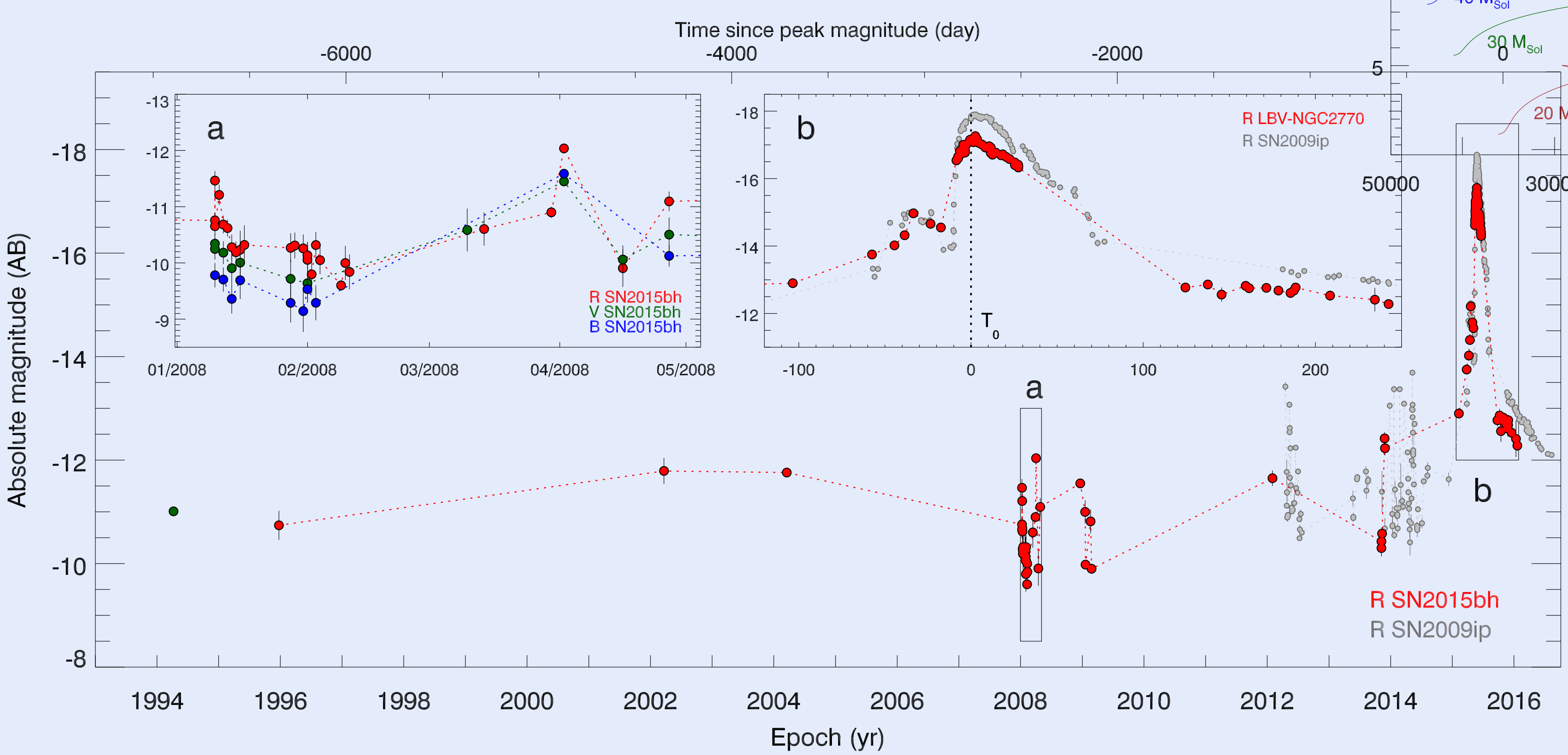
Smartt 2015

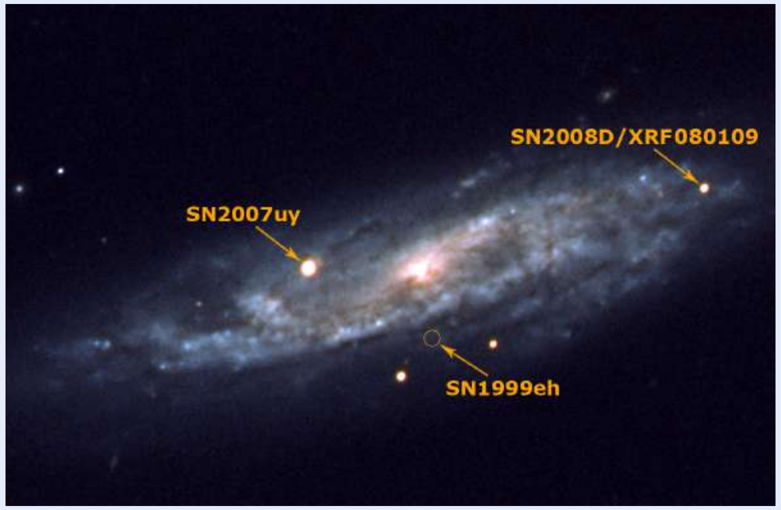
Thöne et al. 2017

SN 2015bh: a SN or an impostor?

- Outburst detected in 2013 (not reported) second outburst in early 2015
- IIn SN (?) in May 2015
- Outbursts during > 21 years!
- Progenitor a >50 M☉ LBV?







Thöne et al. 2017

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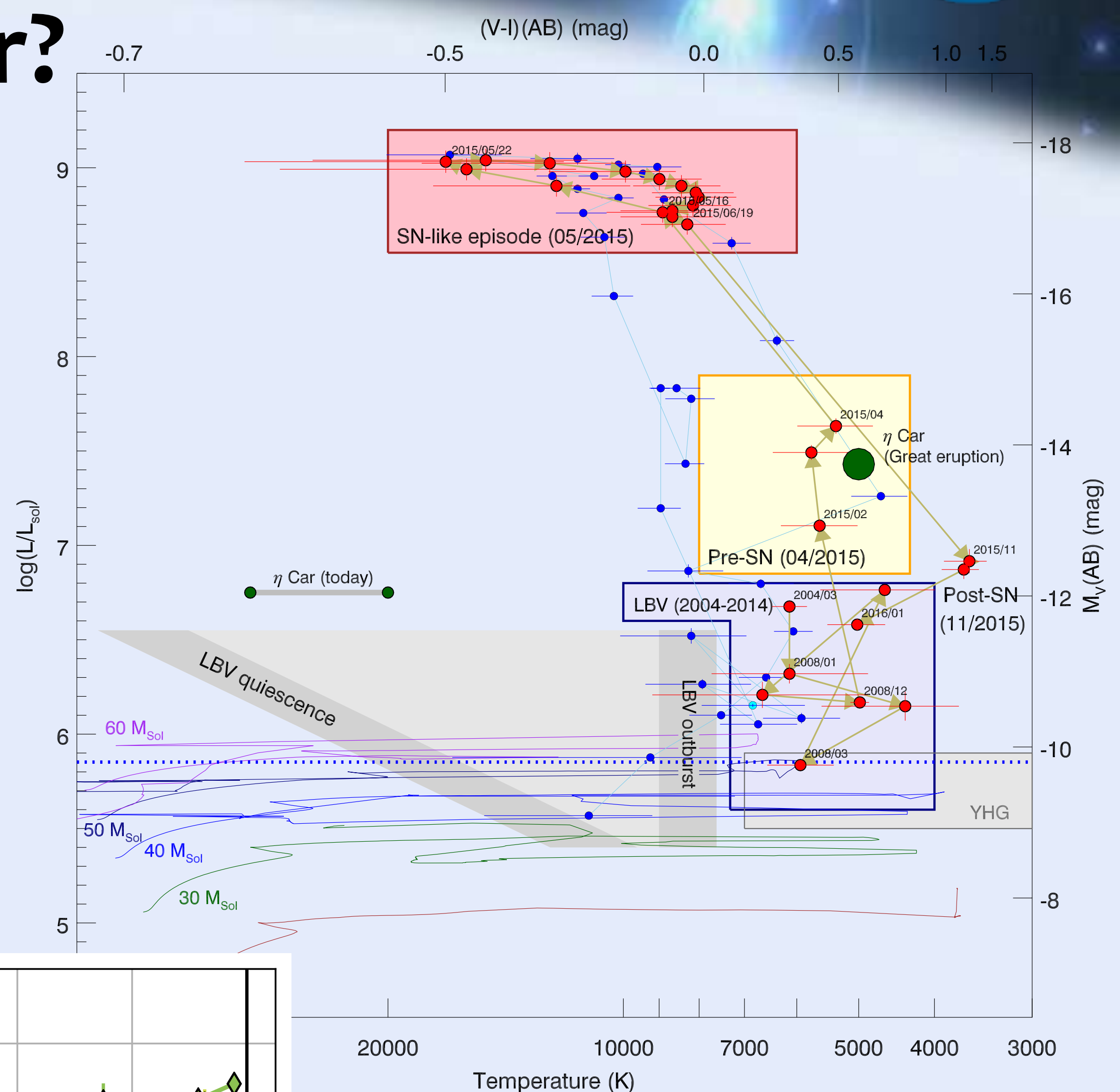
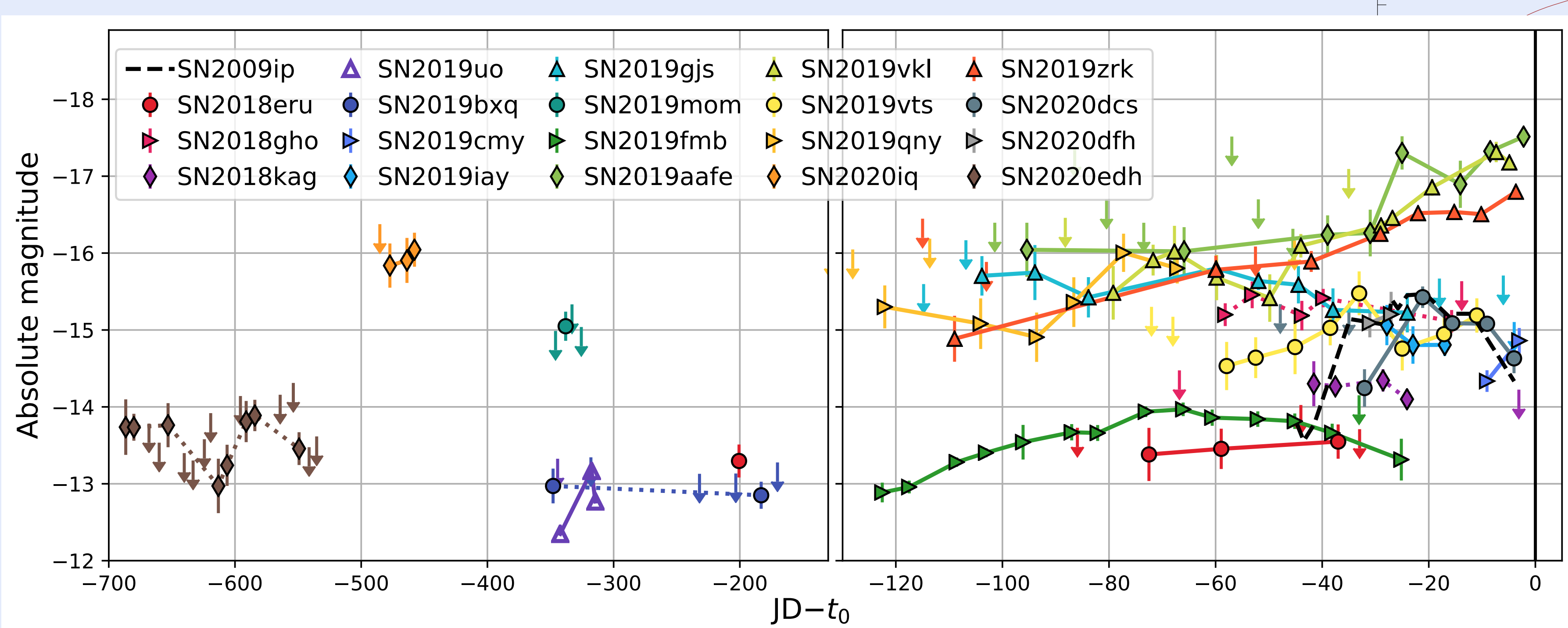
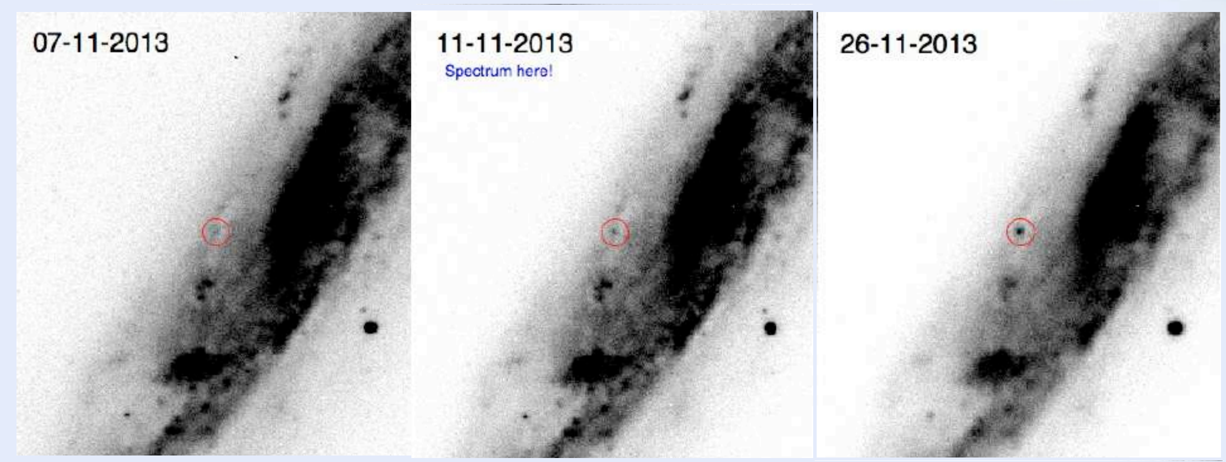


Strotjohann et al. 21

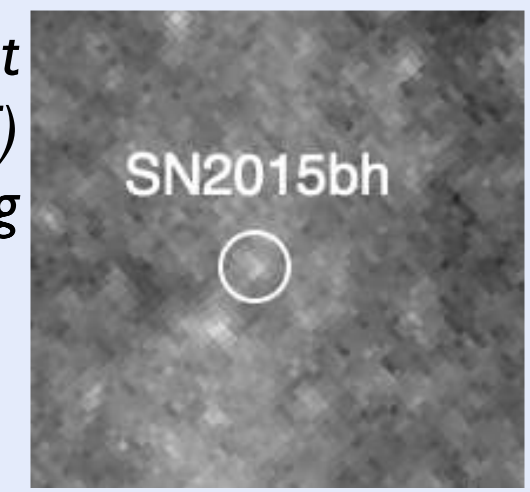


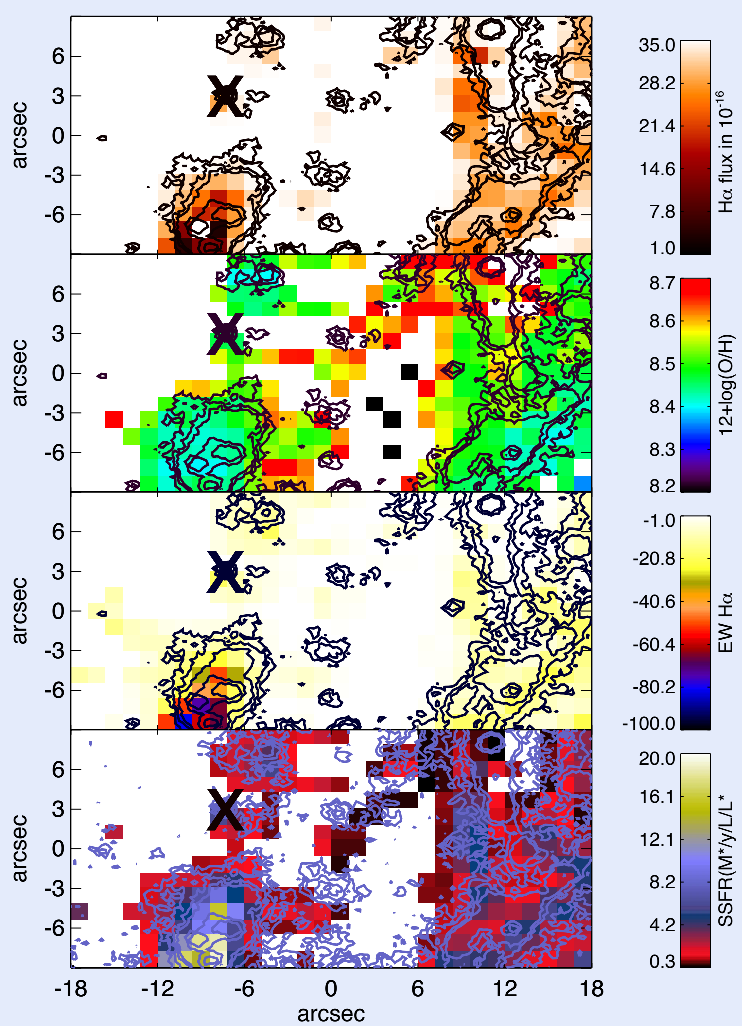
SN 2015bh: from progenitor to explosion (?)

- Serendipitous spectra before 2013 outburst
- First pre-explosion spectrum since 1987A!
- log L/L*=6.3, T=10,000K, dense wind (Boian&Groh18)

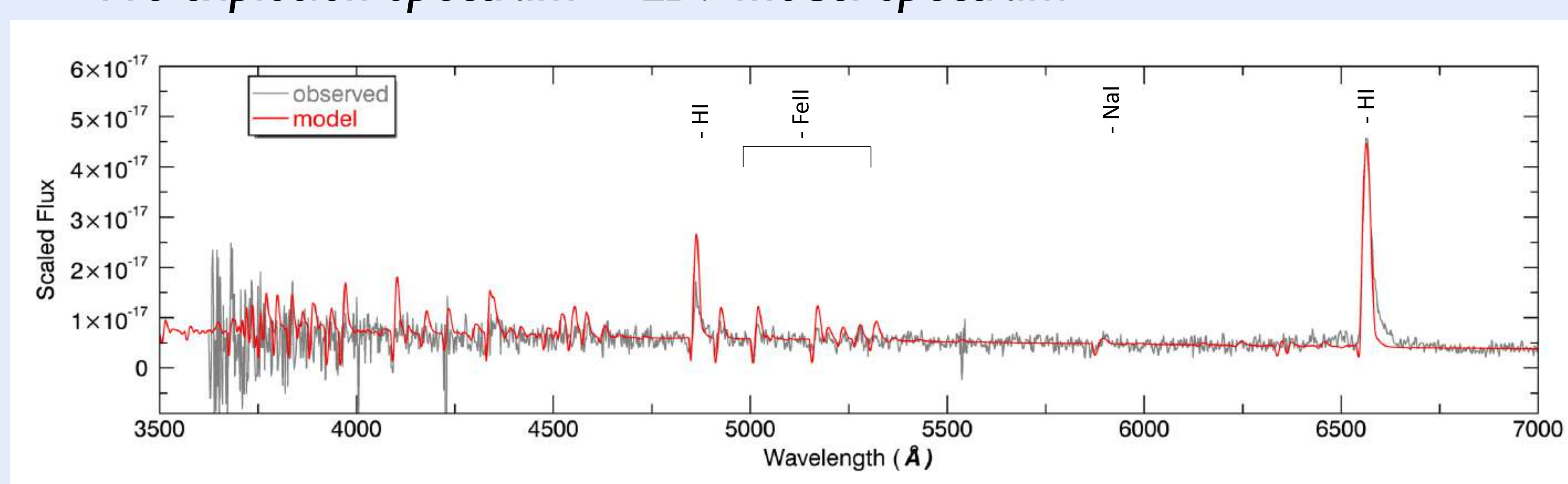


Surviving star/SN remnant in 2018 (HST)
M = -5.9 mag





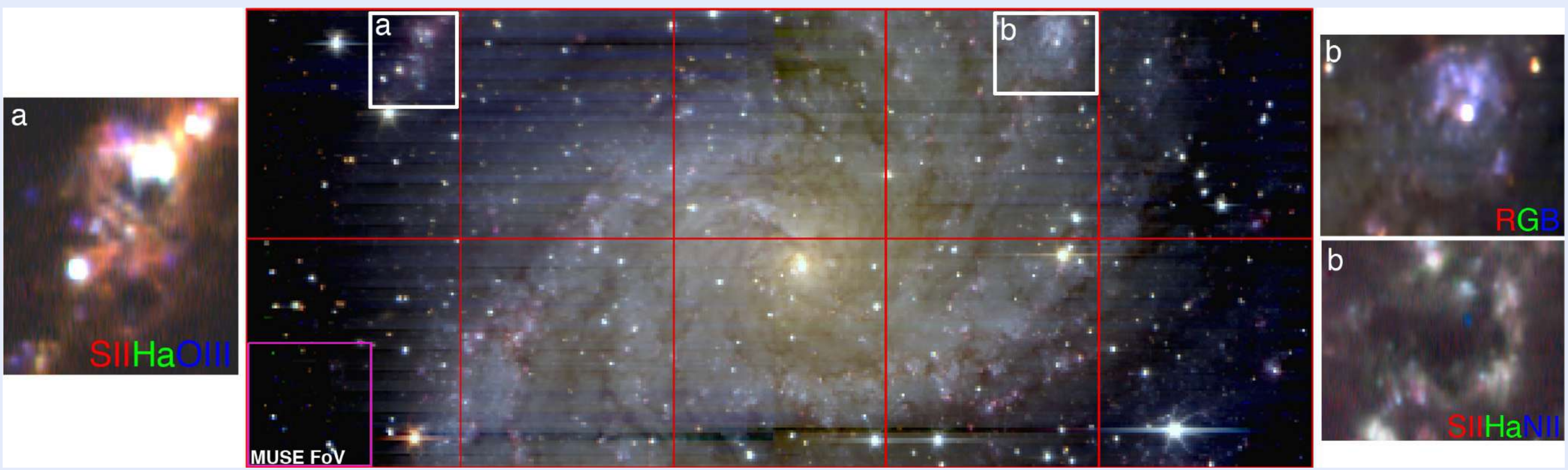
Pre-explosion spectrum + LBV model spectrum



Project: Pre-explosion spectroscopy of SN prognitors

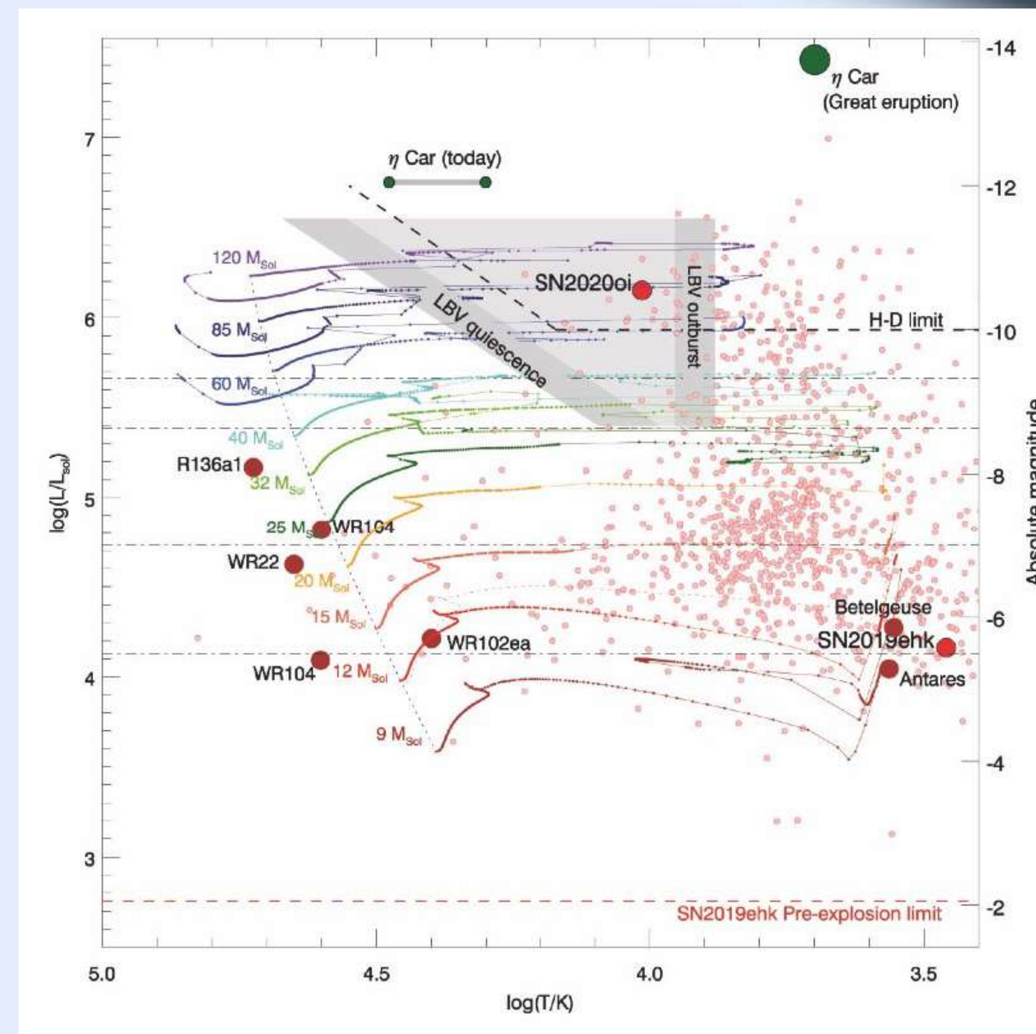
- SN hosts at < 30Mpc with 3+ CC-SNe with IFUs (~48 galaxies)
- Determine massive stellar population
- Lots of legacy value

NGC 6946 („Fireworks galaxy“) Driftscan spectroscopy with OSIRIS/GTC

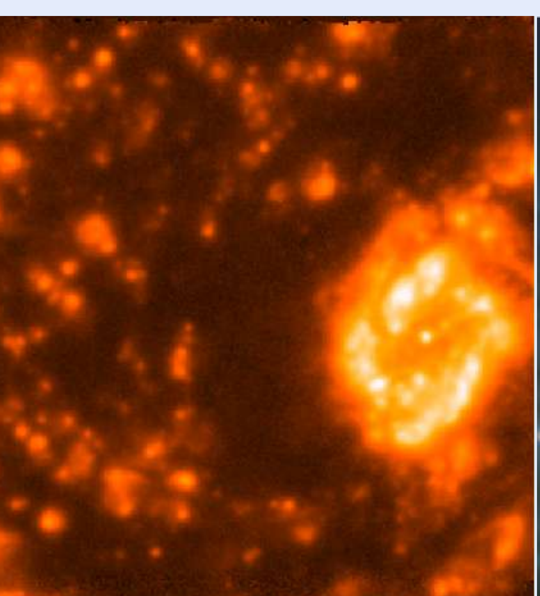


Project: Pre-explosion spectroscopy of SN prognitors

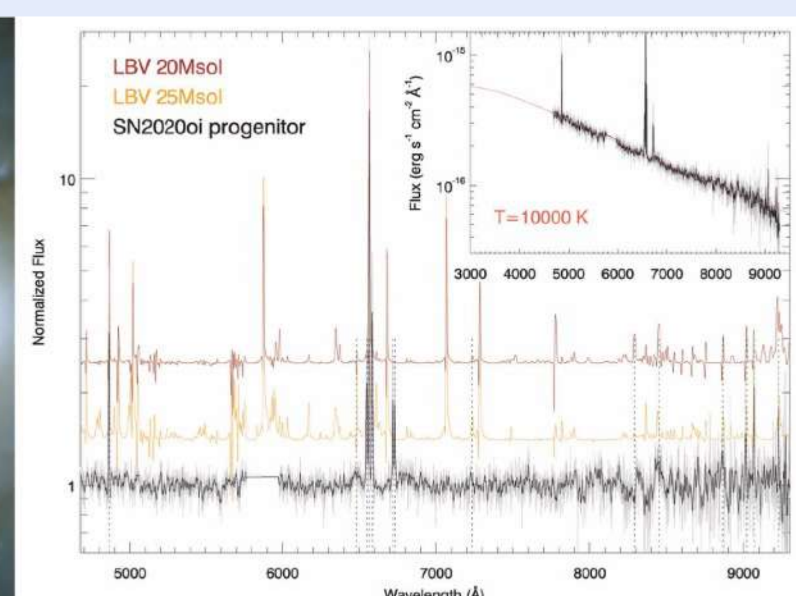
- Showcase: SN2019ehk & SN2020oi in M100
- SN 2019eh: MUSE data 44h before discovery! Hα P-Cygni: wind or SN?
- SN 2020oi: Ic, progenitor with broad lines or small cluster? M_{abs}=-11.5 mag

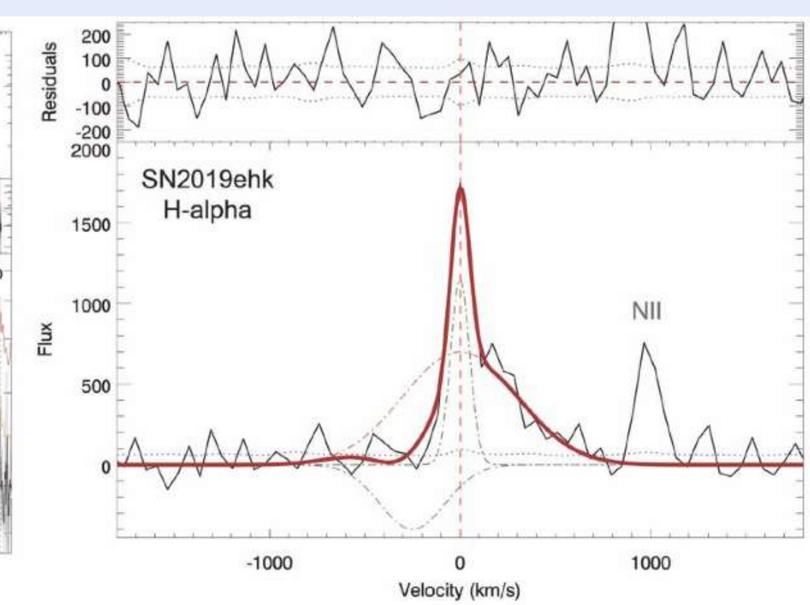


MUSE Hα



HST

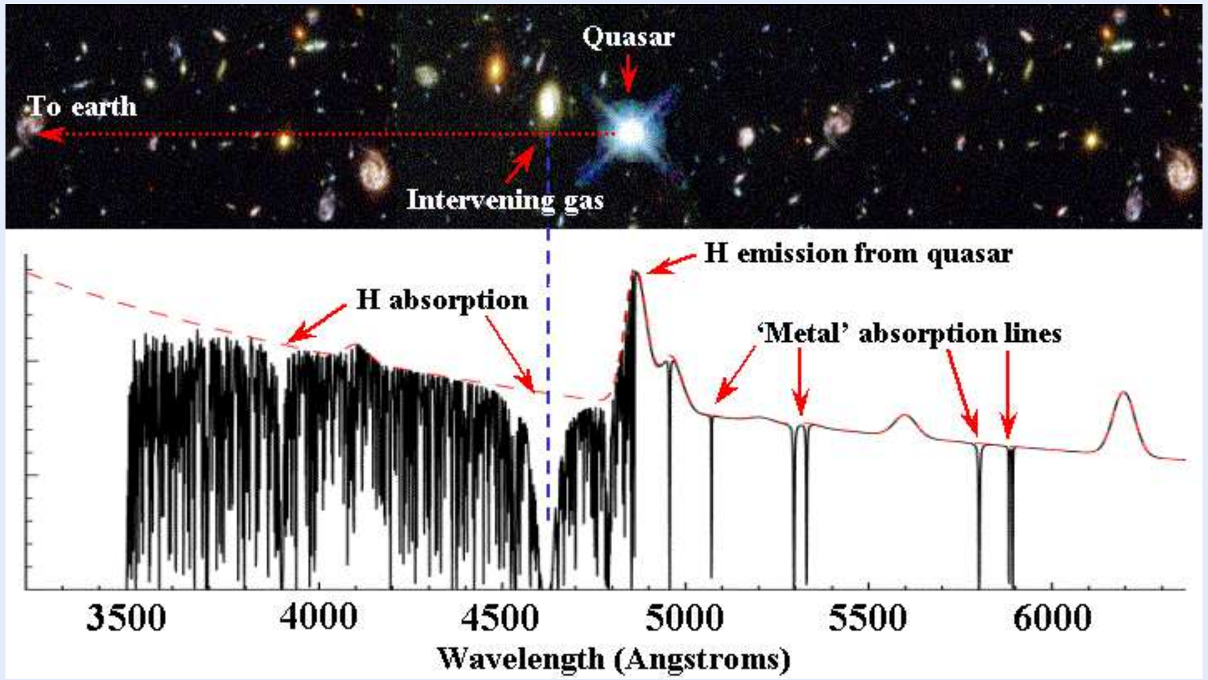


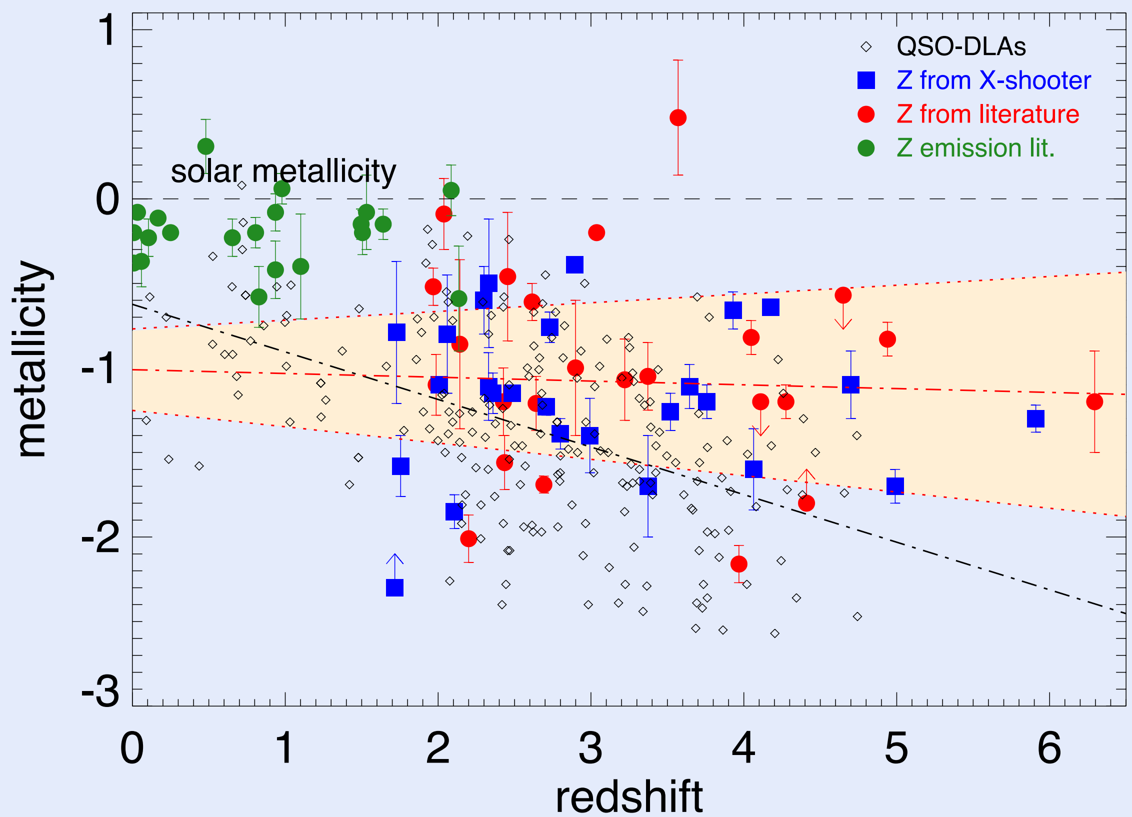


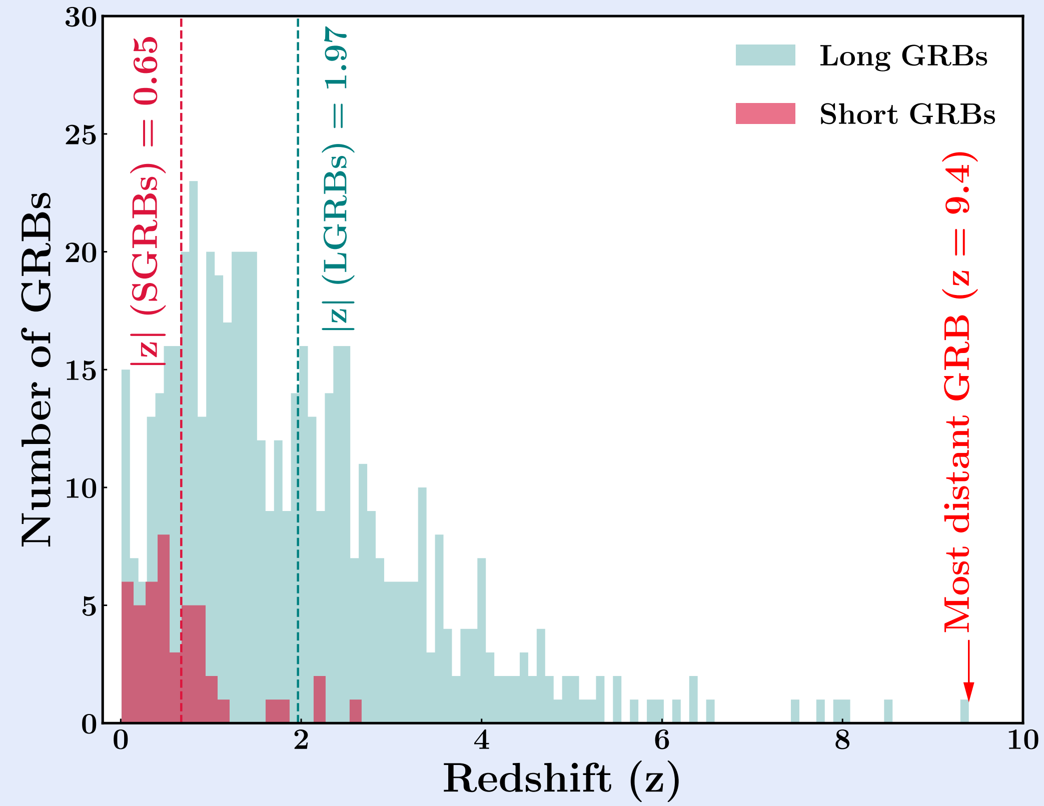
GRBs as lighthouses

GRBs illuminating their high-z ISM

- z = 0 to 9
- Clean synchrotron spectrum, absorption lines from ISM (similar to QSOs)
- Chemical evolution over large range of redshift
- Sometimes rich velocity structure



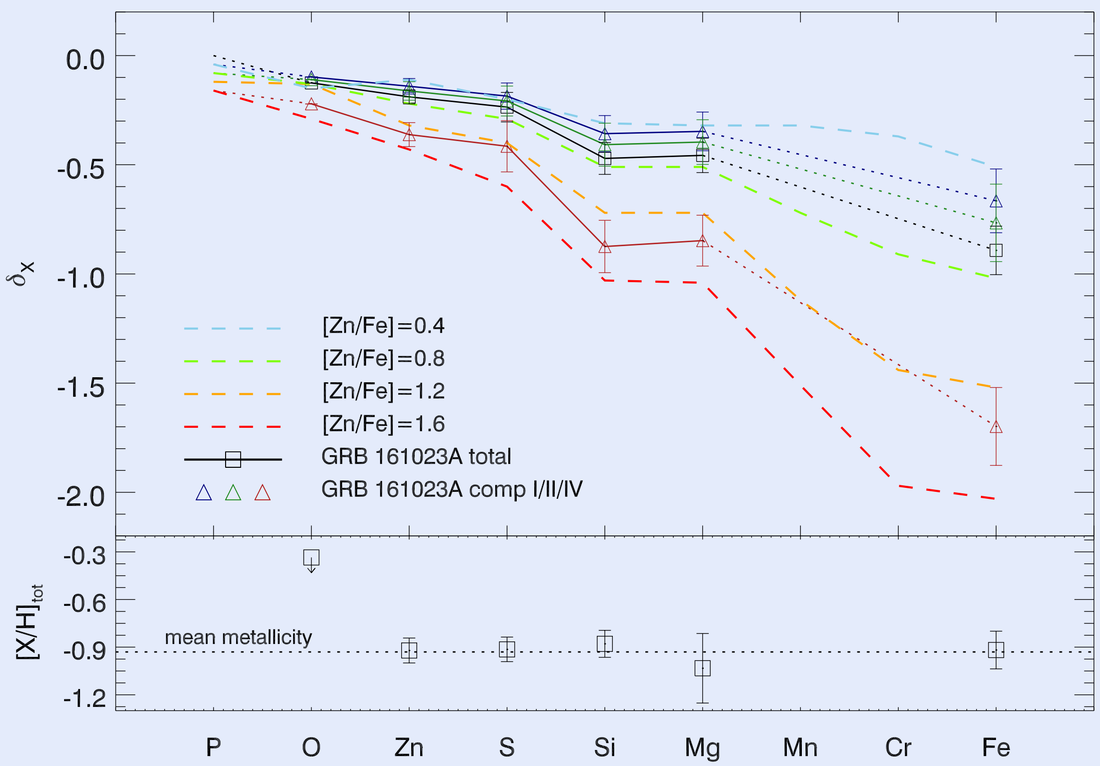




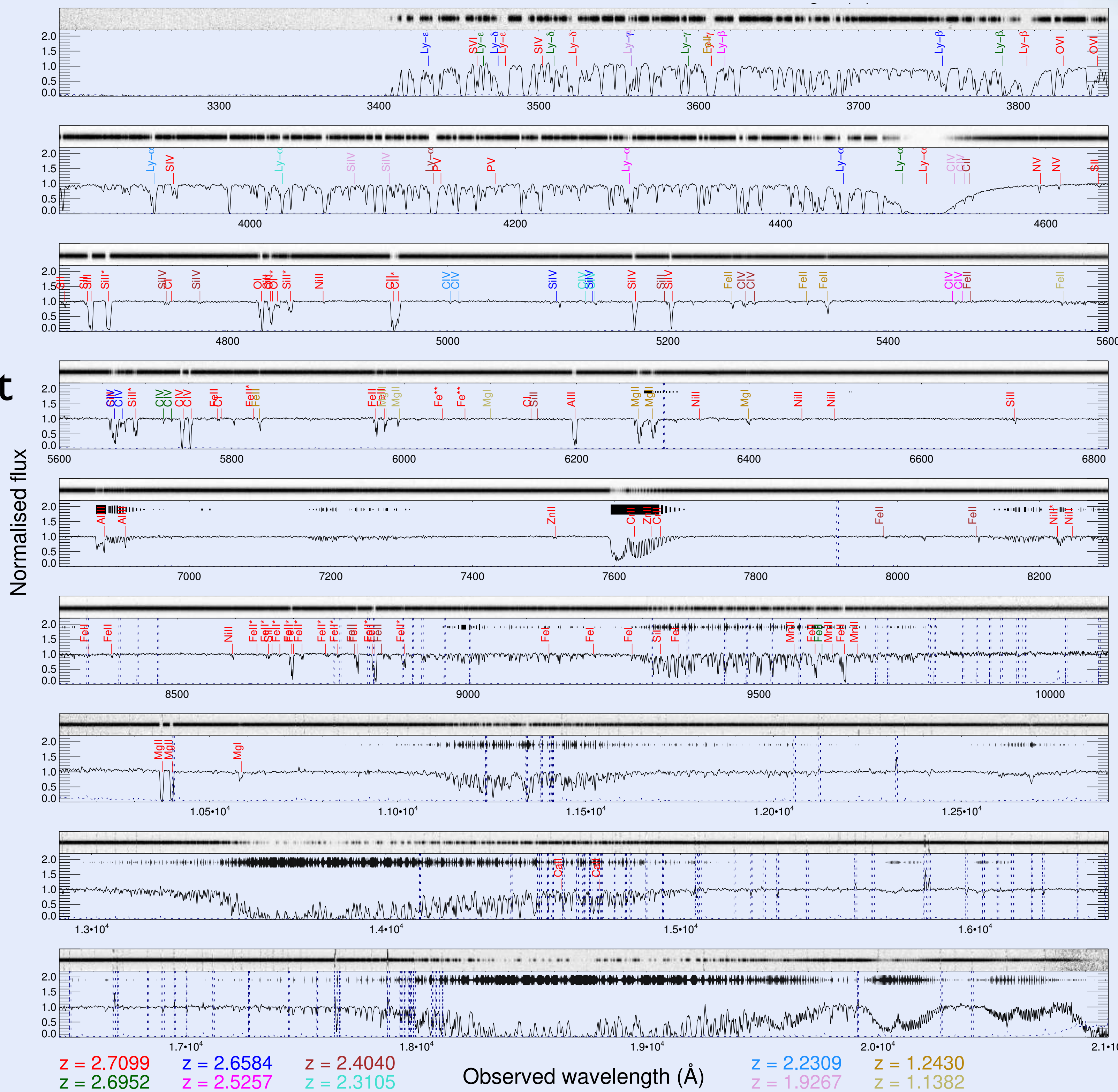
GRB hosts: abundances and distances

- Metallicity, dust in the host and (often) in intervening systems
- e.g. GRB 161023A, z=2.7

  9 intervening systems!
  strong dust depletion in component closest to the GRB



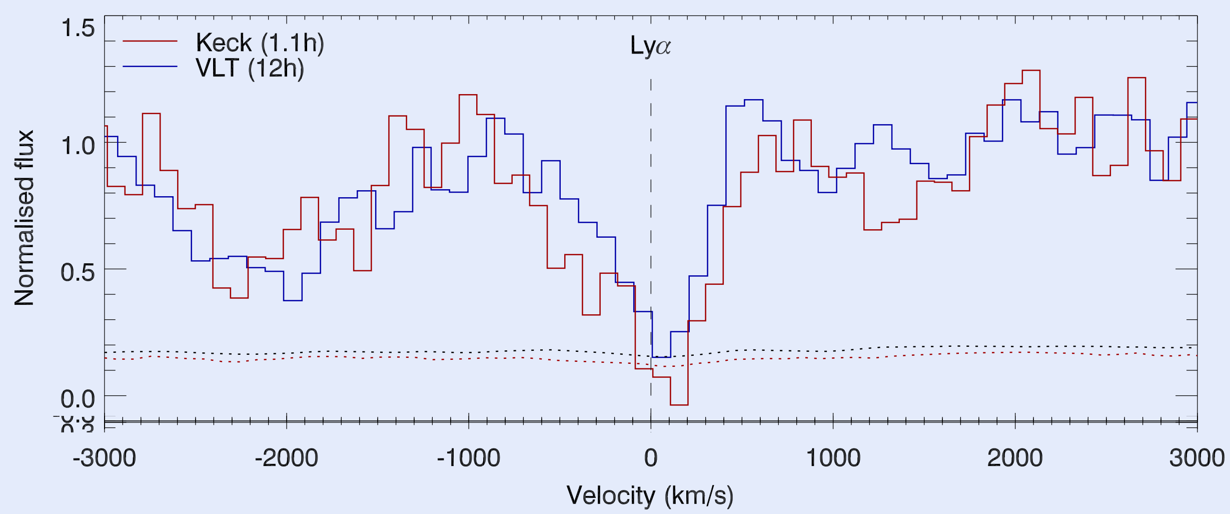
GRB 161023A

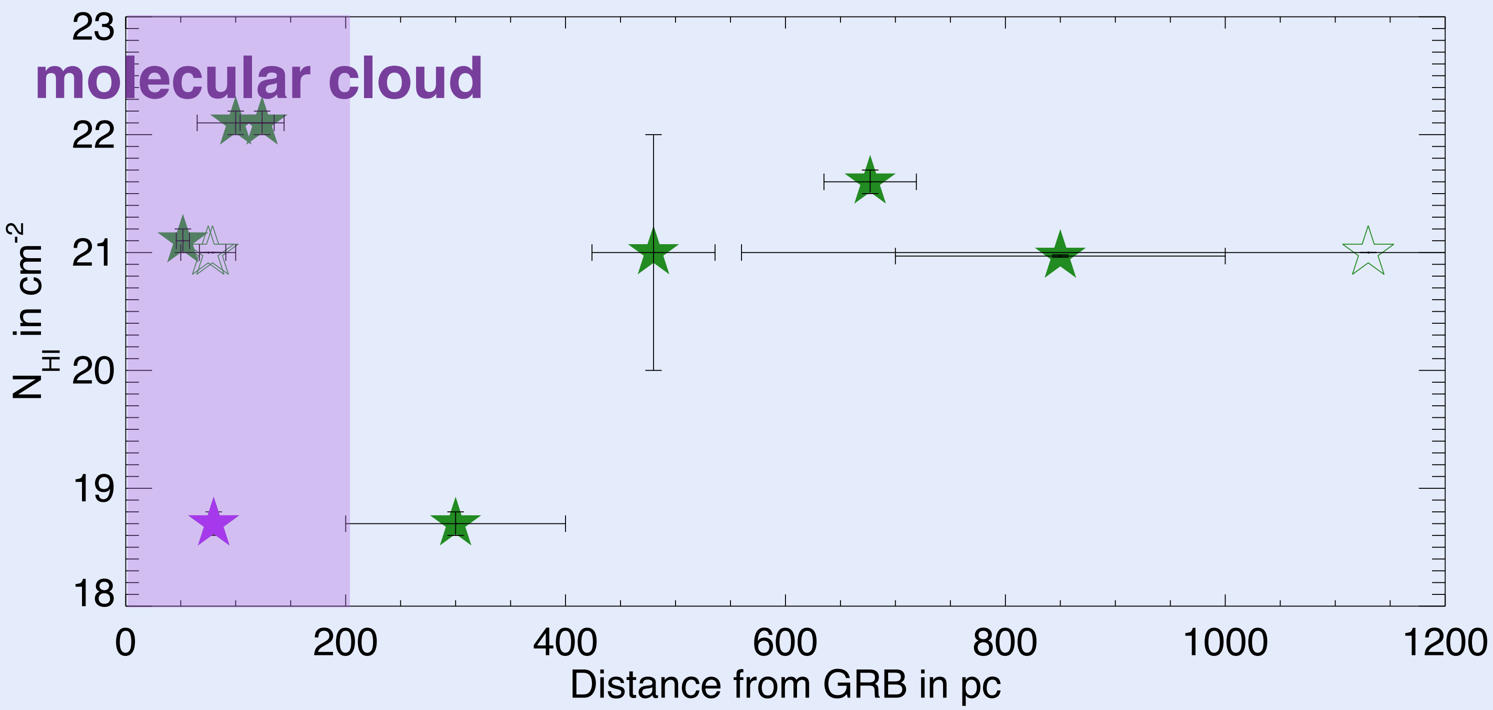


GRB hosts: abundances and distances

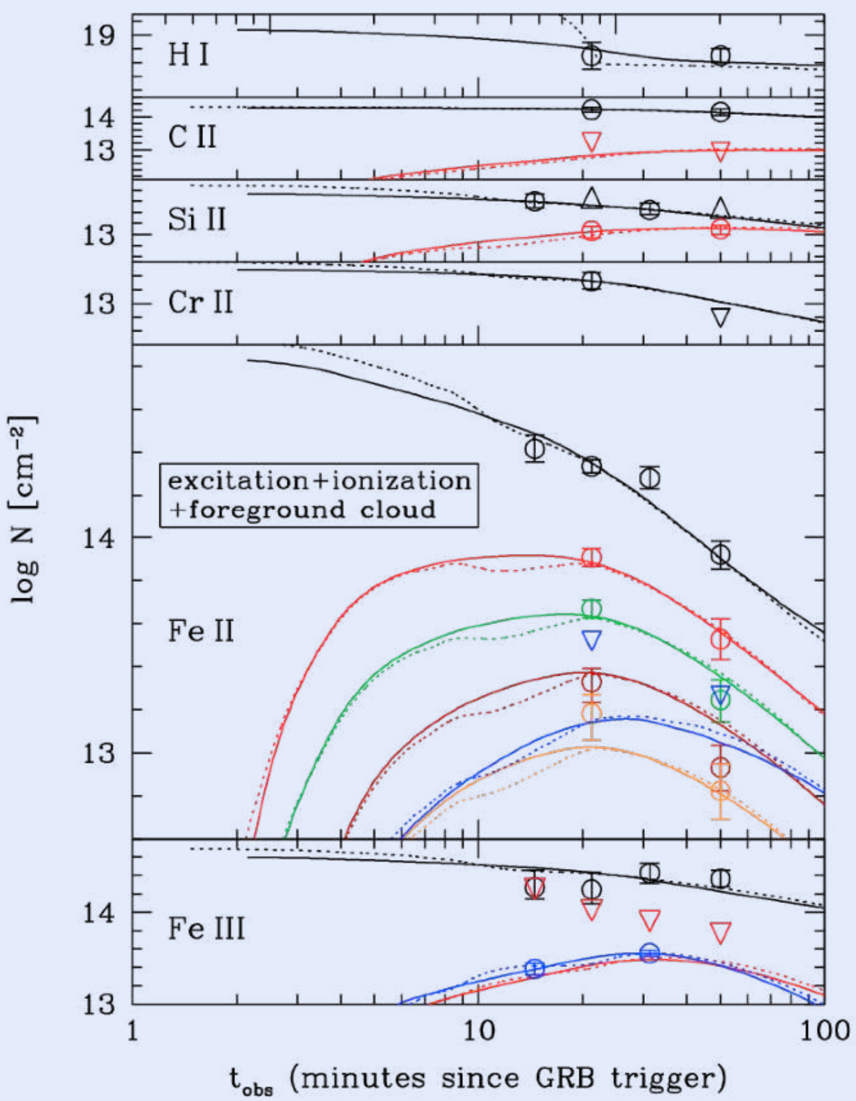
- Fine-structure lines and line variability give distances (excitation by the GRB itself)
- Sometimes rich velocity structure

GRB 090426





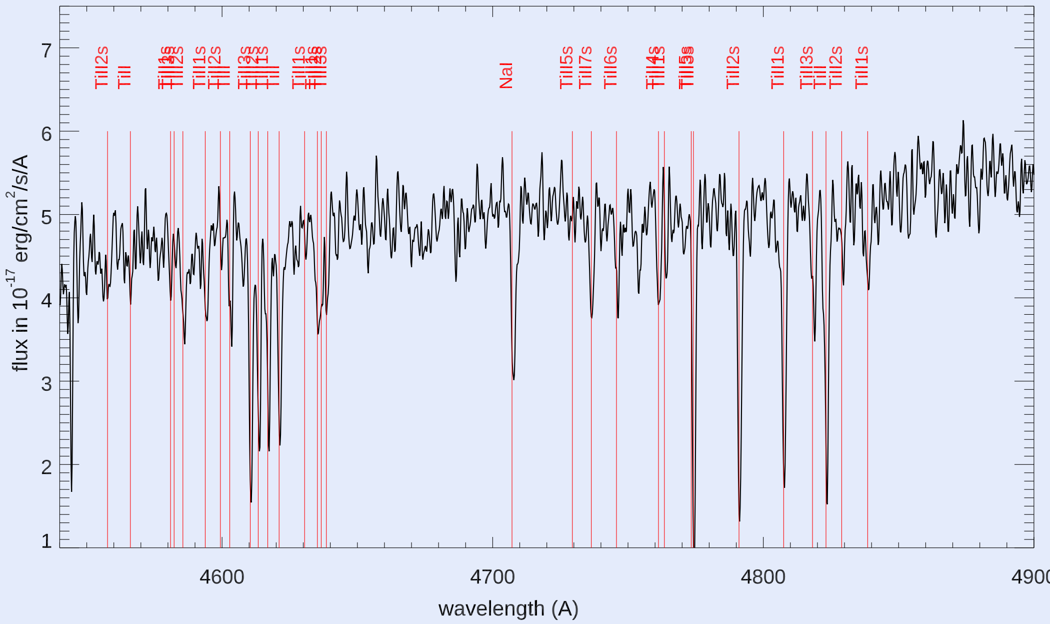
Vreeswijk et al. 12

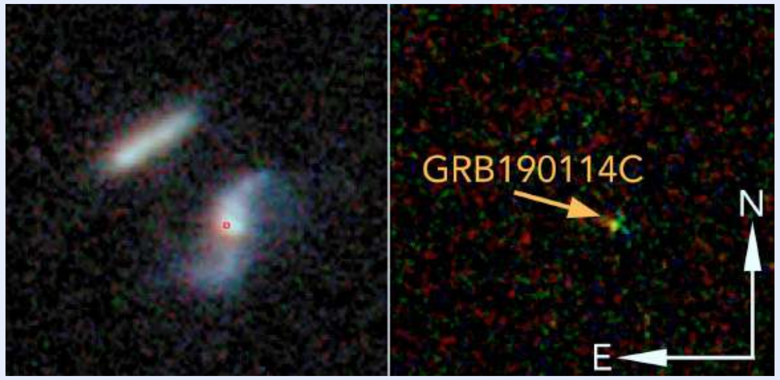


VHE emission in GRBs

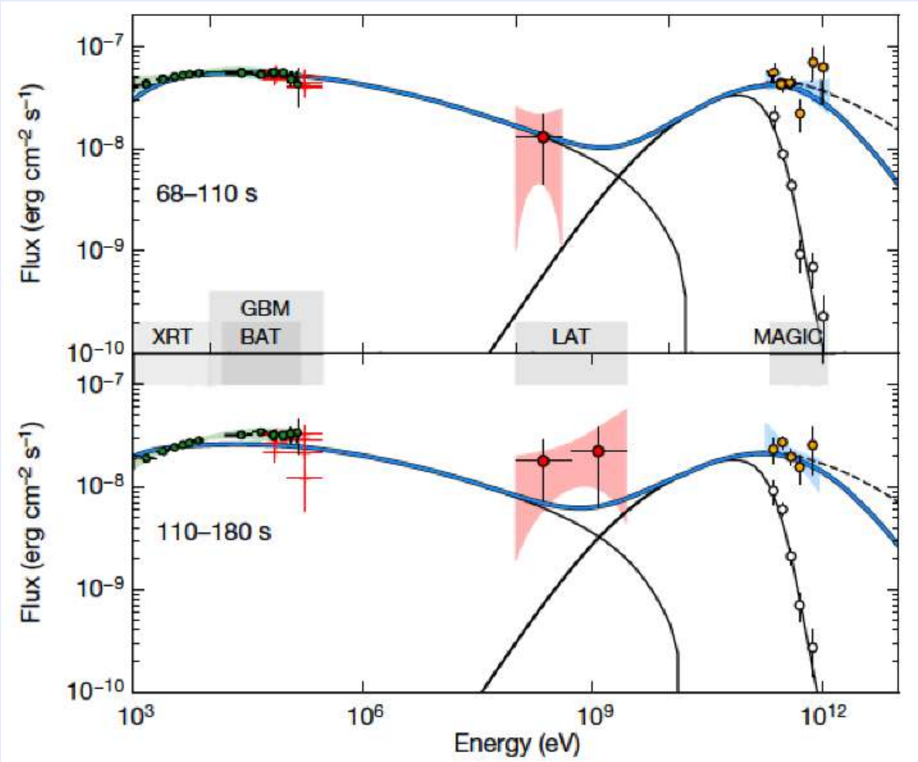
- 5(6?) detections at VHE (TeV) with MAGIC/H.E.S.S inverse Compton?
- peculiar environments: excited lines of Ti, Fe, HeI
- dense/dusty environment needed to produce UHEs?

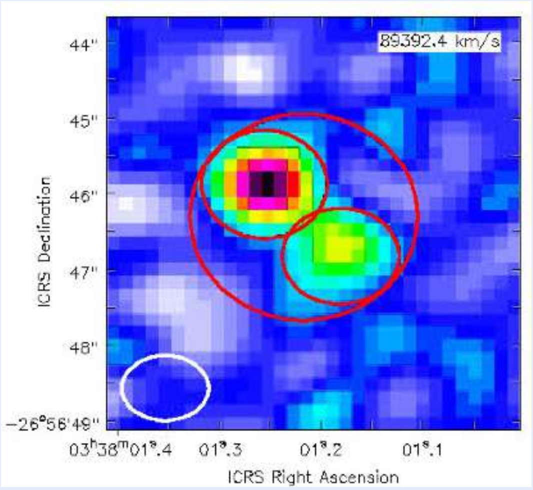
Ti fine structure



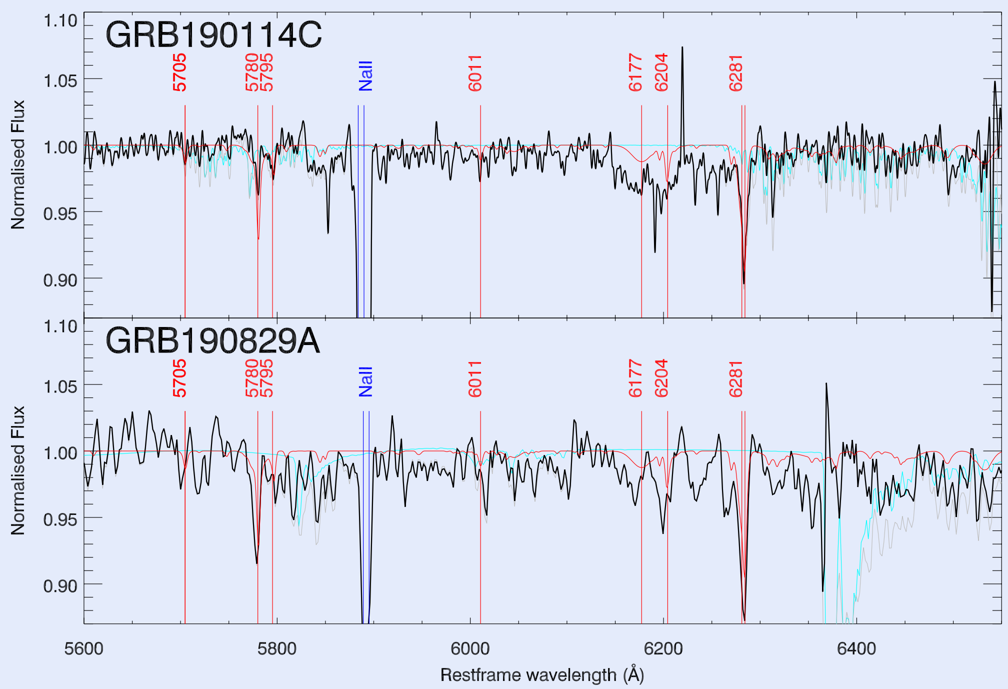


SED





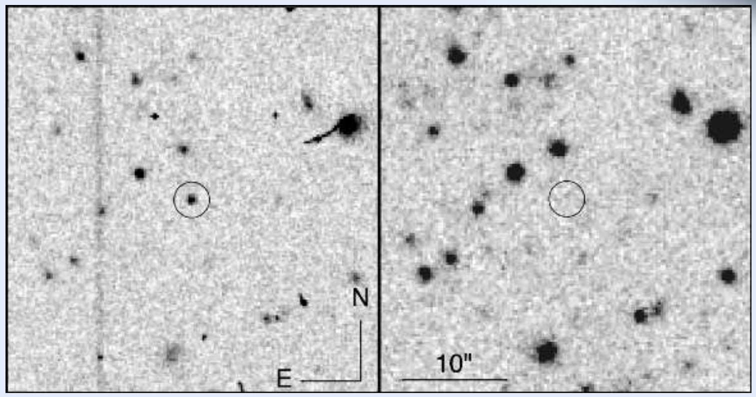
DIBs



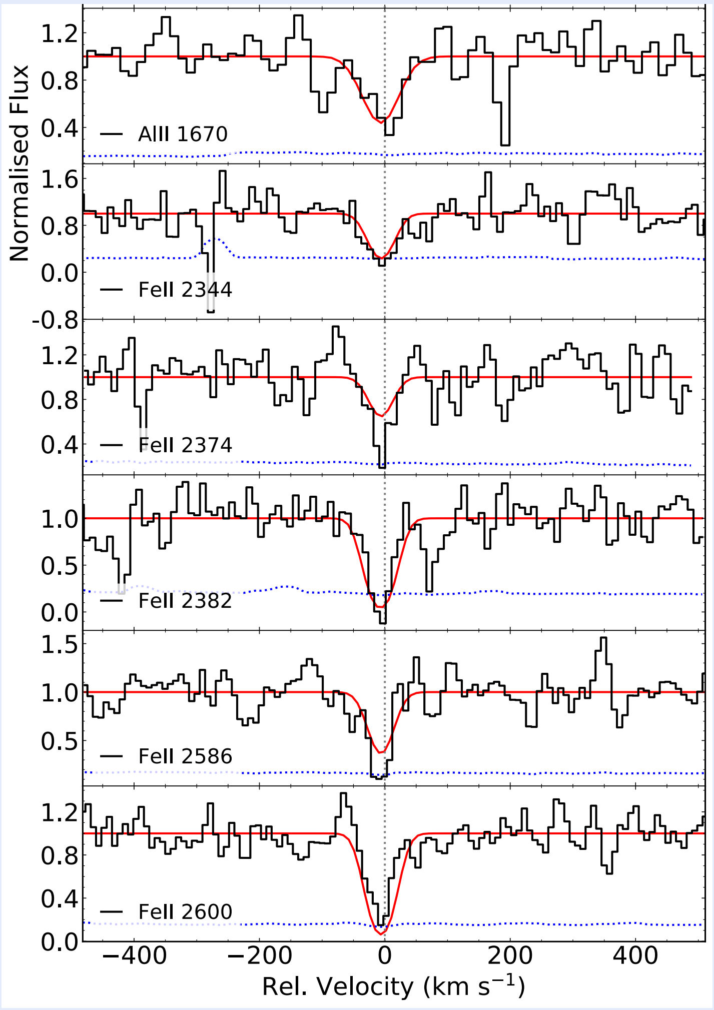
Agüí Fernández, Thöne et al. under rev.

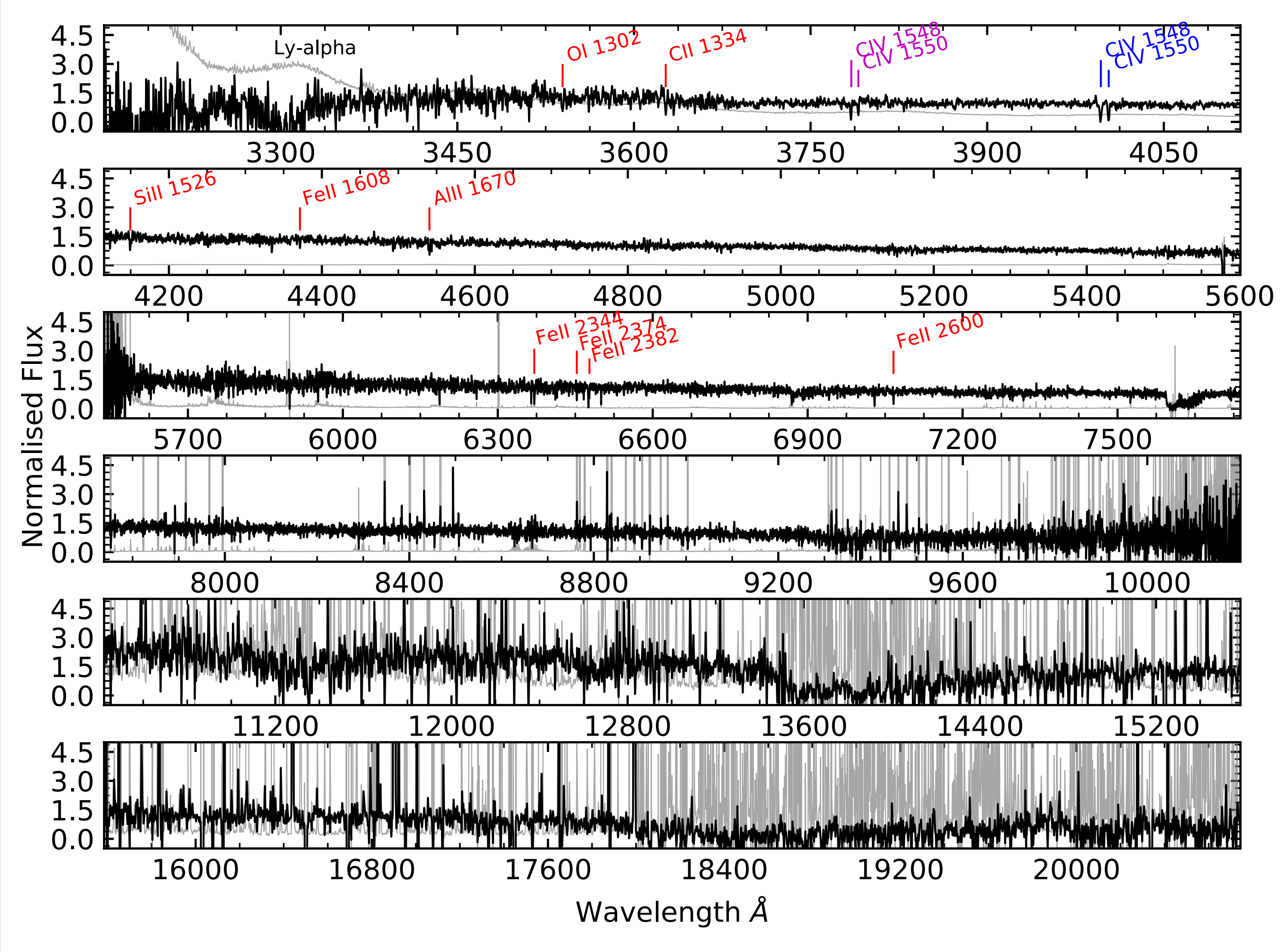
First metallicity: 160410A

- X-shooter spectrum 8min post GRB, z=1.7
- Weak absorption lines, no CIV/SiIV, single component
- very low metallicity: [Fe/H] = -2.7
- no dust depletion
- no host galaxy (M_{abs} > -18.17 mag)



afterglow (host)





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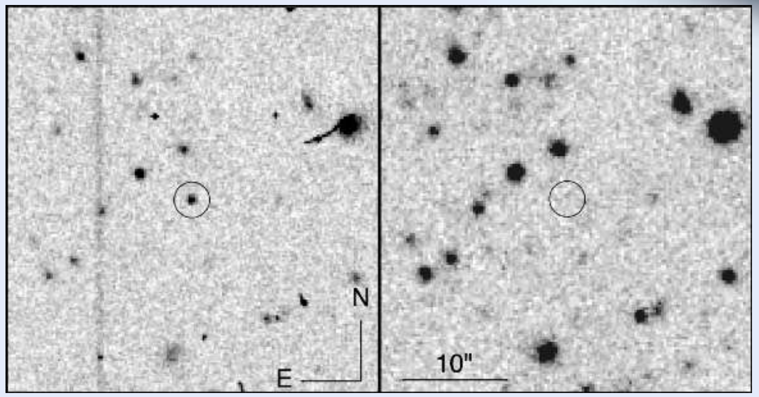

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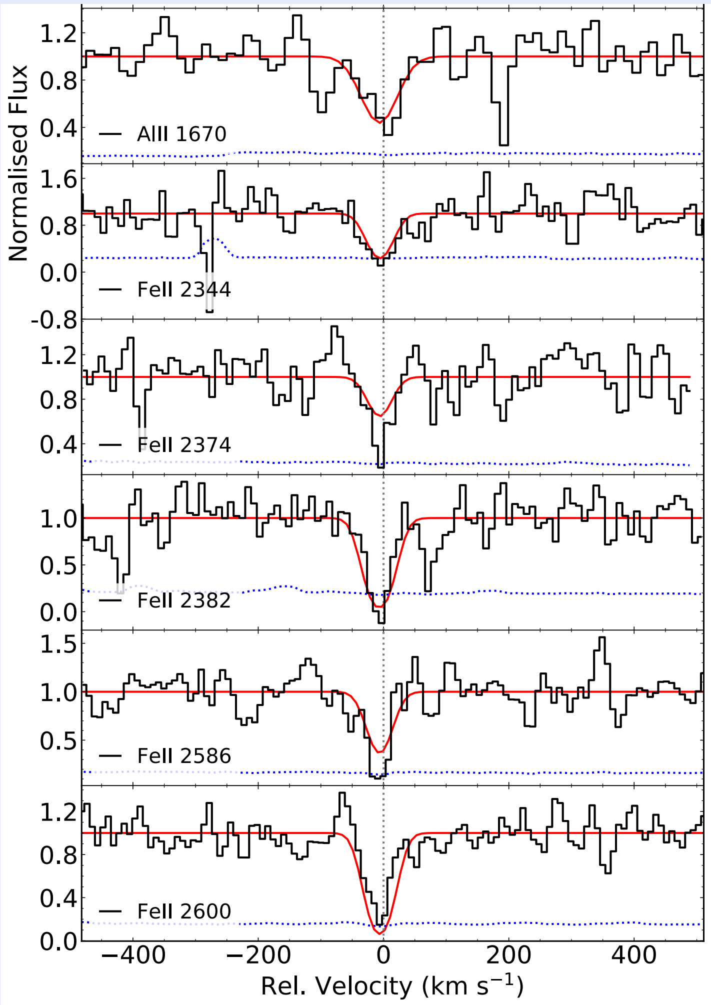
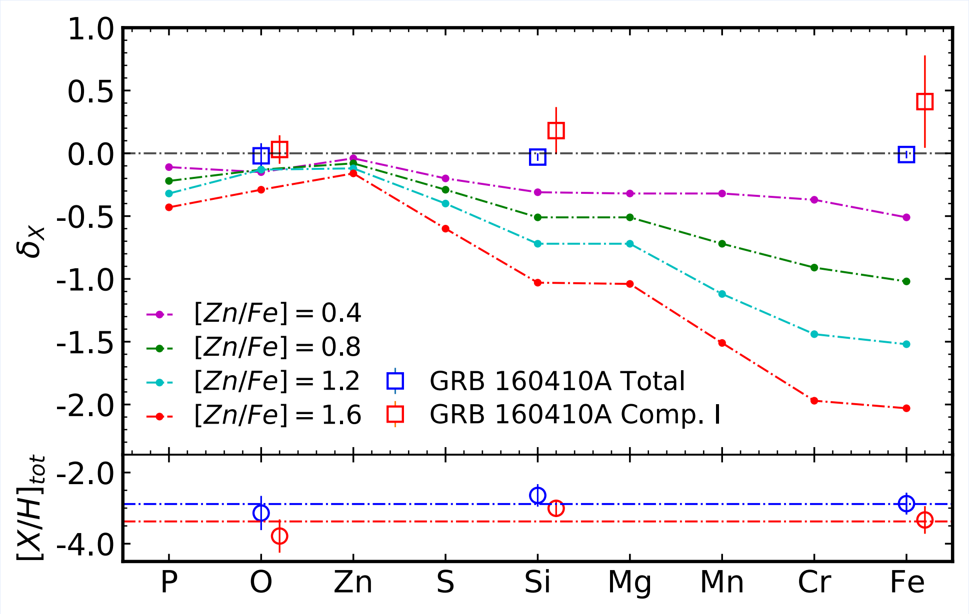
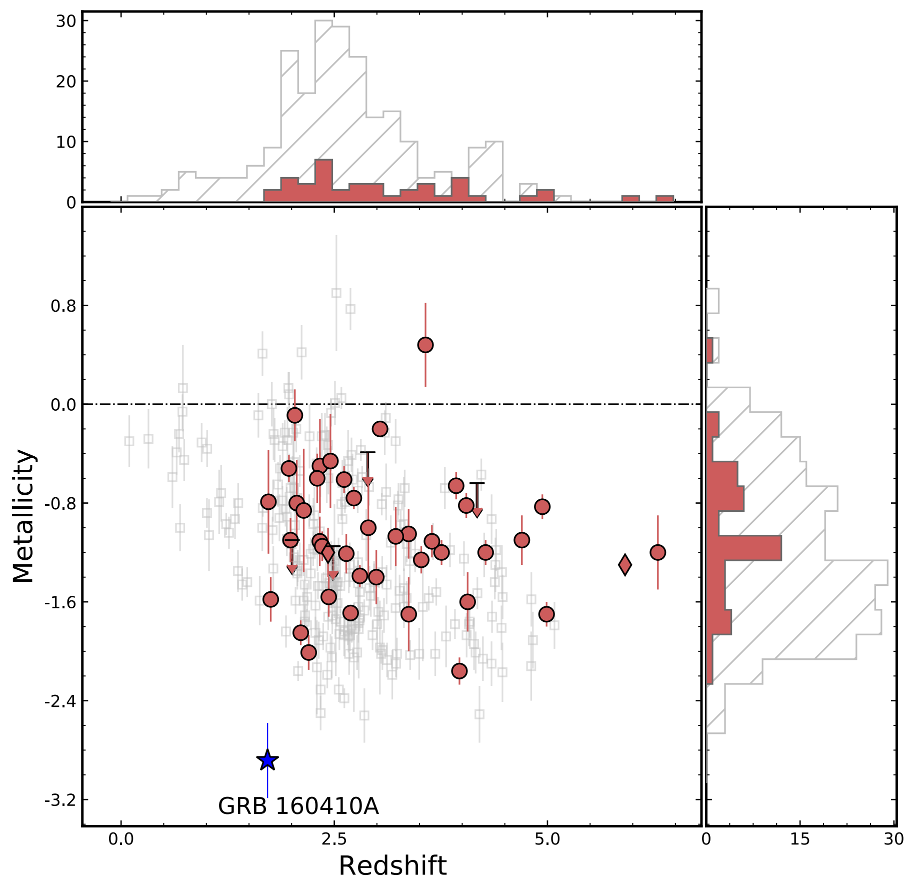
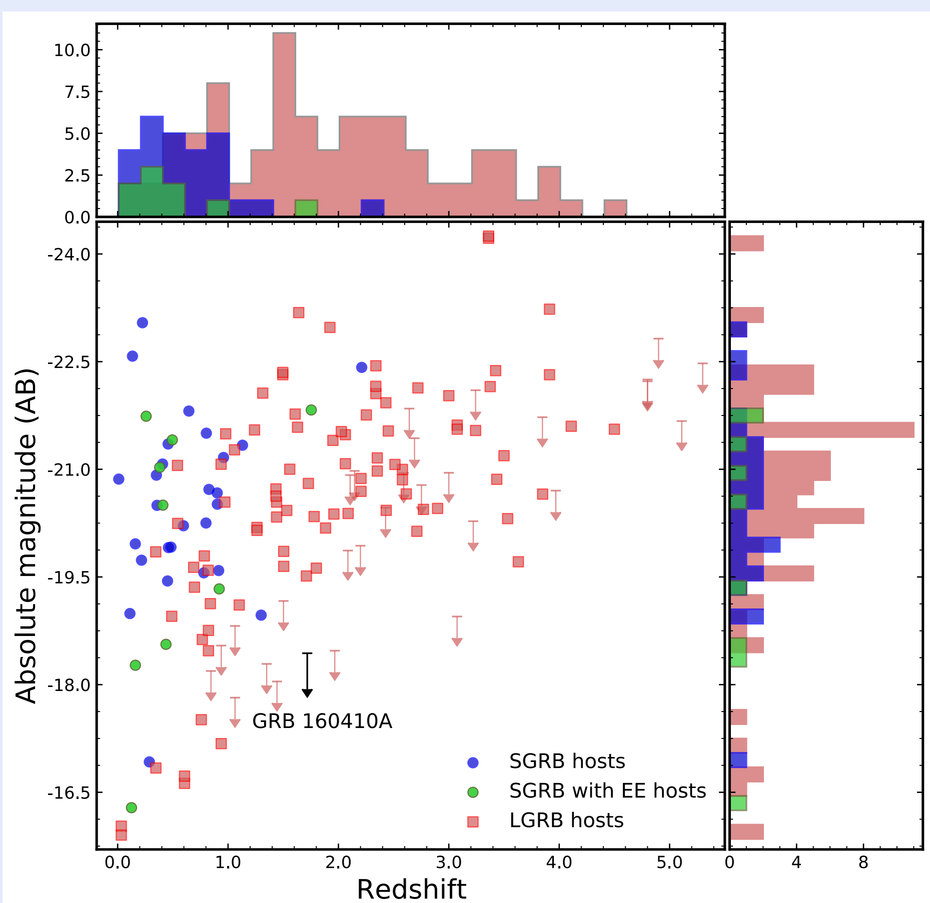


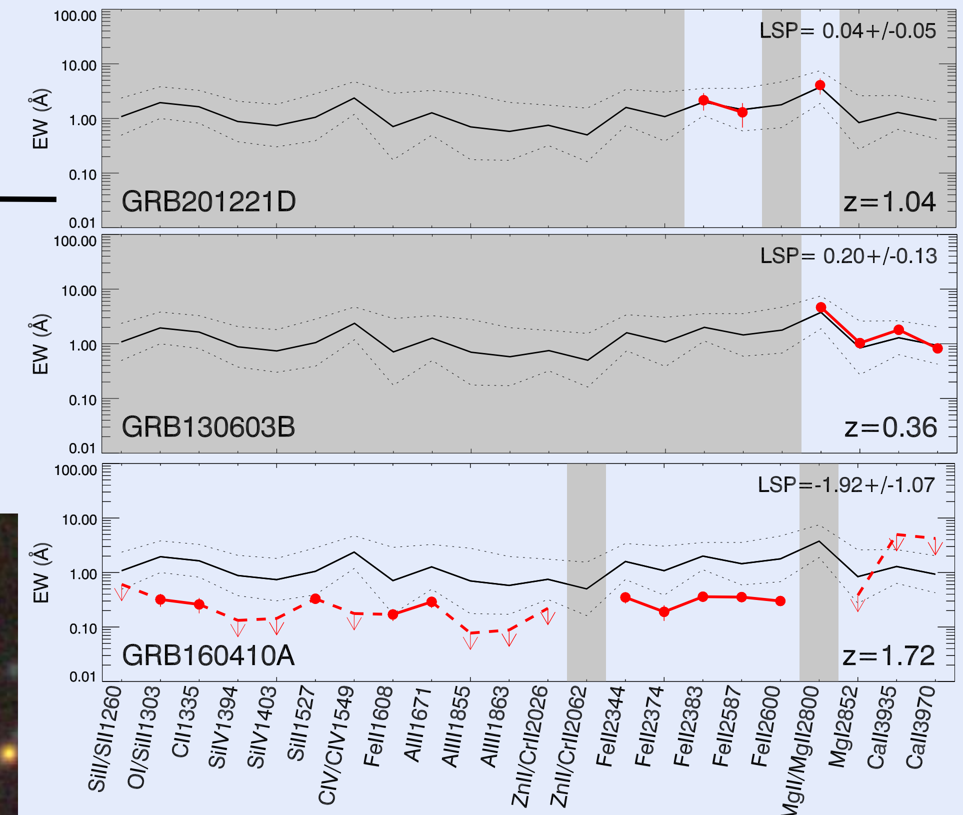


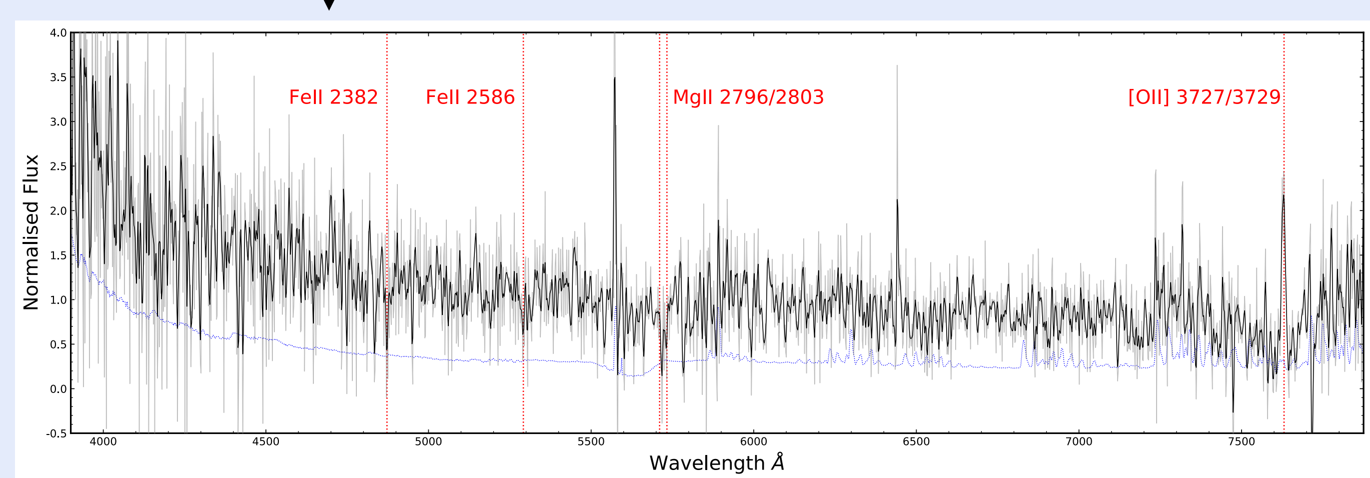


Are short GRB environments special? or not?

- 161004A: Low density environment 130603B+201221D have average environment (compared to lGRBs)
- Are EE-GRB hosts/environments different?







Conclusions

- Hosts of different stellar explosions are indeed different
- Depending on the host the immediate environment is most crucial
- Star-formation triggers still largely unknown and might be different for different hosts/samples
- Need to get better correlations environment - progenitor in the very nearby Universe
- GRBs very interesting as probes of the high-z galaxy ISM, but large samples at high-z missing
- Is the ISM in short GRB hosts significantly different? or not?