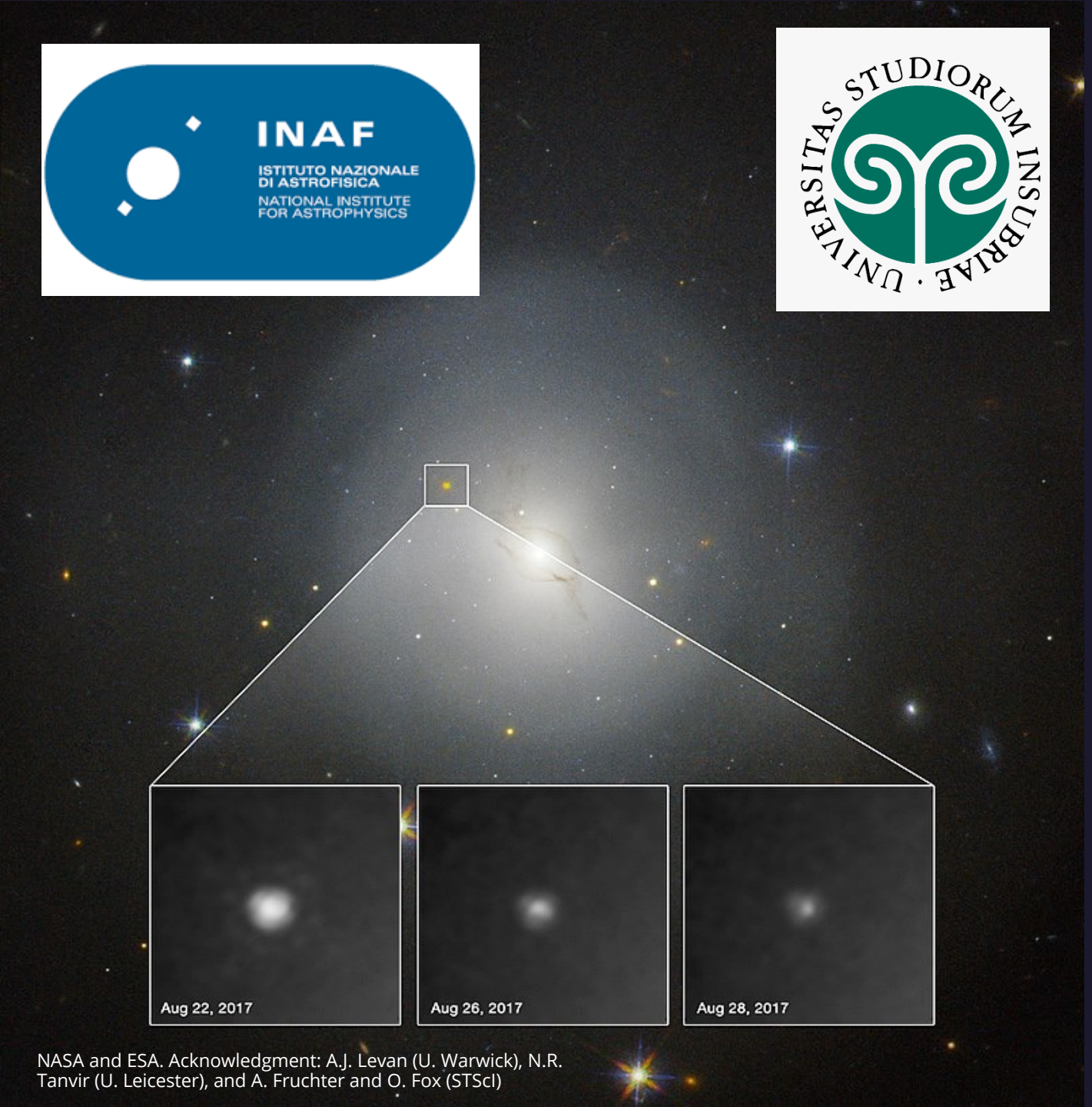

NASA and ESA. Acknowledgment: A.J. Levan (U. Warwick), N.R. Tanvir (U. Leicester), and A. Fruchter and O. Fox (STScI)

Search for afterglow and kilonova emission in short GRBs

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V Congresso Nazionale GRB

13/09/22 - Trieste

Analysis of two short GRBs:

- GRB 211106A
- GRB 211227A

For which:

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Short GRBs sample presented by *D'Avanzo et al.* (2014), 16 SGRBs:

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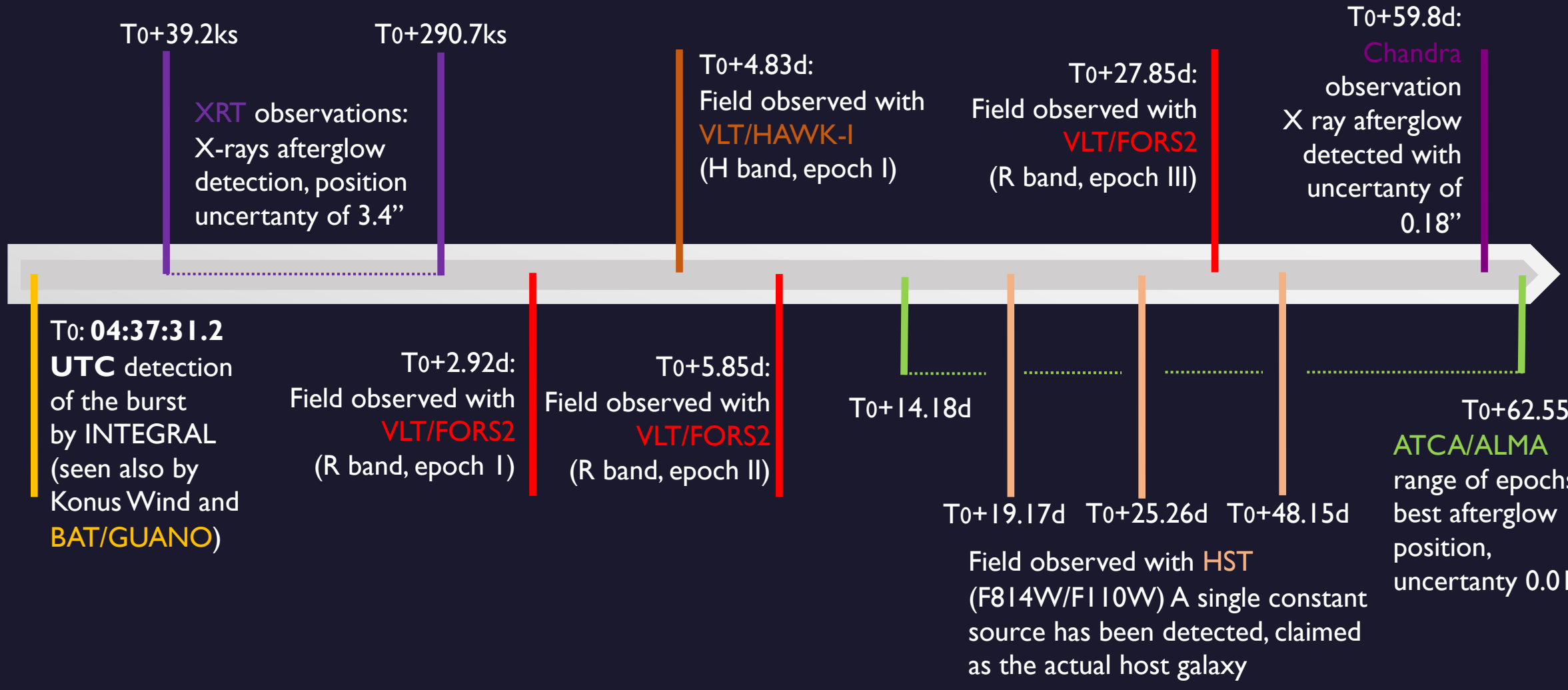
For GRB 211227A we performed spectral analysis from VLT/X-SHOOTER data to examine its host galaxy features such as SFR and metallicity

Timeline: GRB 211106A



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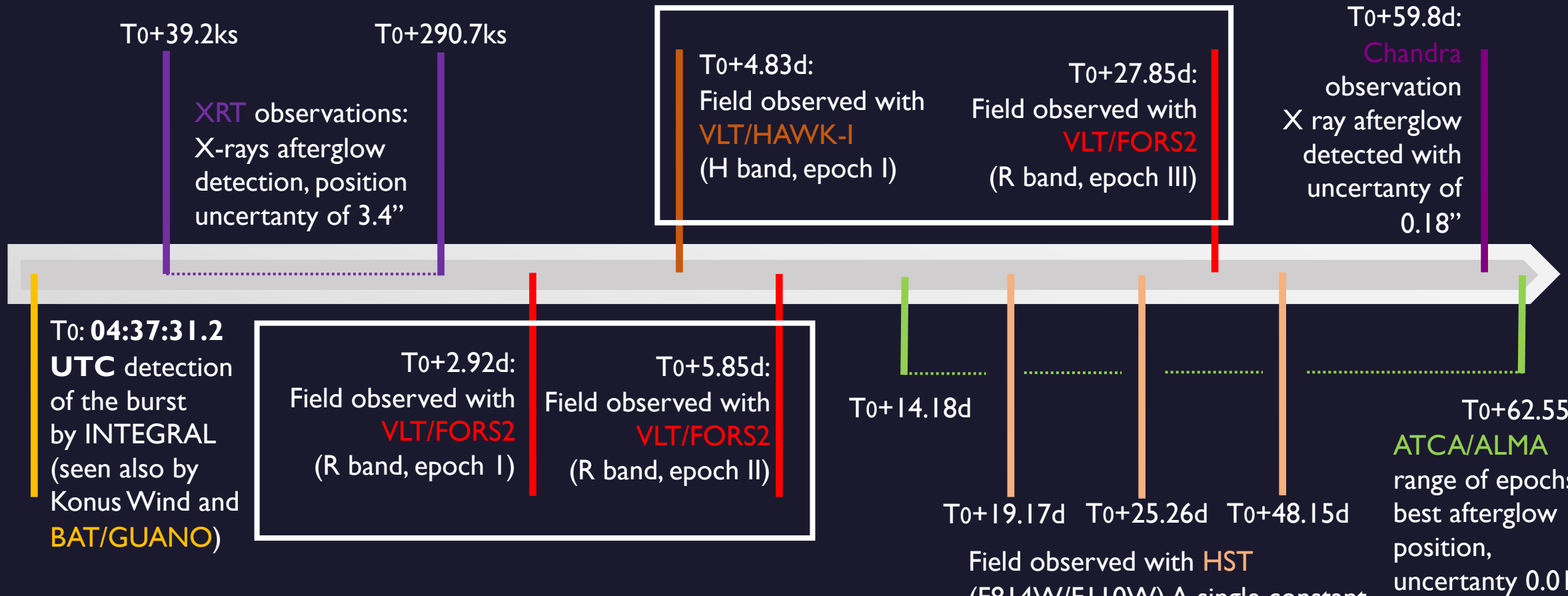
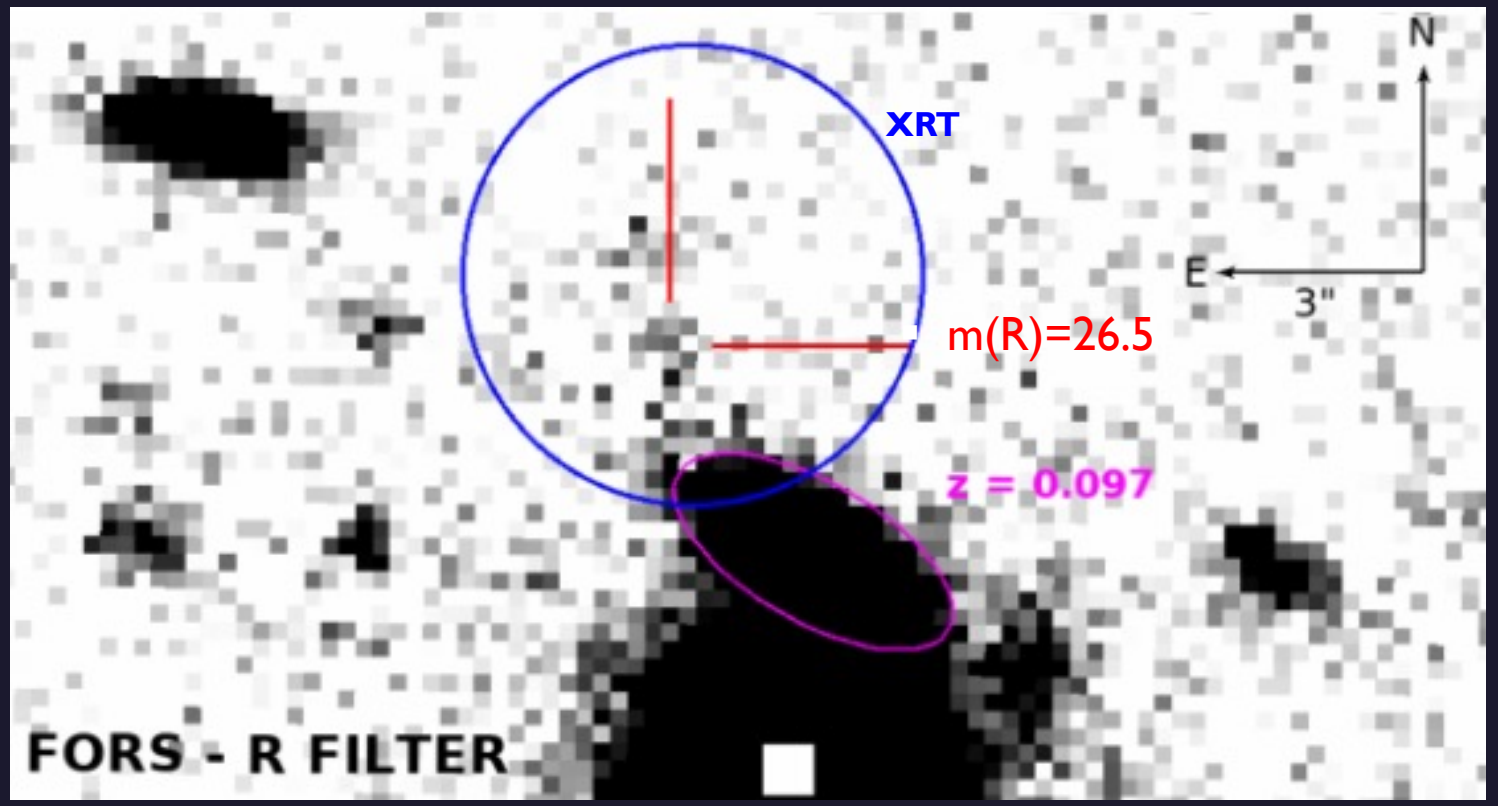
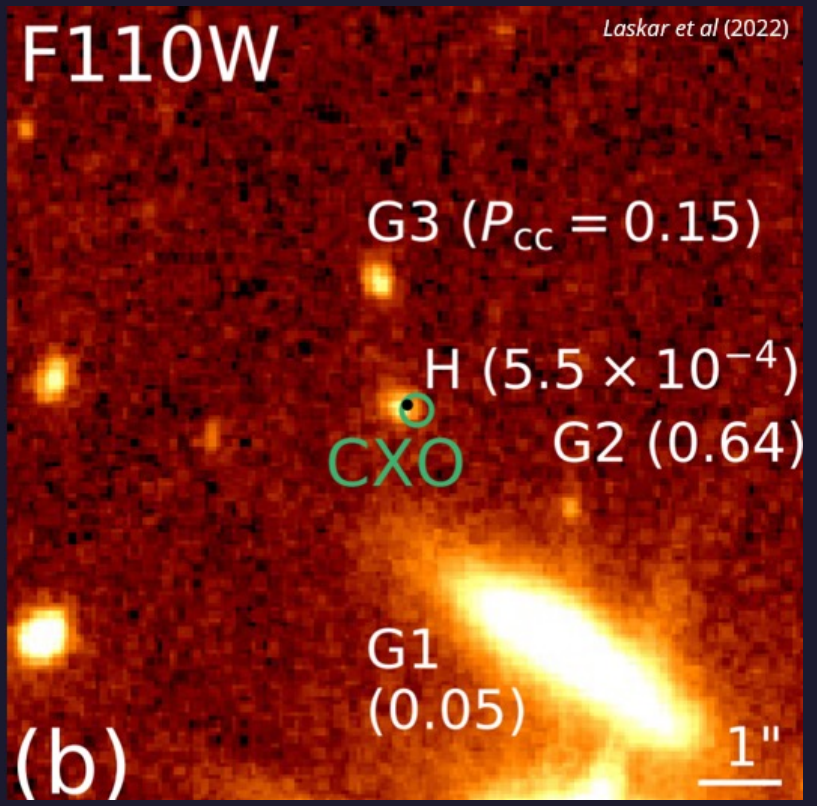


Afterglow search for GRB 211106A

Field observed with VLT/FORS2 (3 epochs, R filter):





- a constant source coincident with the one found by HST was spotted by PSF photometry. The claimed host galaxy! The ALMA afterglow detection is embedded inside the HST source

Afterglow search for GRB 211106A

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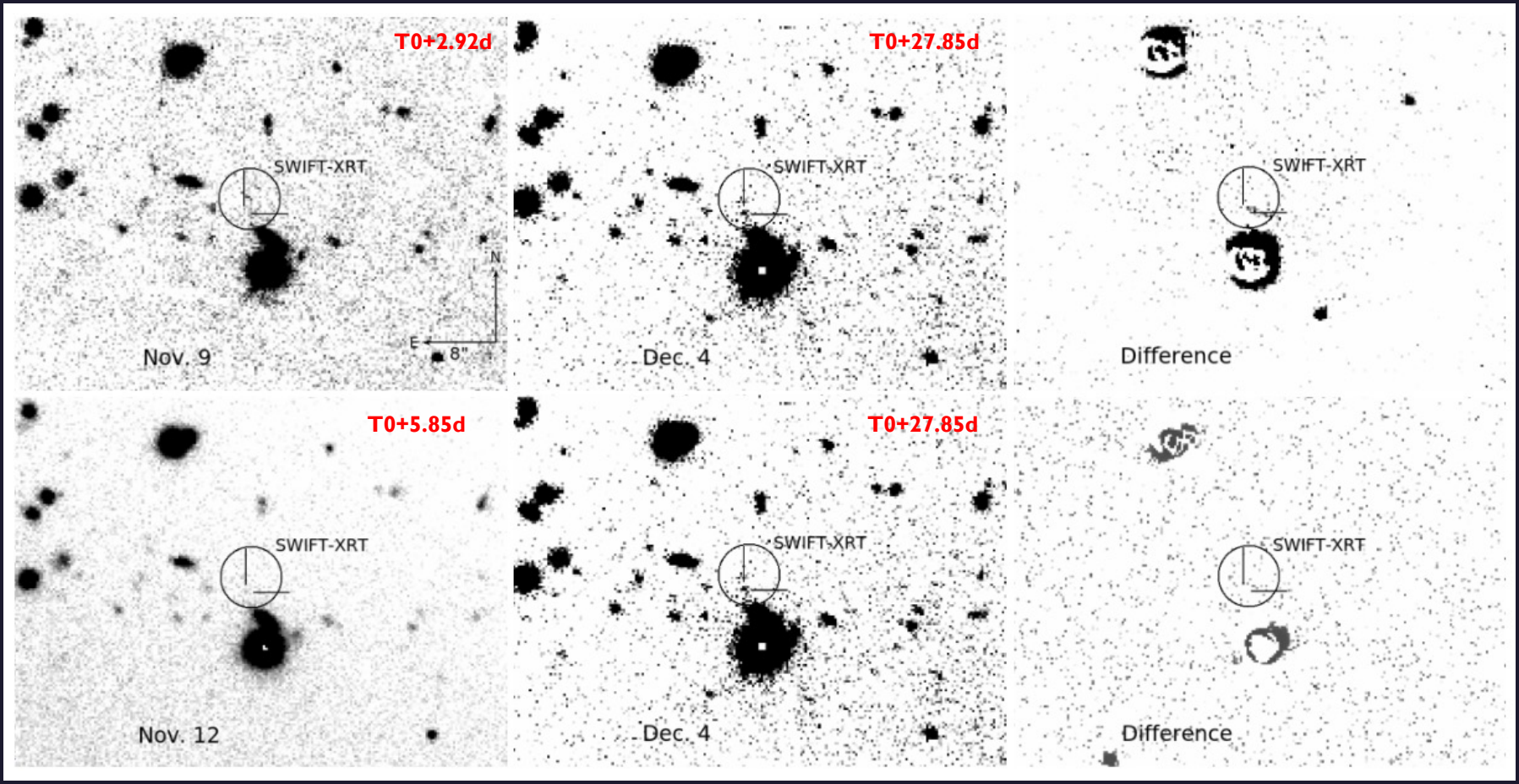
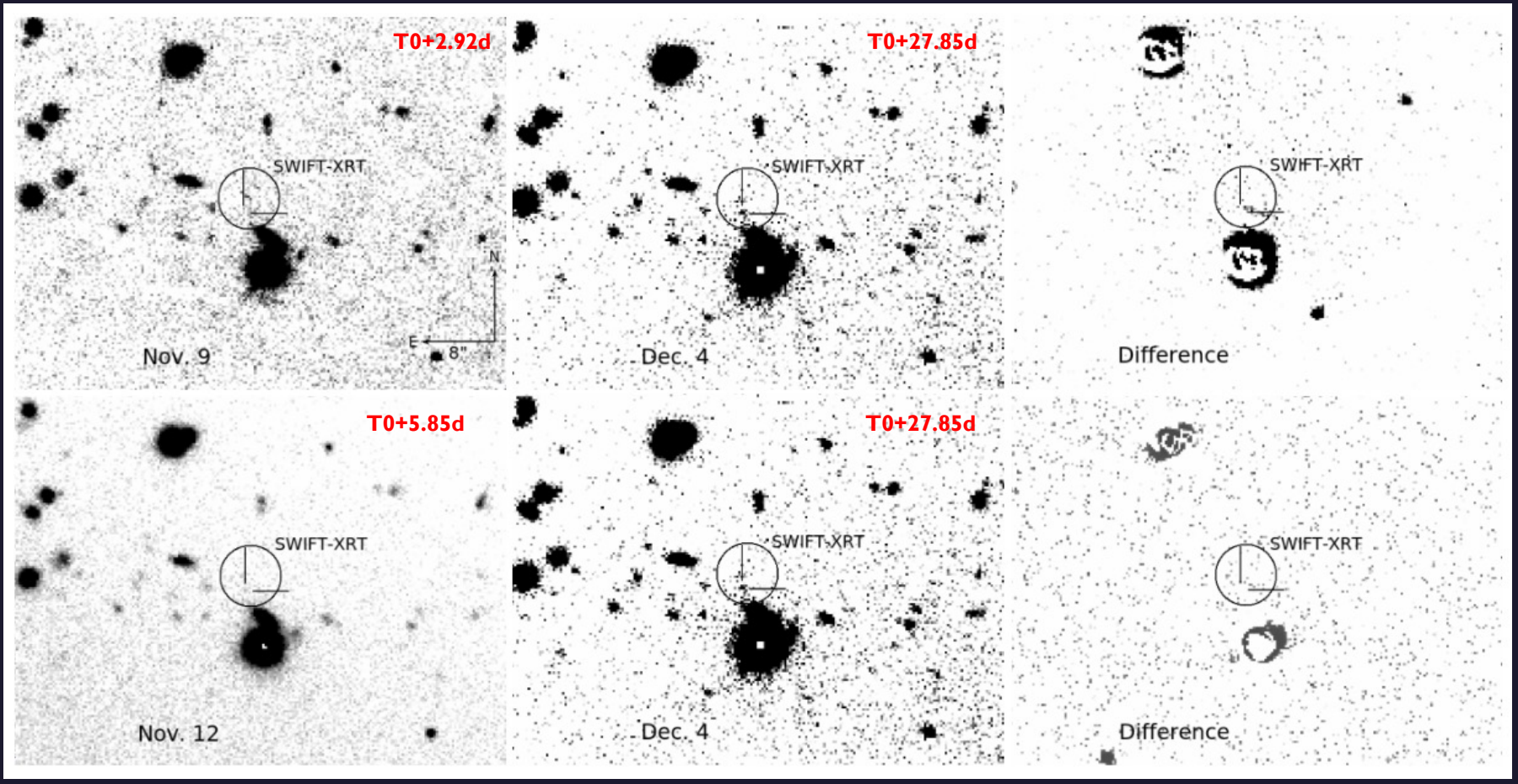


- In order to pinpoint a possible variation inside the source we performed two images subtraction (epoch 1-3 and 2-3): nothing was found at the source position both with object detection than with aperture photometry

Afterglow search for GRB 211106A

Field observed with VLT/FORS2 (3 epochs, R filter):

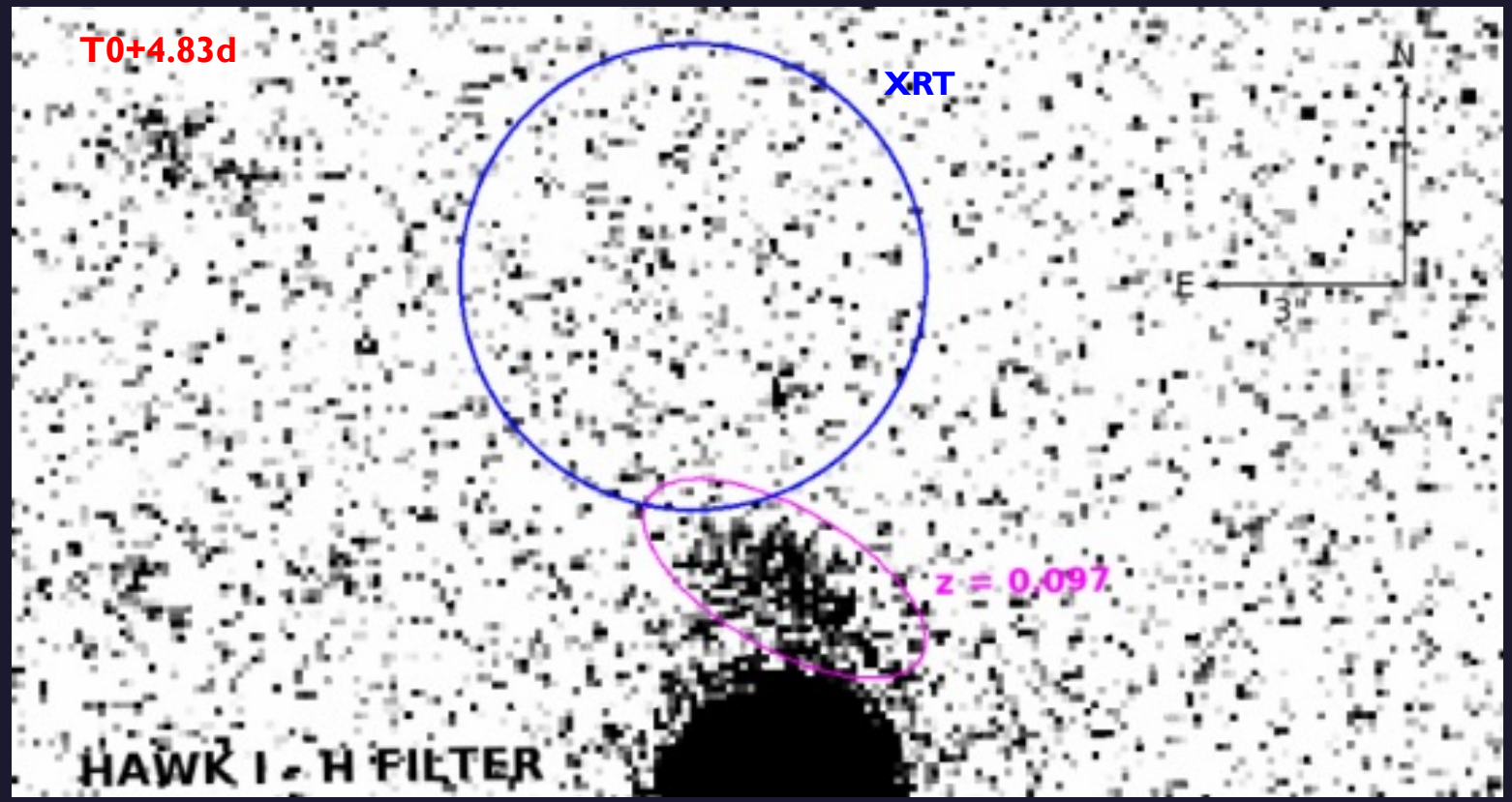


From images subtraction and PSF photometry we inferred the magnitude limit for the afterglow detection in the three epochs (AB system):

- $m_1(R)=26.7$
- $m_2(R)=26.8$
- $m_3(R)=26.6$

Afterglow search for GRB 211106A

Field observed with VLT/HAWKI (single epoch, H filter):



We carried out PSF photometry on the H band image:

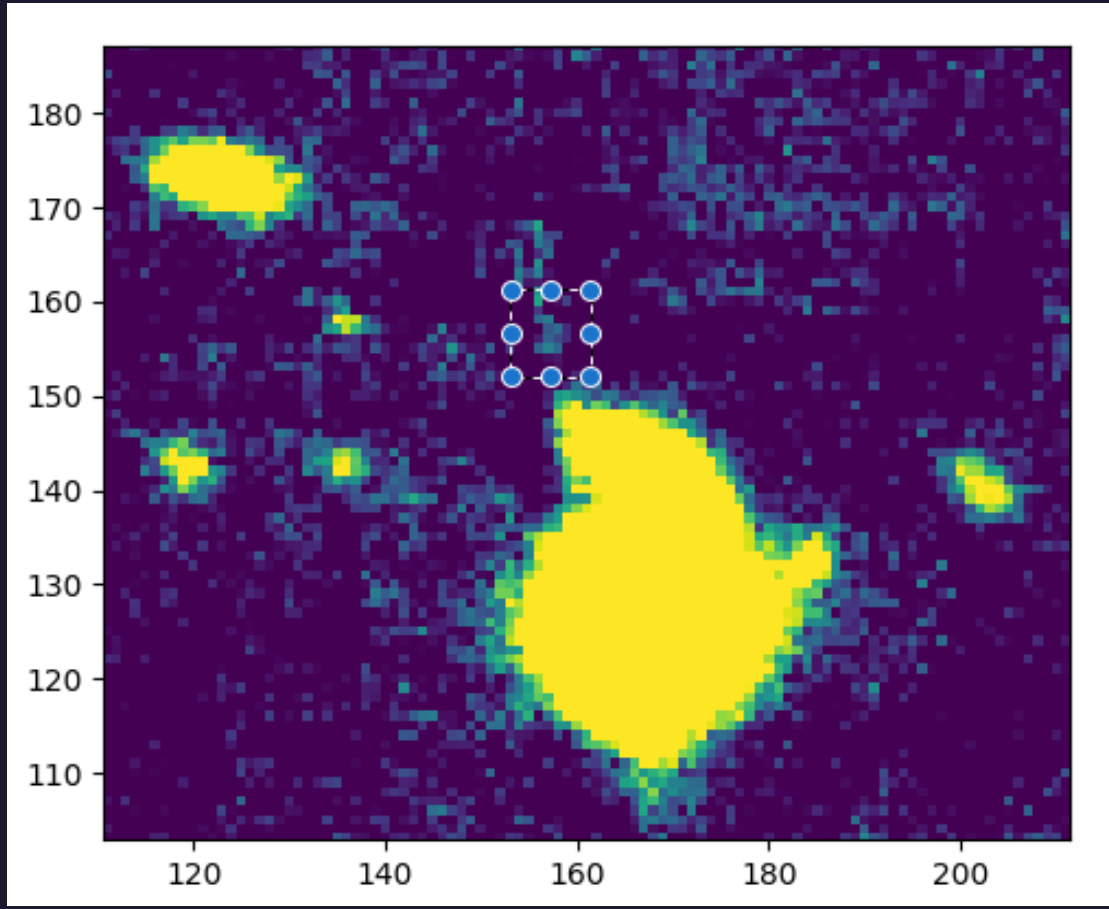
no credible objects were found with a position consistent with the HST-VLT/FORS2 detected source

From PSF photometry on the field a magnitude limit for the observation was computed (AB system):

- m(H)=23.58

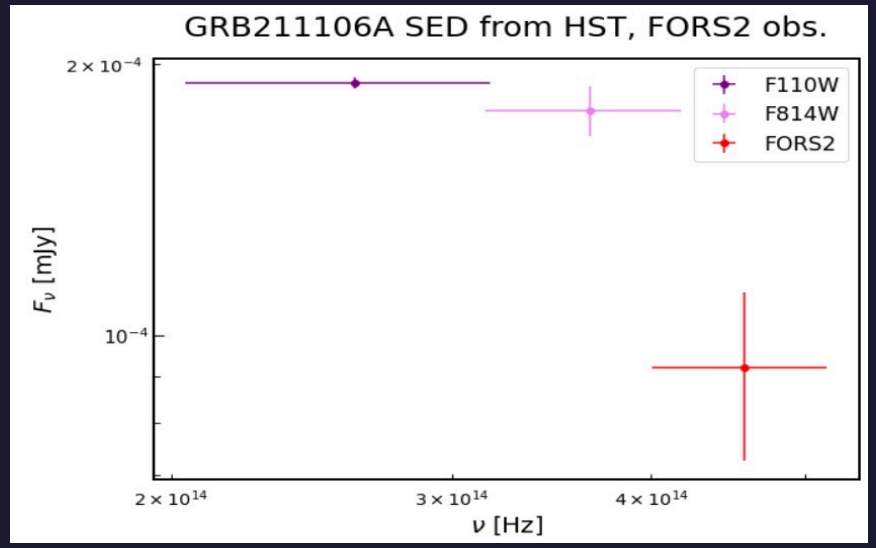
MUSE observation for GRB 211106A

Field observed with VLT/MUSE at T0+3.88d:



Combining VLT, HST and MUSE observations we got a photometric redshift estimation for the host galaxy detected in our R band images

This preliminary redshift was obtained from the modeling of the host SED consisting in our 3rd epoch R magnitude, the two HST magnitude (F814W/F110W) and two V and R magnitudes extracted from the MUSE observations

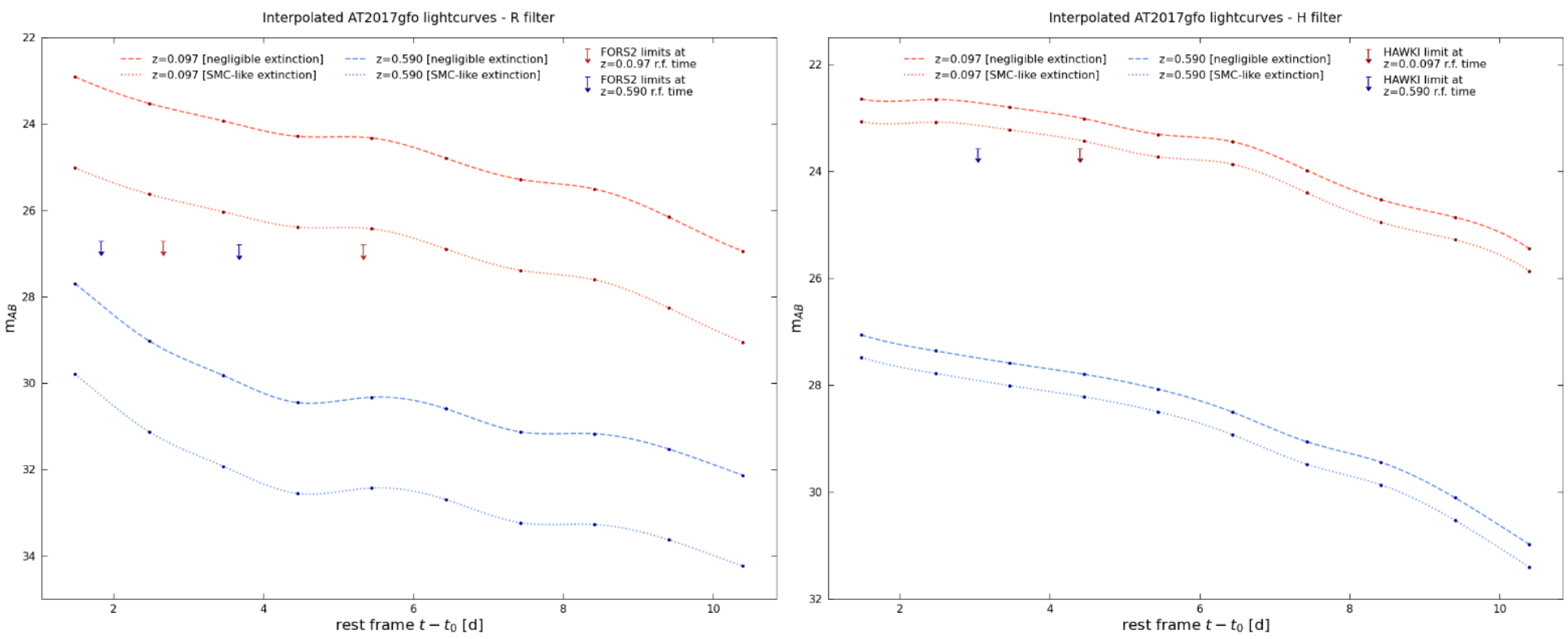


z_{ph}=0.59 [-0.12,+0.11]

kilonova search for GRB 211106A

- In order to investigate the features of the possible presence of a kilonova emission we built an AT2017gfo-like template light curve for both the R and the H band: light curves depend on the distance at which the template is placed, from ***Rossi et al. (2020)***

- We also included two opposite possibilities for the intrinsic galaxy extinction to be accounted in the magnitude light curves: a negligible absorption and a SMC-like extinction model with A_V=2.6, claimed as a lower limit by ***Laskar et al.* (2022)** from the lack of optical afterglow detection coupled with the bright millimeter counterpart



→ at z=0.097 all the magnitudes would have been above our limits!

Instead for the photometric redshift z=0.59 an AT2017gfo-like event is clearly undetectable

Host galaxy redshift for GRB 211106A

As seen from kilonova templates the redshift of HST-FORS2/VLT host galaxy (P_{ch}<1%) is most likely farther than z=0.097: we found that a Kilonova AT2017gfo-like should have been undetectable in all our observations for z>0.39 (unabsorbed) and z>0.15 (A_V=2.6 SMC-like galaxy extinction)

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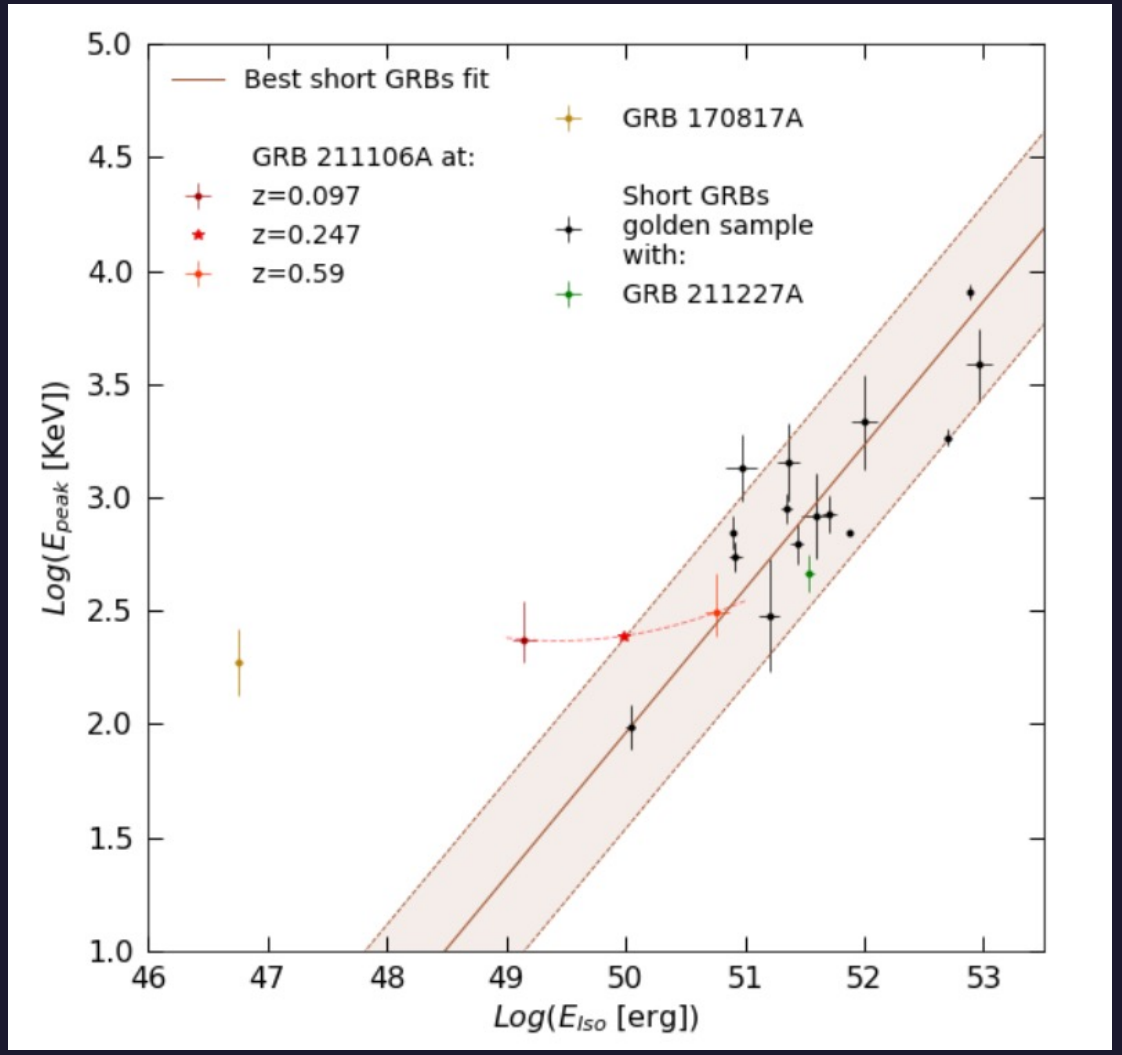
In order to strengthen this hypotesis we also explored the consistency of GRB 211106A, placed at increasing values of redshift, with the **Short Amati relation** obtained using the SBAT4 sample (***D'Avanzo et al., 2014***):

- The burst becomes consistent with the dispersion of the sample around the best fit for z>0.25

All the found limits are well consistent with the photometric redshift!



Summary on GRB 211106A

- We analyzed the three VLT/FORS2 and the one HAWKI images: we did not detected any variability in the XRT and Chandra error circle, but we spotted the probable host galaxy in the R-band images

- We coinstrained the presence of the optical and infrared afterglow (or kilonova presence) for our observartions, down to ~26.6 and ~23.6 respectively in R and H filters

- We found different lower limits (more than twice the first claimed redshift) for the unknown redshift of the host galaxy, both trough kilonova templates and with the consistency with the investigated *Short Amati relation*

  → These proofs are in agreement with the photometric redshift $z_{ph}=0.59$ [-0.12,+0.11]

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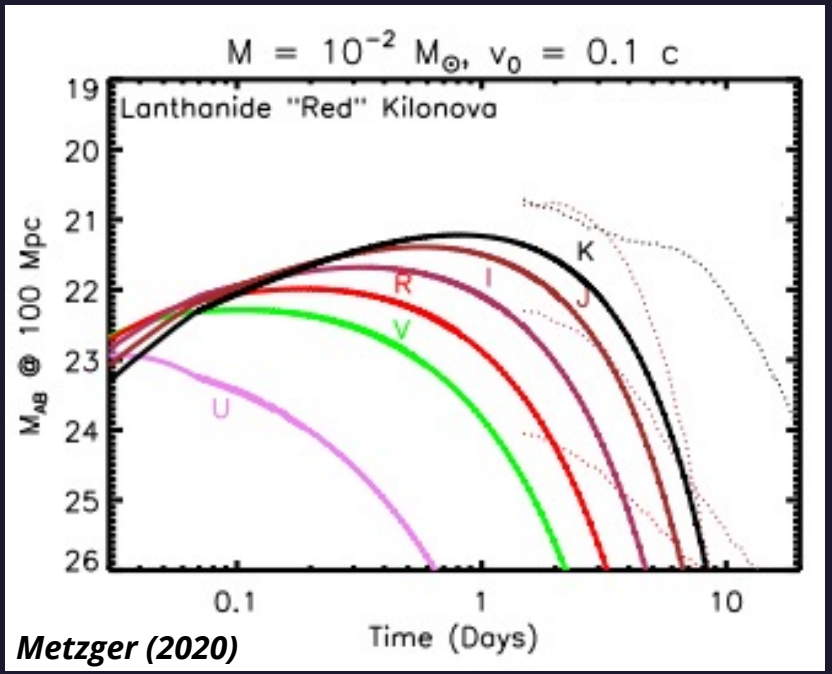
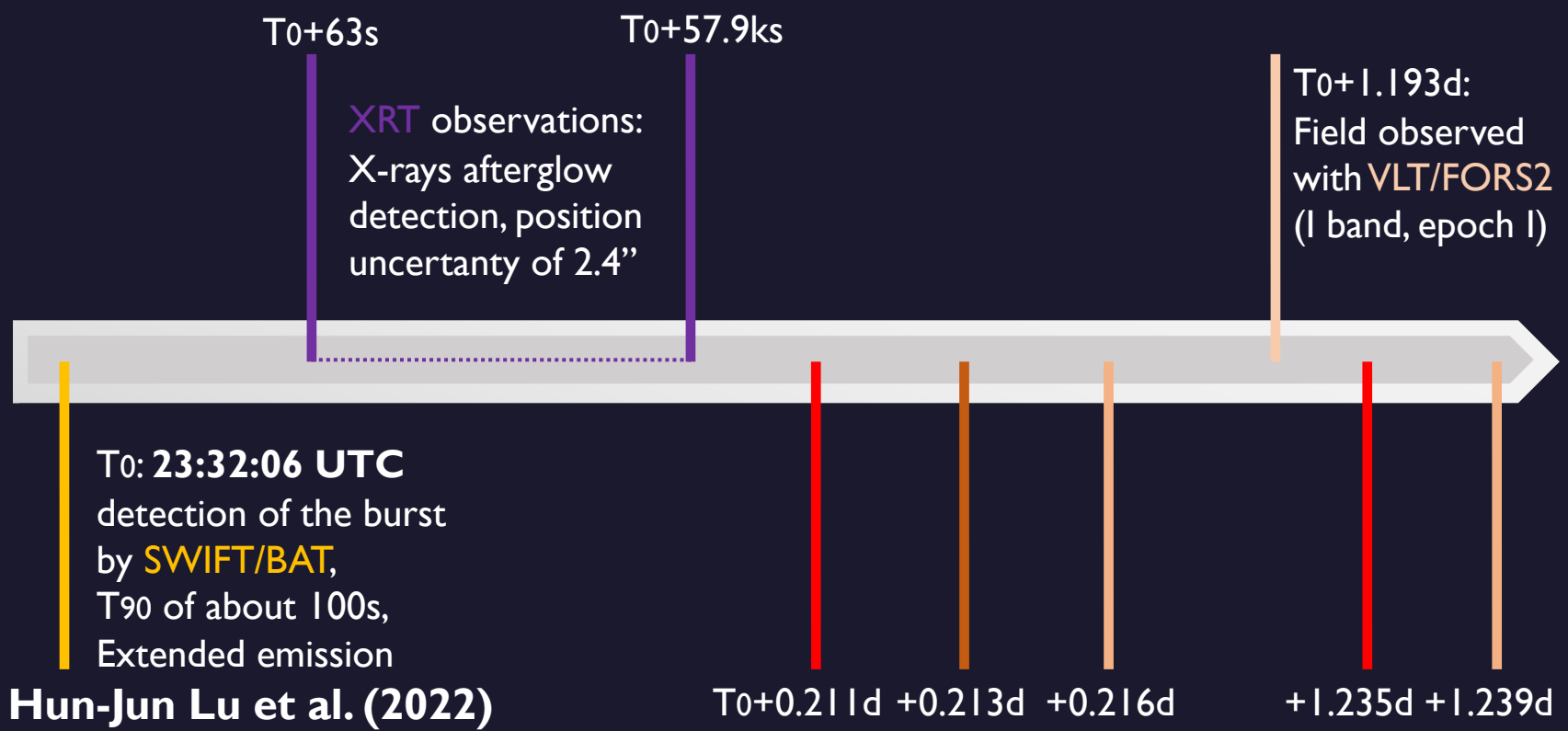
More to do:

- Test our photometric limits vs. Kilonova emission models different from AT2017gfo (only "red kilonova", Fall back accretion…)

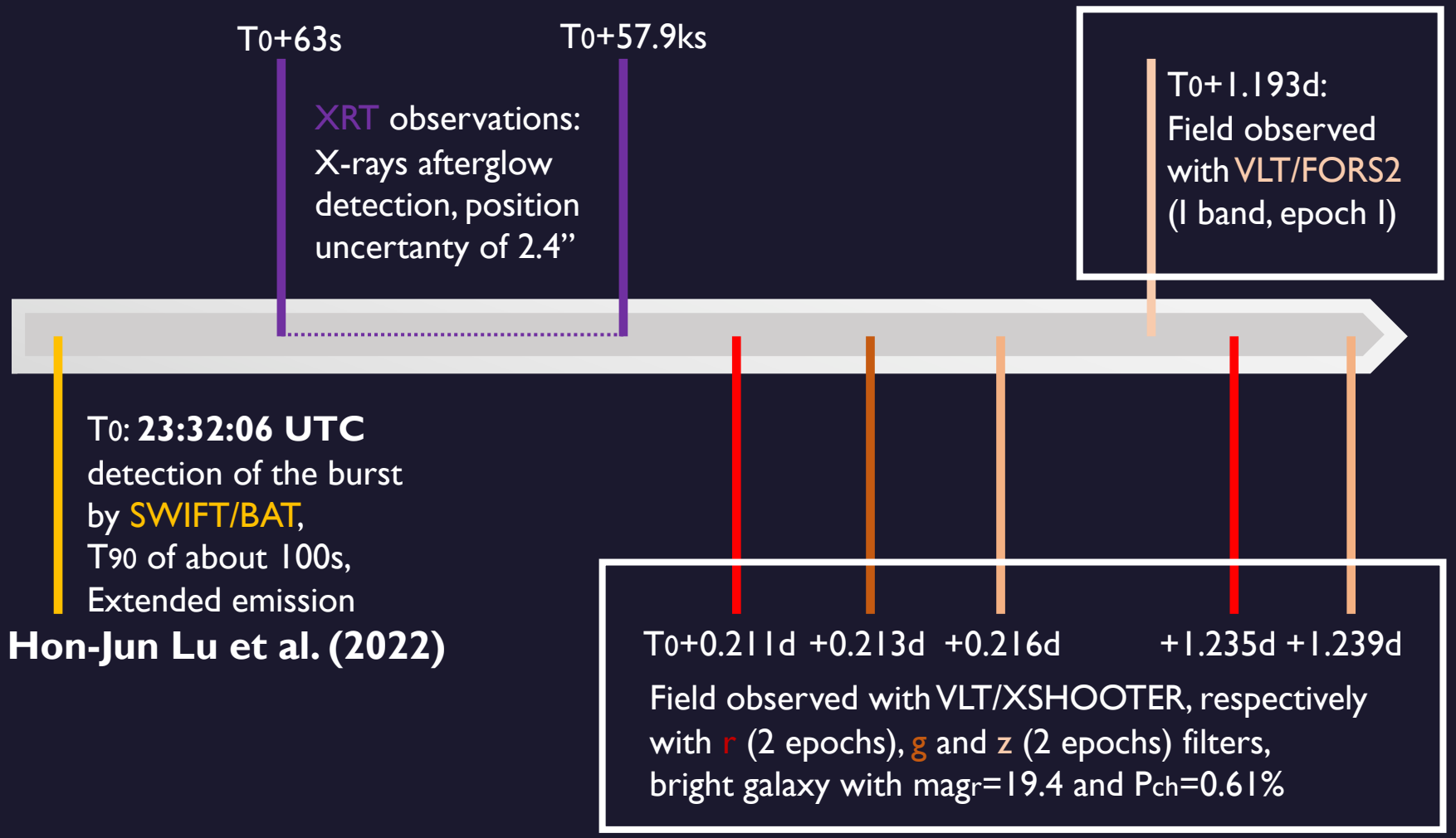


Metzger (2020)

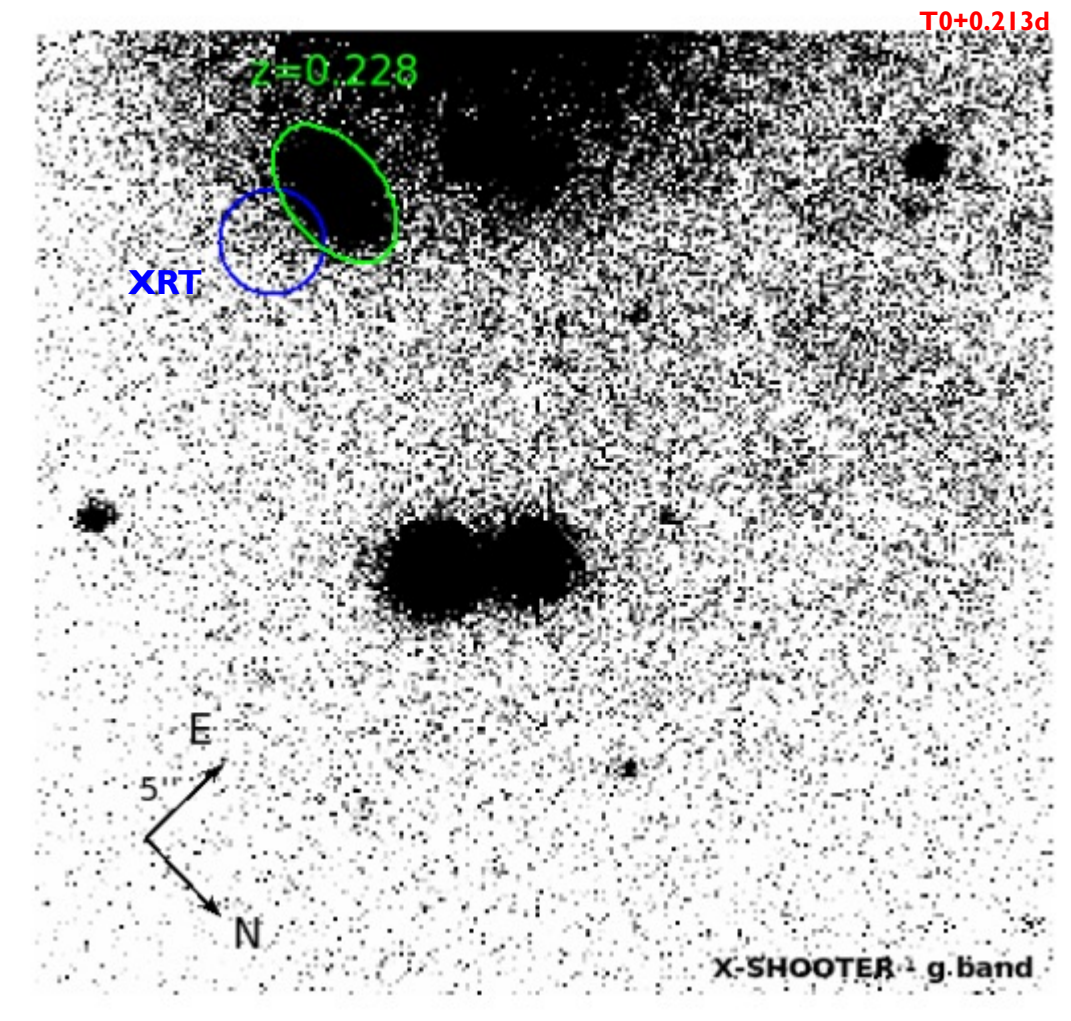
Timeline: GRB 211227A



Timeline: GRB 211227A



GRB 211227A: afterglow search



We analyzed the I band FORS2 observation and all 5 X-SHOOTER images (2 r epochs, 2 z epochs and a g filter epochs)

We performed PSF photometry on the field of GRB 211227A but no credible source was found inside the XRT error circle in all the images down to (AB system):

- $m_1(r)=25.36$ [T0+0.211d]
- $m_1(g)=25.44$ [T0+0.213d]
- $m_1(z)=24.80$ [T0+0.216d]
- $m_2(I)=25.80$ [T0+1.193d]
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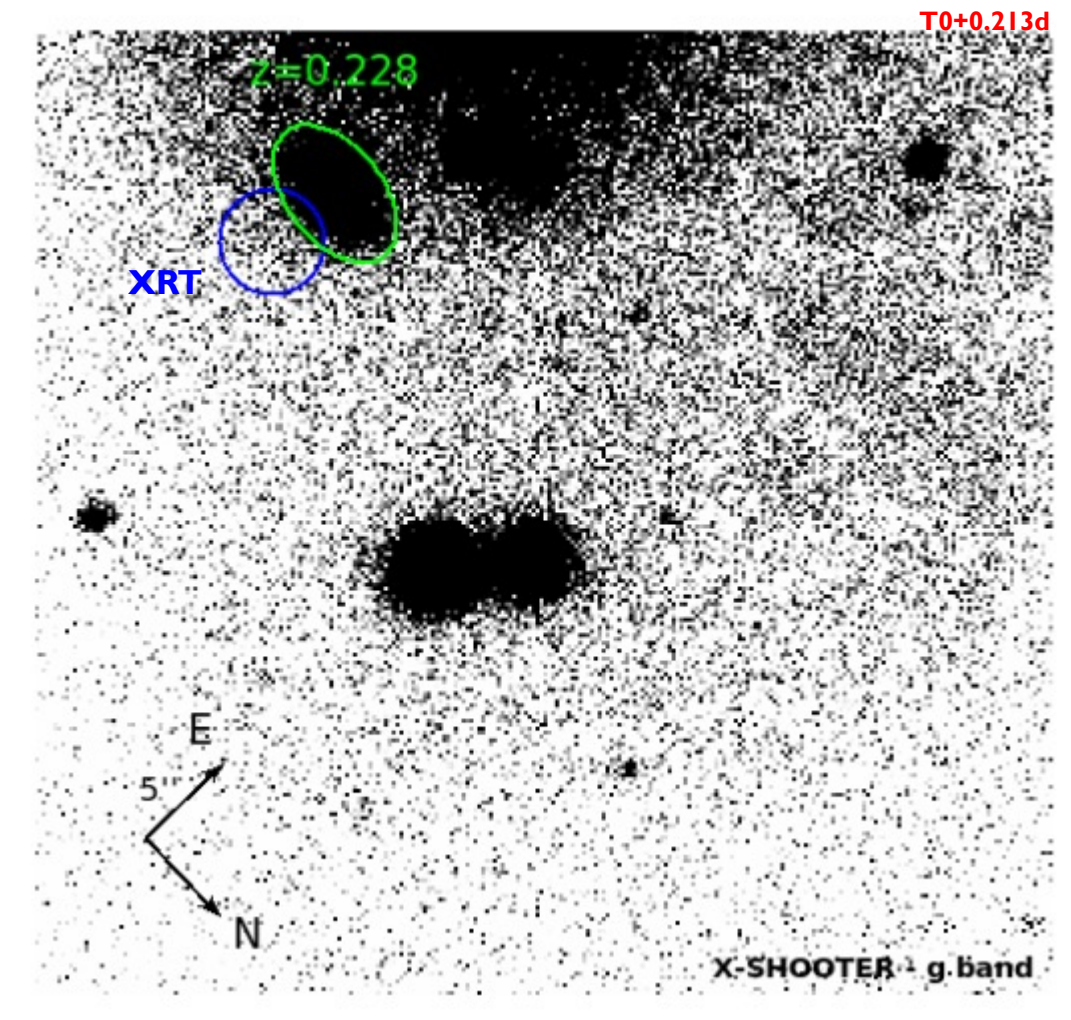

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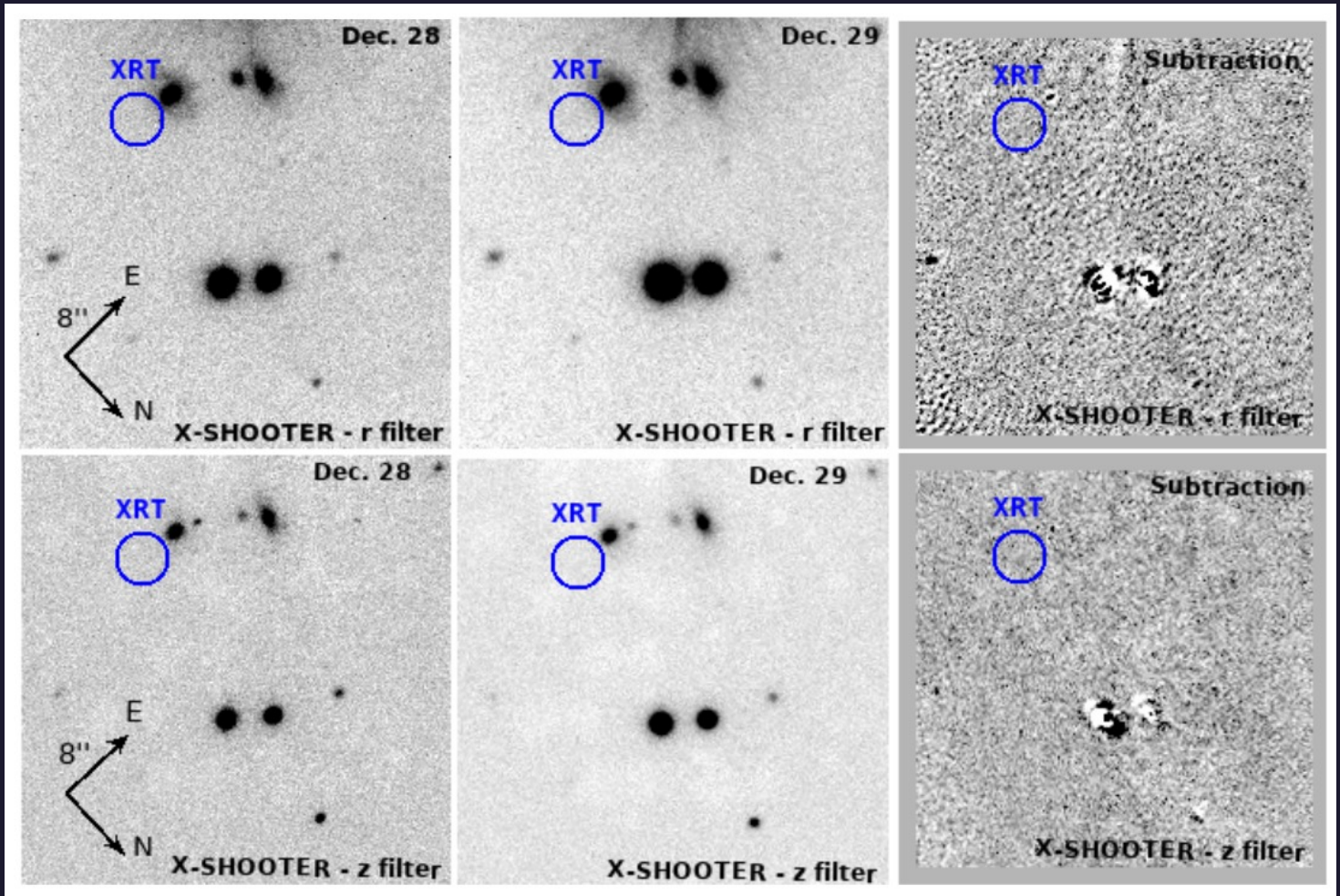
Nearby galaxy (distance of 3.66") at z=0.228 as reported by ***Malesani et al.* (2021, GCN #31324)** → We computed a $P_{ch}=0.006$

GRB 211227A: afterglow search



For the afterglow search, we performed image subtraction for the two epochs in the r and z filter in order to confidently rule out the presence of variable sources inside the XRT error circle

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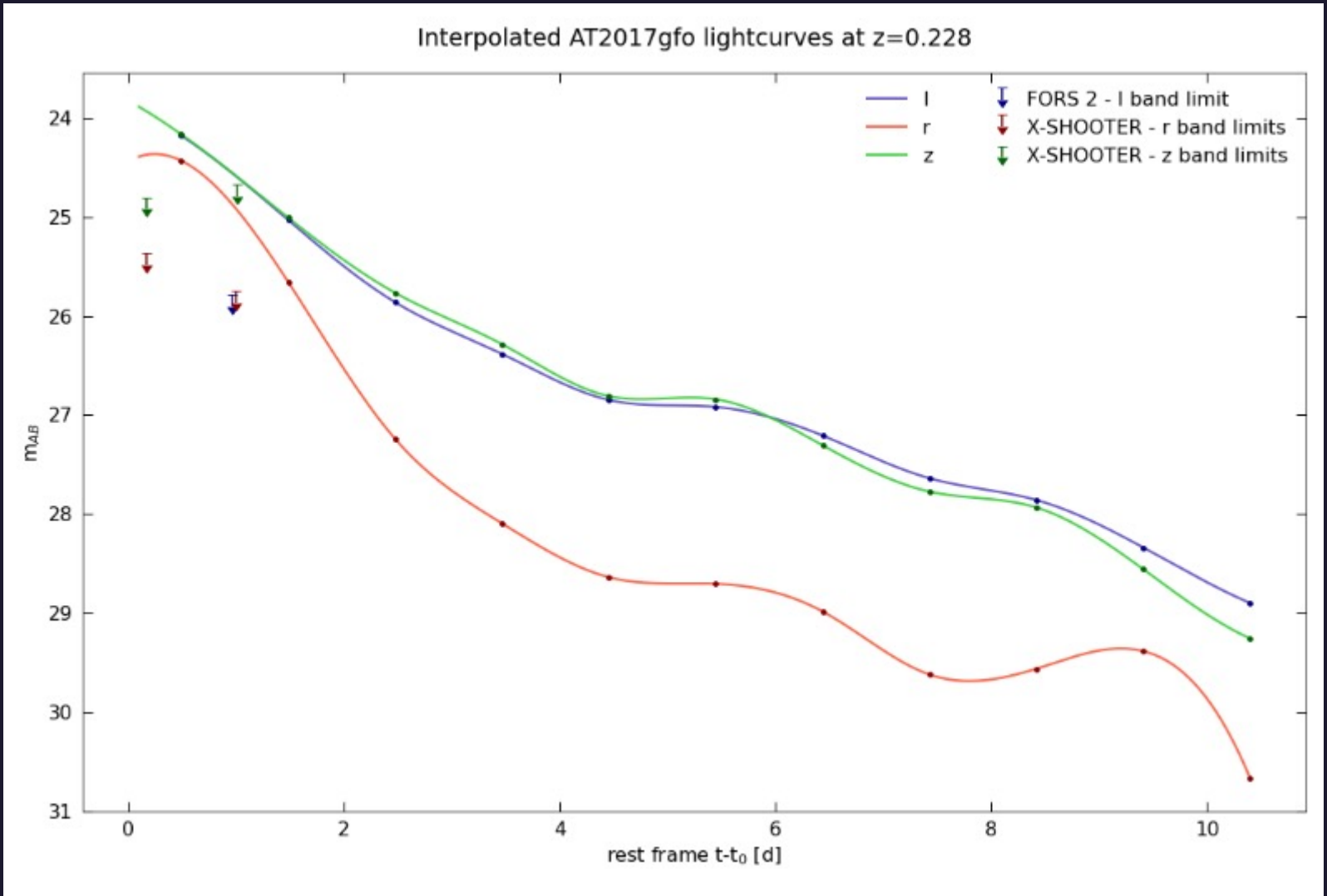
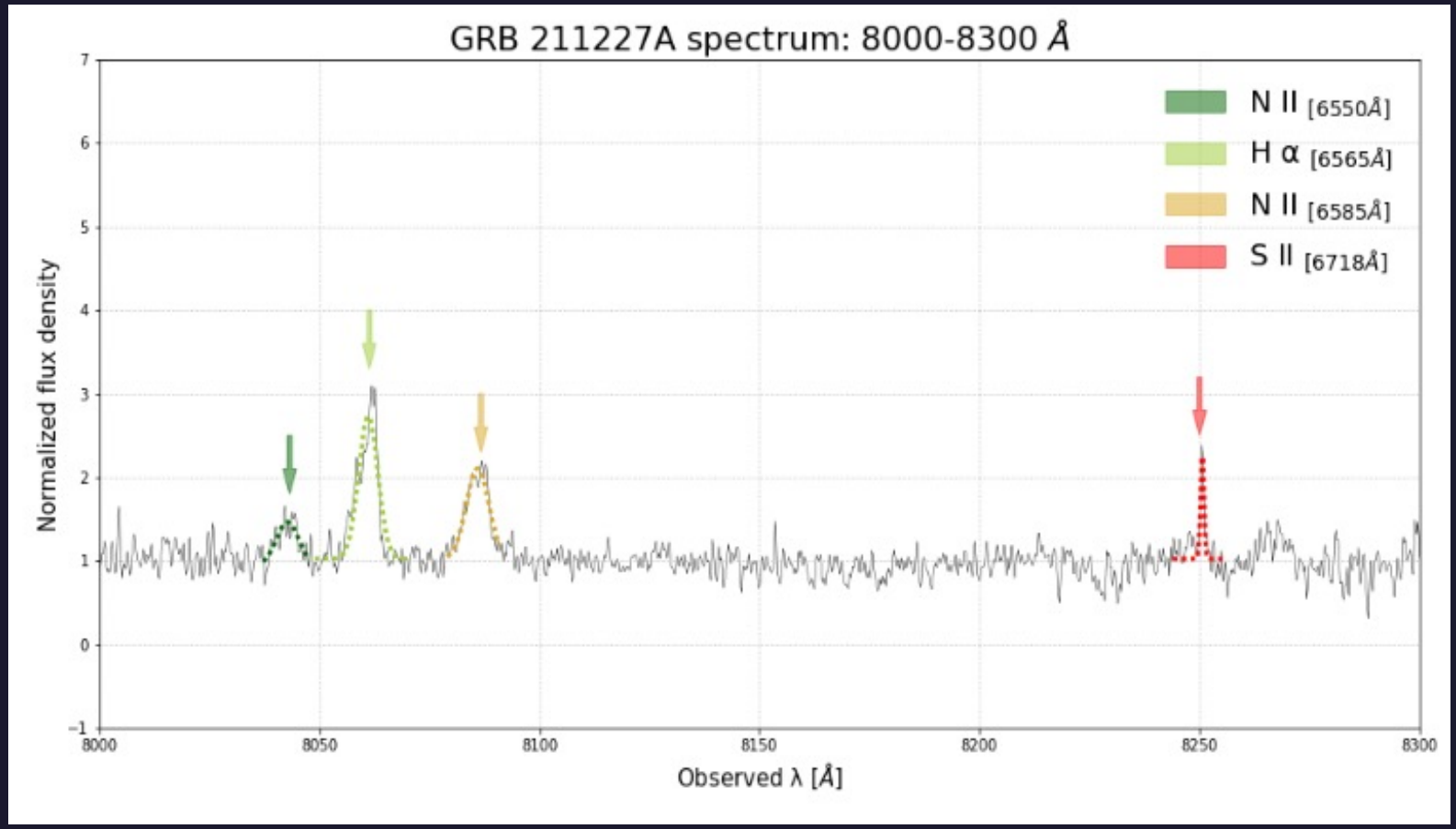
GRB 211227A: kilonova search



In a similar way to what we did for GRB 211106A we compared the limit in our 5 VLT/X-SHOOTER and VLT/FORS2 observations with the the AT2017gfo template, placed at z=0.228, no intrinsic extinction was considered.

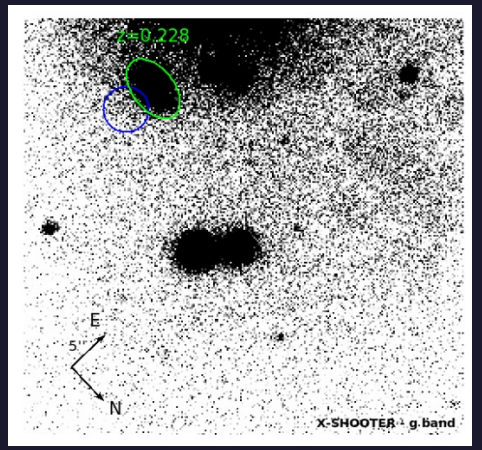
Given the confidence of the the host galaxy association in this case (P_{ch}<1%) it is clear that an AT2017gfo-like event should have been clearly visible at our early-time epochs (~0.2 d and ~1.2 d after T_0)

GRB 211227A: Host galaxy spectrum



We reduced and investigated the spectrum of the presented host galaxy taken at T0+0.233d with X-SHOOTER

We were able to estimate the luminosity of several emission lines and we computed a preliminary slit losses correction of ~2.75. We also confirmed the redshift reported by ***Malesani et al.* (2021, GCN #31324)**: z=0.228



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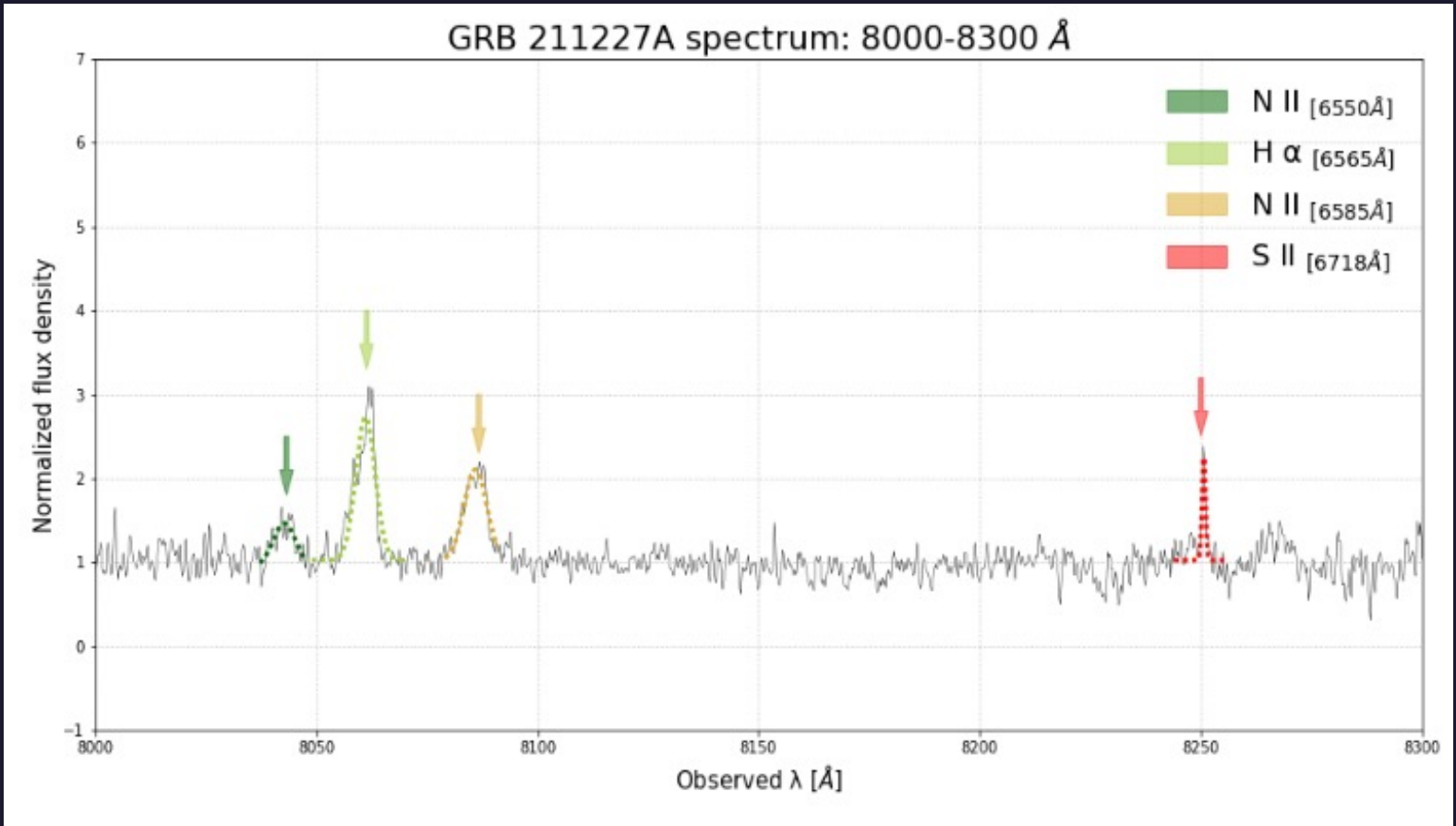

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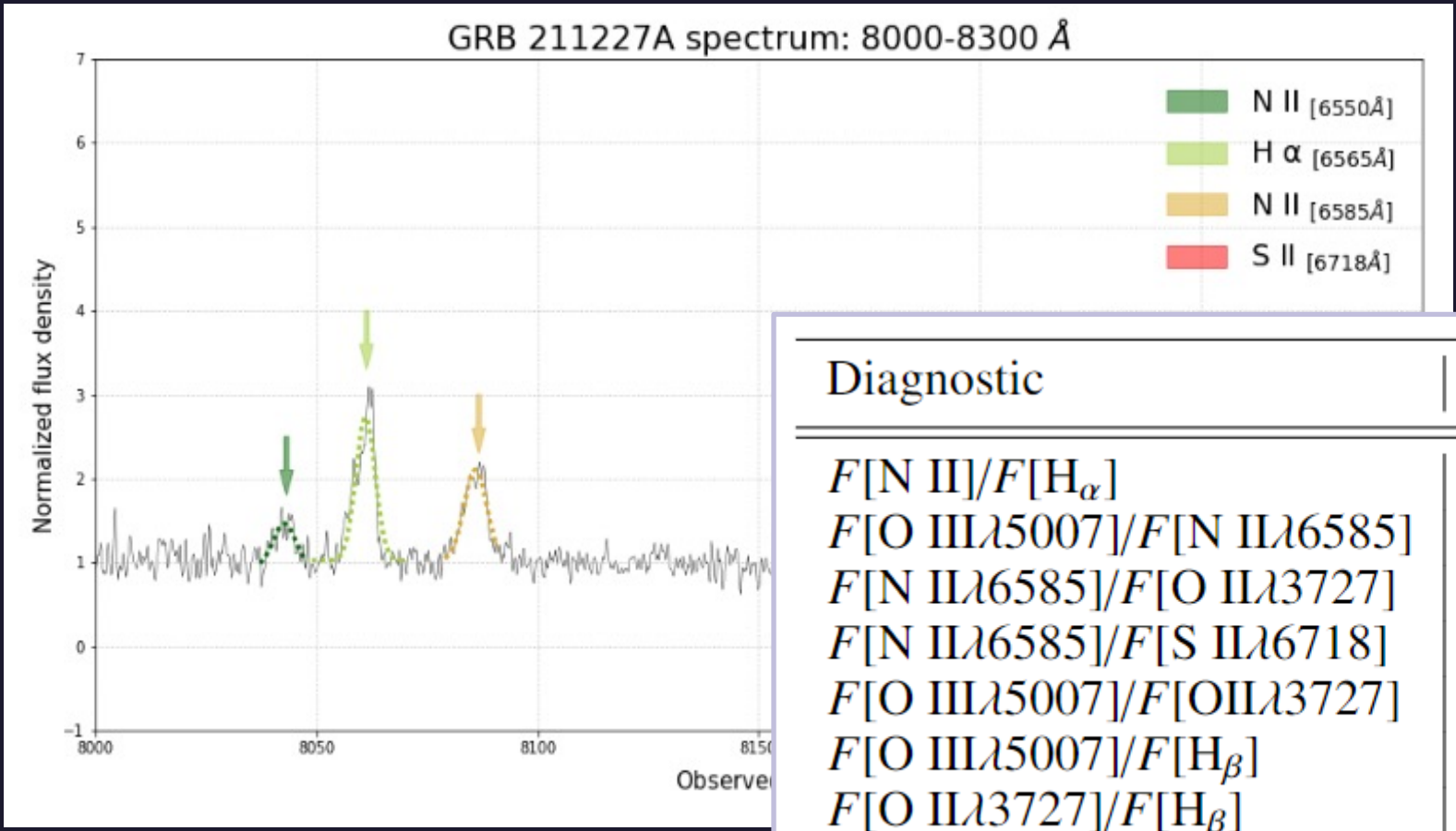
From [O II] and Hα we got two values for the stellar formation rate (SFR), following **Kennicutt (1998)**:

- SFR(Hα)=0.484±0.041 (M_{sun}/yr)
- SFR([O II])=0.344±0.011 (M_{sun}/yr)

Consistent at 3σ level

GRB 211227A: Host galaxy spectrum

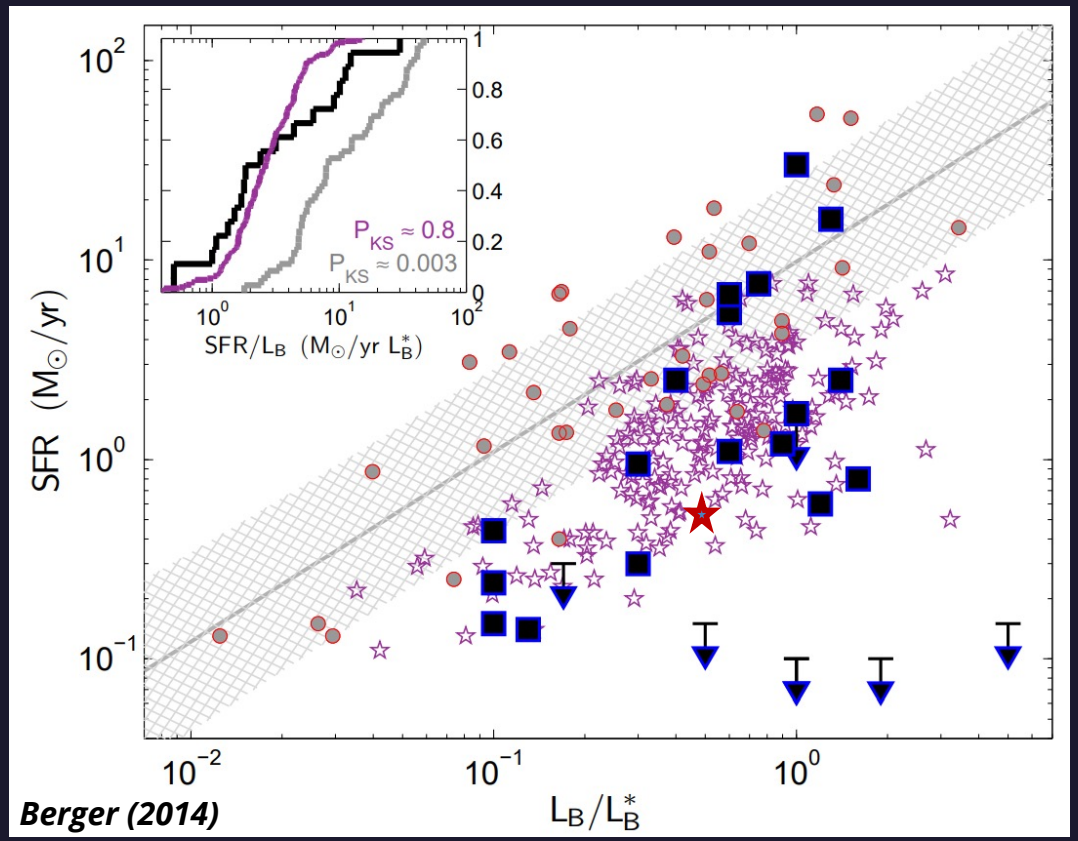


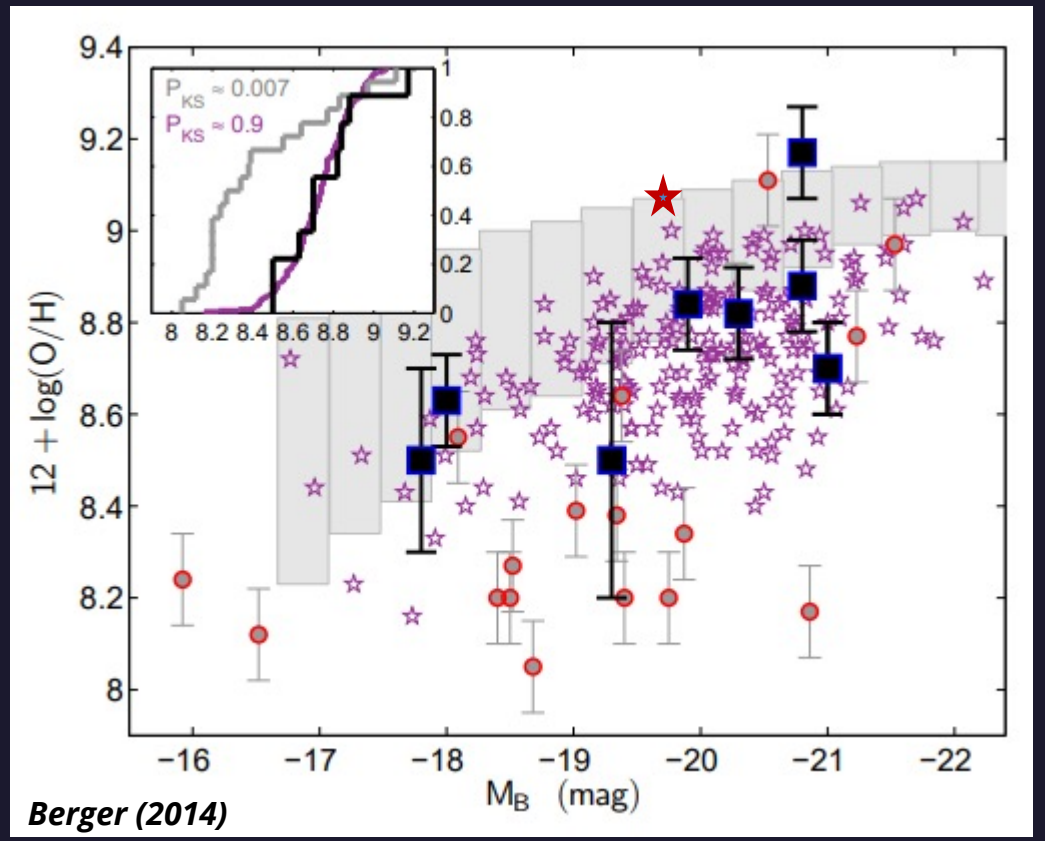
From **Nagao et al. (2006)** we evaluated the metallicity of the galaxy from different commonly used metallicity indicators, derived from emission line fluxes:

Diagnostic	Value	12 + log(O/H)
F[N II]/F[H$_\alpha$]	0.74±0.05	>9.25
F[O IIIλ5007]/F[N IIλ6585]	0.14±0.04	9.24[-0.06,+0.05]
F[N IIλ6585]/F[O IIλ3727]	0.93±0.09	9.17[-0.02,+0.02]
F[N IIλ6585]/F[S IIλ6718]	6.20±0.89	>9.25
F[O IIIλ5007]/F[OIIλ3727]	0.13±0.03	9.18[-0.10,+0.09]
F[O IIIλ5007]/F[H$_\beta$]	0.43±0.14	9.01[-0.08,+0.07]
F[O IIλ3727]/F[H$_\beta$]	3.32±0.77	8.74[-0.15,+0.18]

GRB 211227A: Host galaxy spectrum

We derived the B band rest frame magnitude of the host galaxy m_B=-19.95 from which we computed a B band luminosity L_B=0.55L_B^*, where L_B^* is the average rest frame luminosity of field galaxies





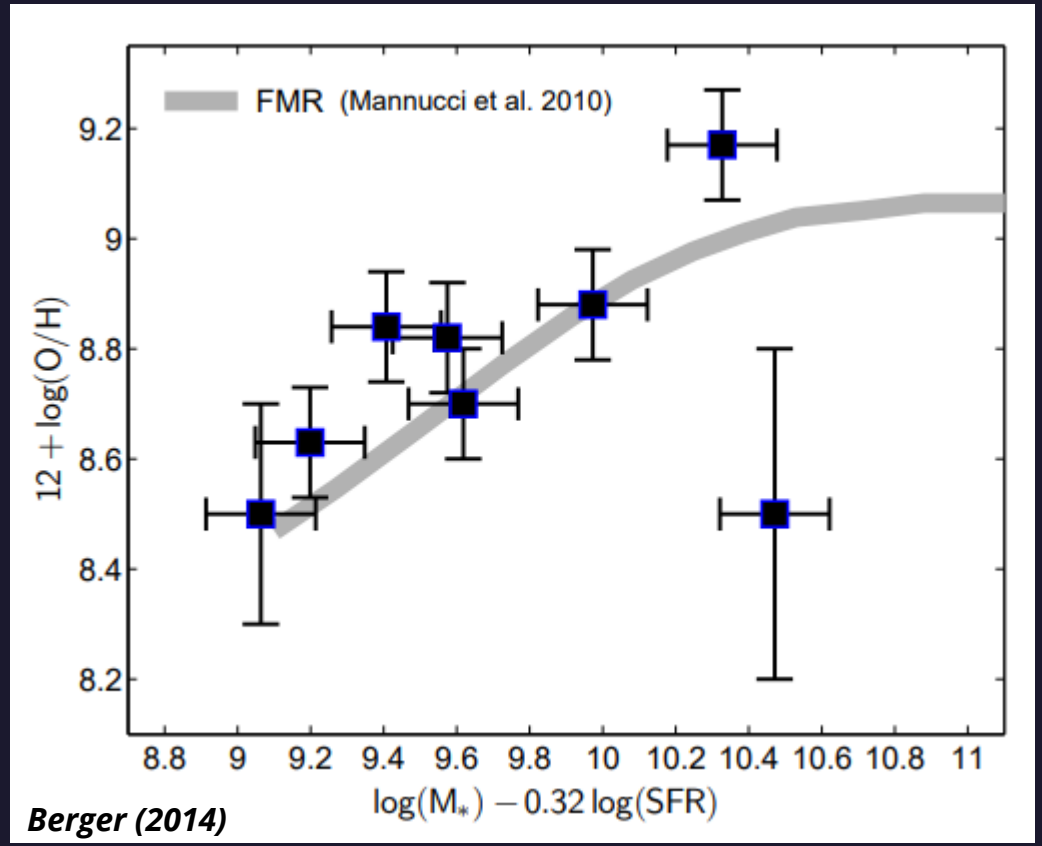
From our preliminar analysis given the two values of SFR, L_B/L_B^*, m_B and a mean metallicity of ~9.07 we have a relatively low SFR and high metallicity

GRB 211227A: more work to do

- For what concerns the kilonova investigation for this burst it becomes relevant to take into account different Kilonova emission model and/or a contribution from intrinsic extinction to explain the Kilonova non-detection at the given redshift: for instance an extinction of A_I=1.22 would have made the kilonova undetectable in the FORS2 image

- Our optical and infrared magnitude limits don't completely exclude a farther and fainter host galaxy, as in the case of GRB 211106A. It will be therefore important to constrain with more precision the host parameters. However, the first check on the properties of the candidate suggests that they are consistent with those of short GRBs hosts

- We aim at obtaining a more complete characterization of the host galaxy candidate by estimating its mass. This will enable, e.g., to check for its consistency with the Fundamental Metallicity Relation



Berger (2014)

THANKS FOR YOUR ATTENTION