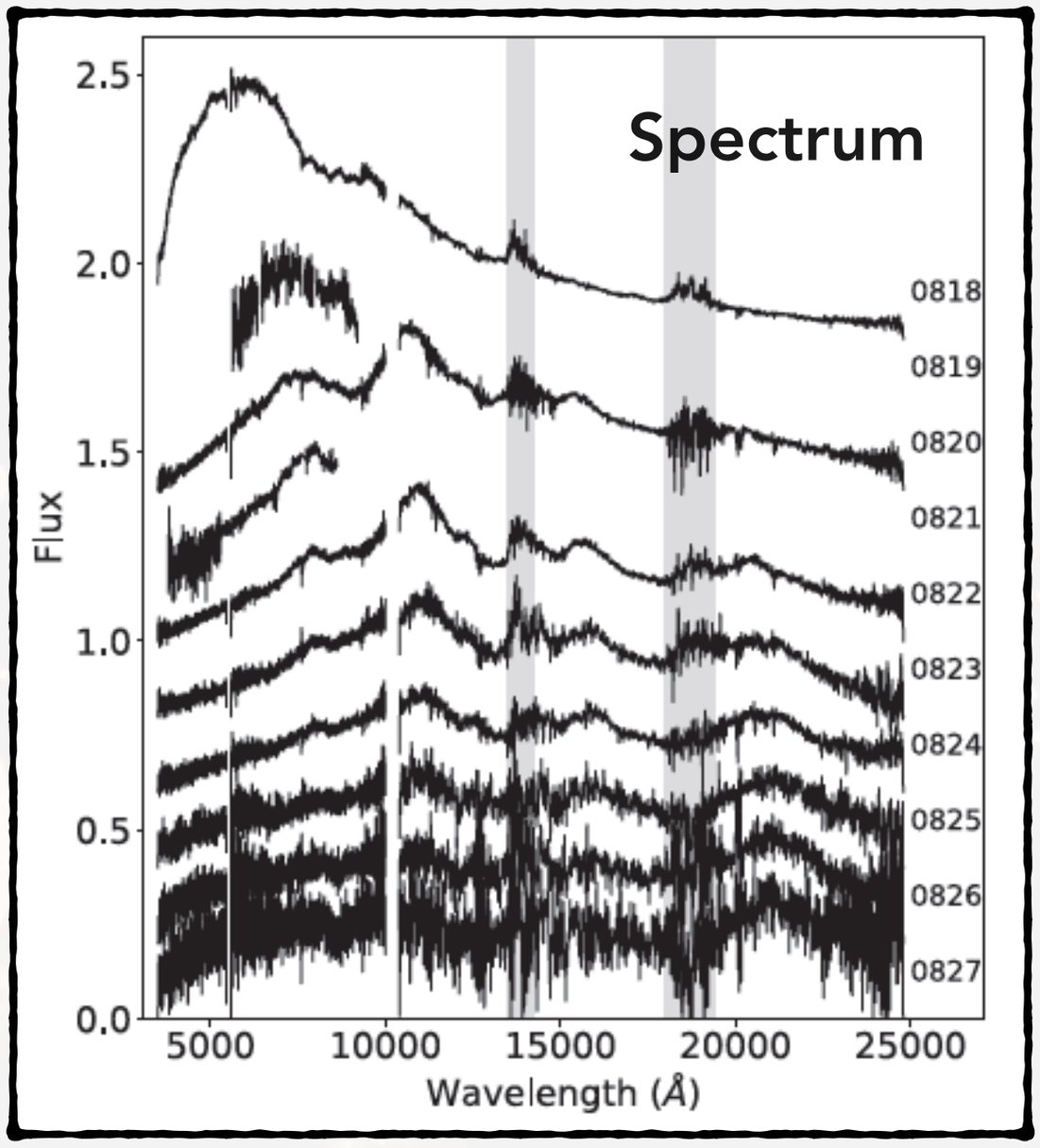
Prédiction et suivi des signaux multi-messagers : O4 et ngravé

S.D. Vergani

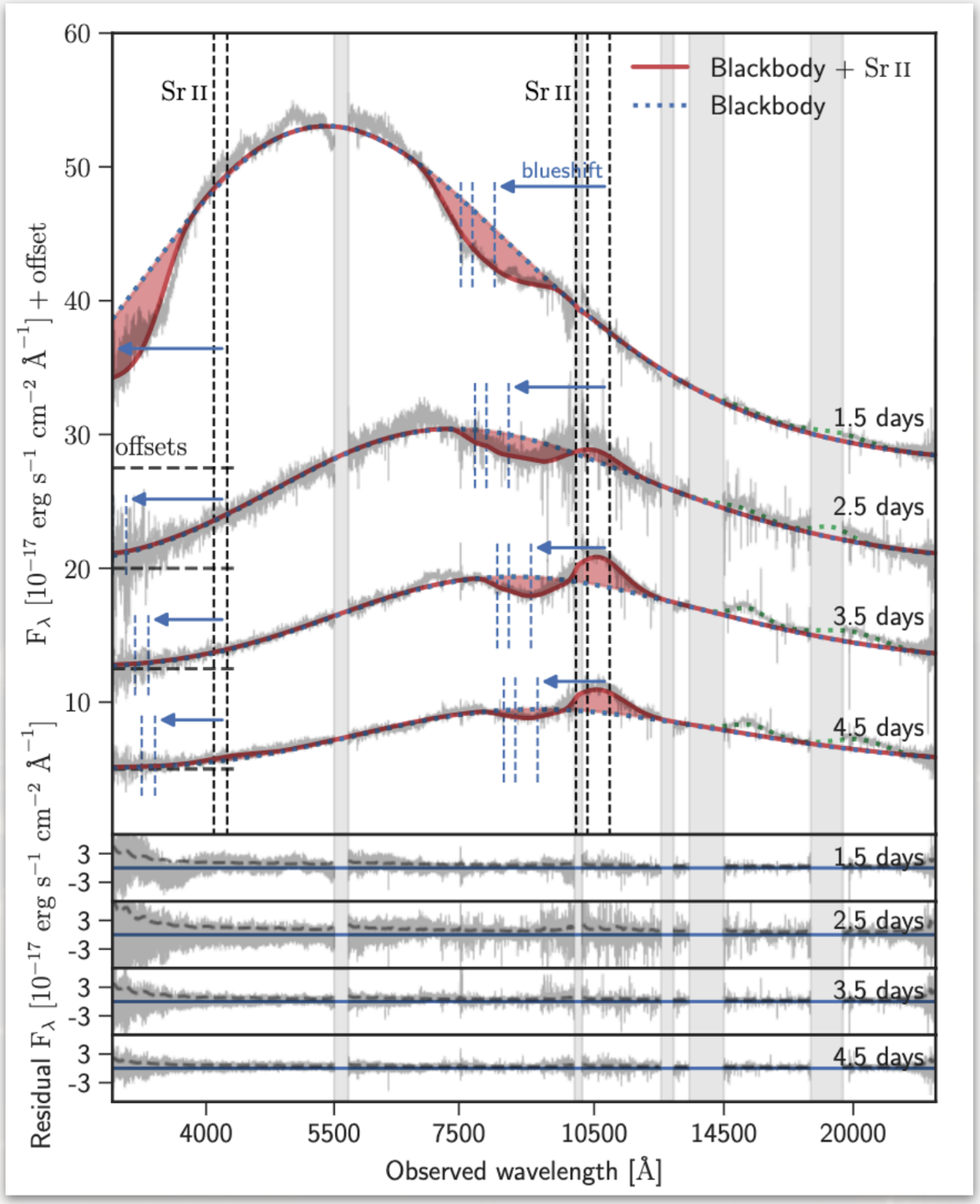
GW170817 results & open questions

Kilonova

ESO-VLT/X-Shooter Pian et al. 2017, Nature

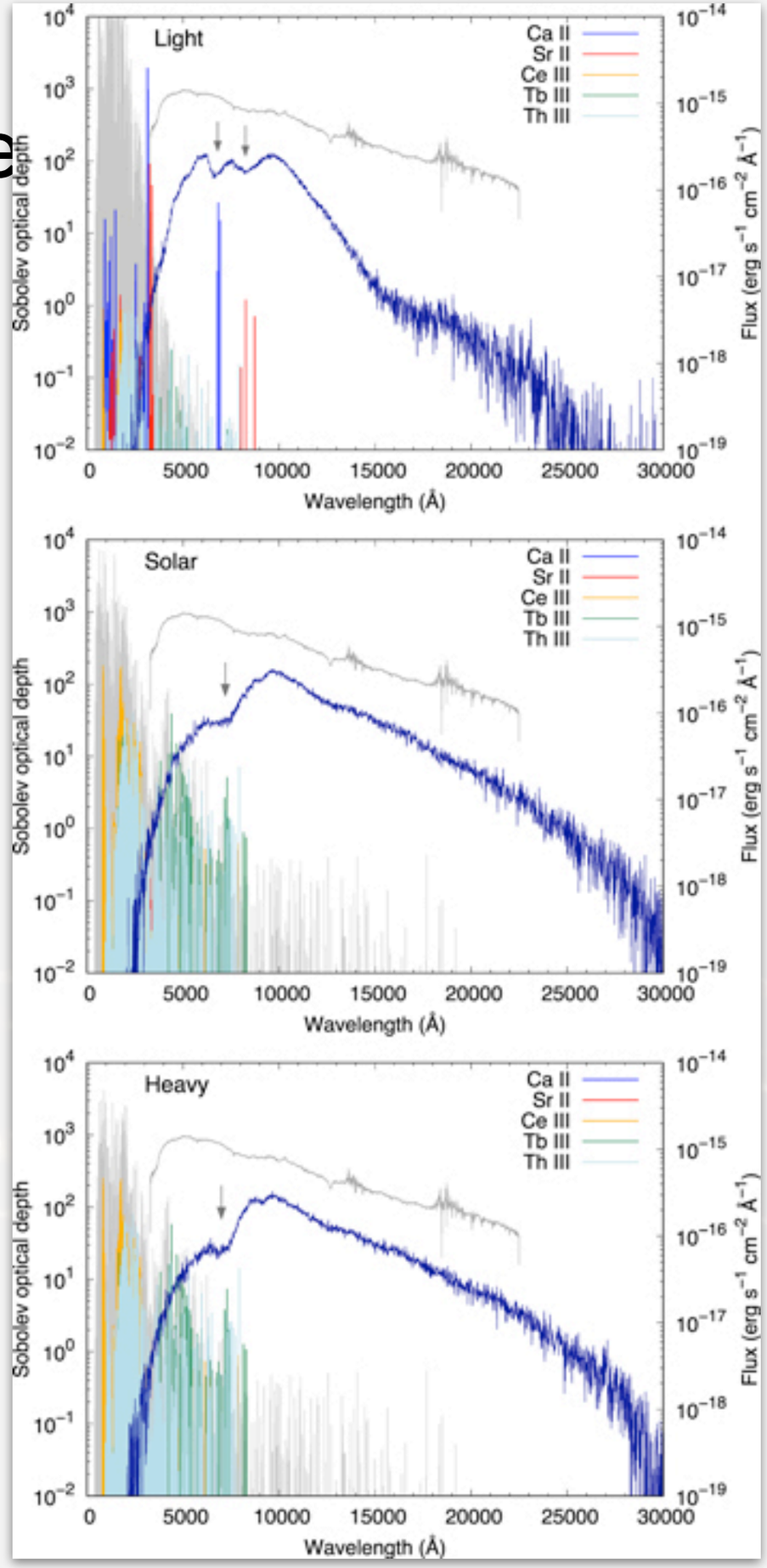


GW170817 results & ope



Watson et al. 2019

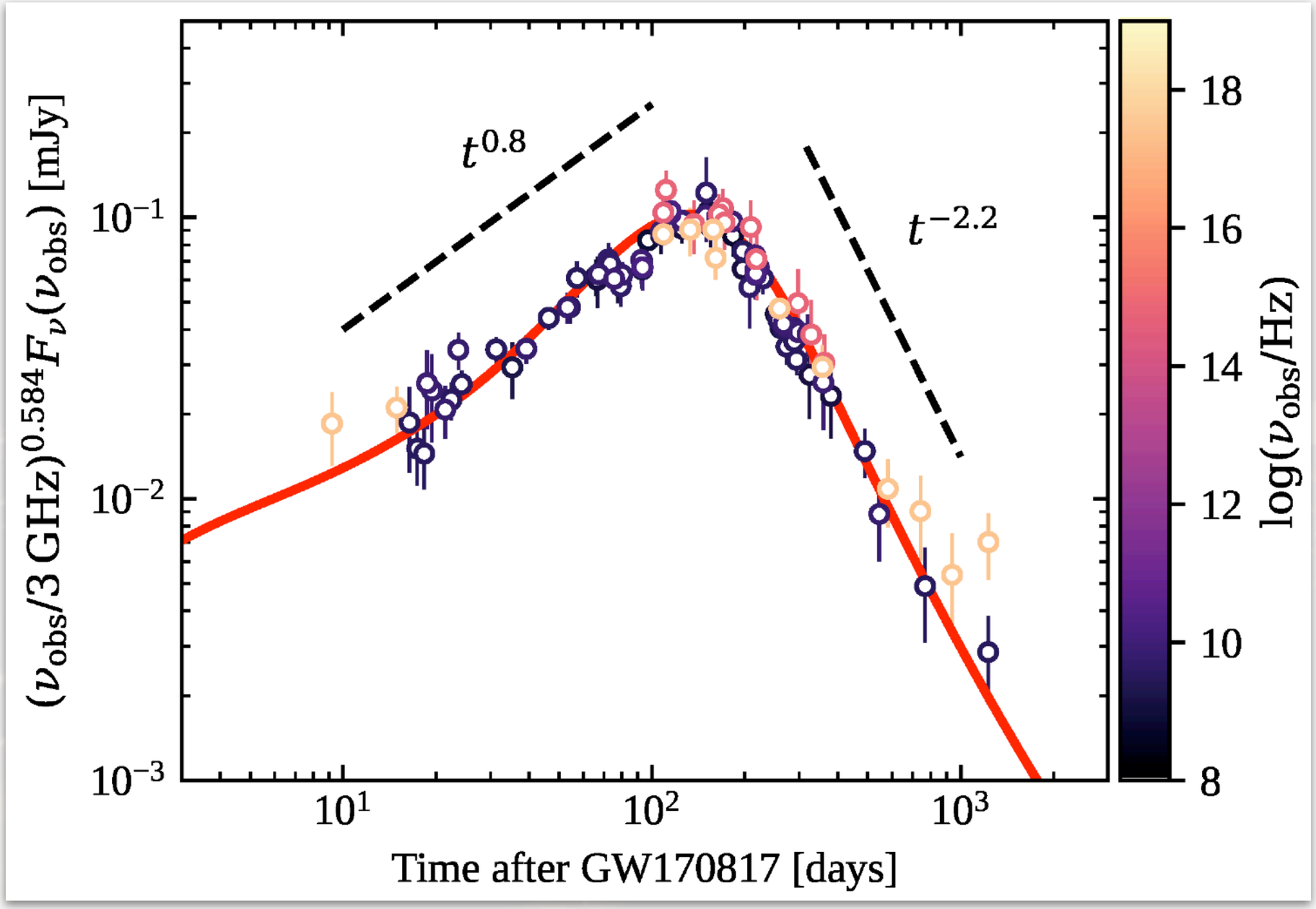
Domoto et al. 2021



GW170817 results & open questions

GRB afterglow

Salafia & Ghirlanda 2022



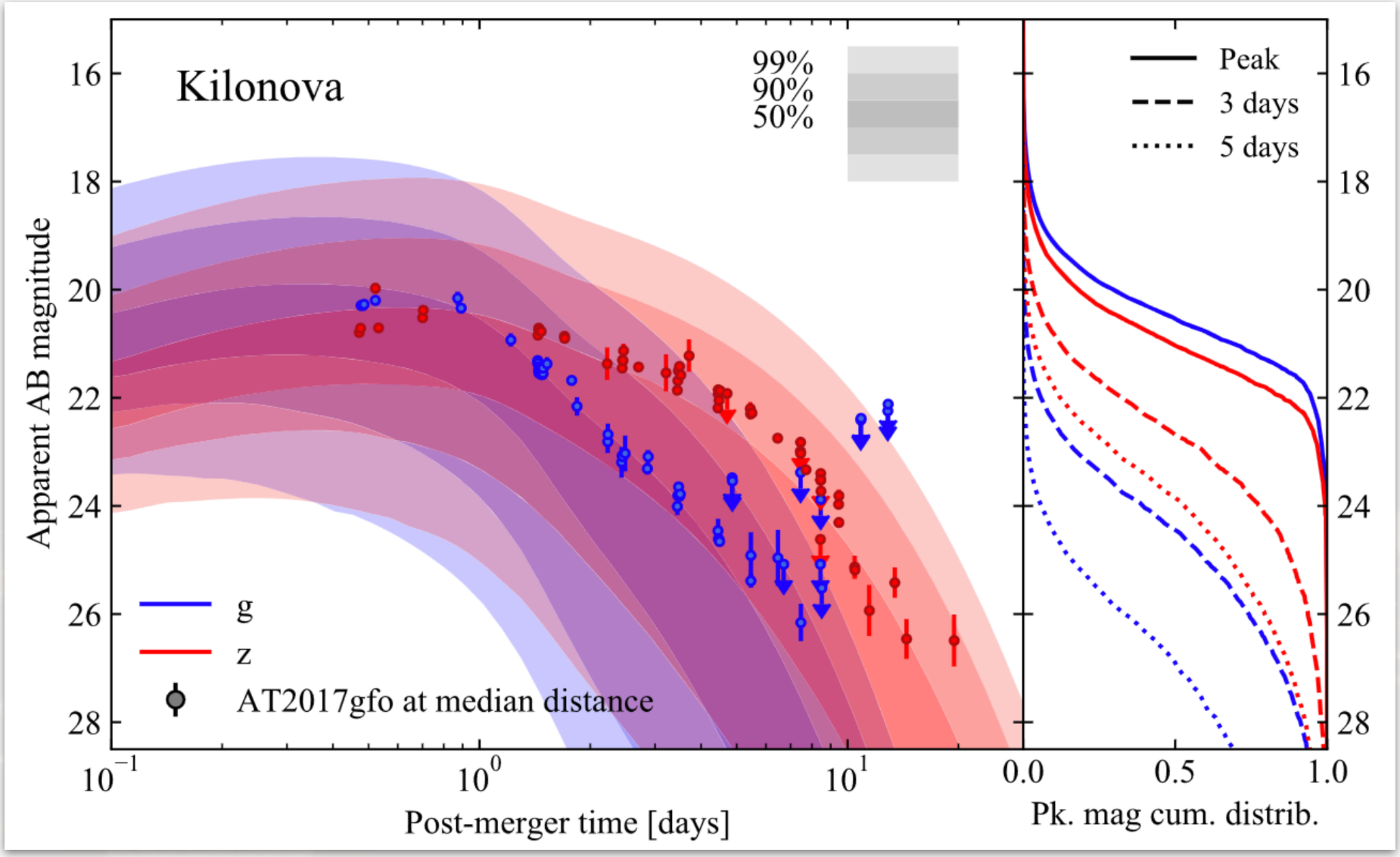
GW170817 lessons & open questions

- Are all BNS similar to GW170817 (EM side)?
- Rate?
- Population?
- Are all BNS associated with SGRB?
- Are all SGRB associated with BNS?
- NSBH ?
- r-process heavy element production

We were lucky

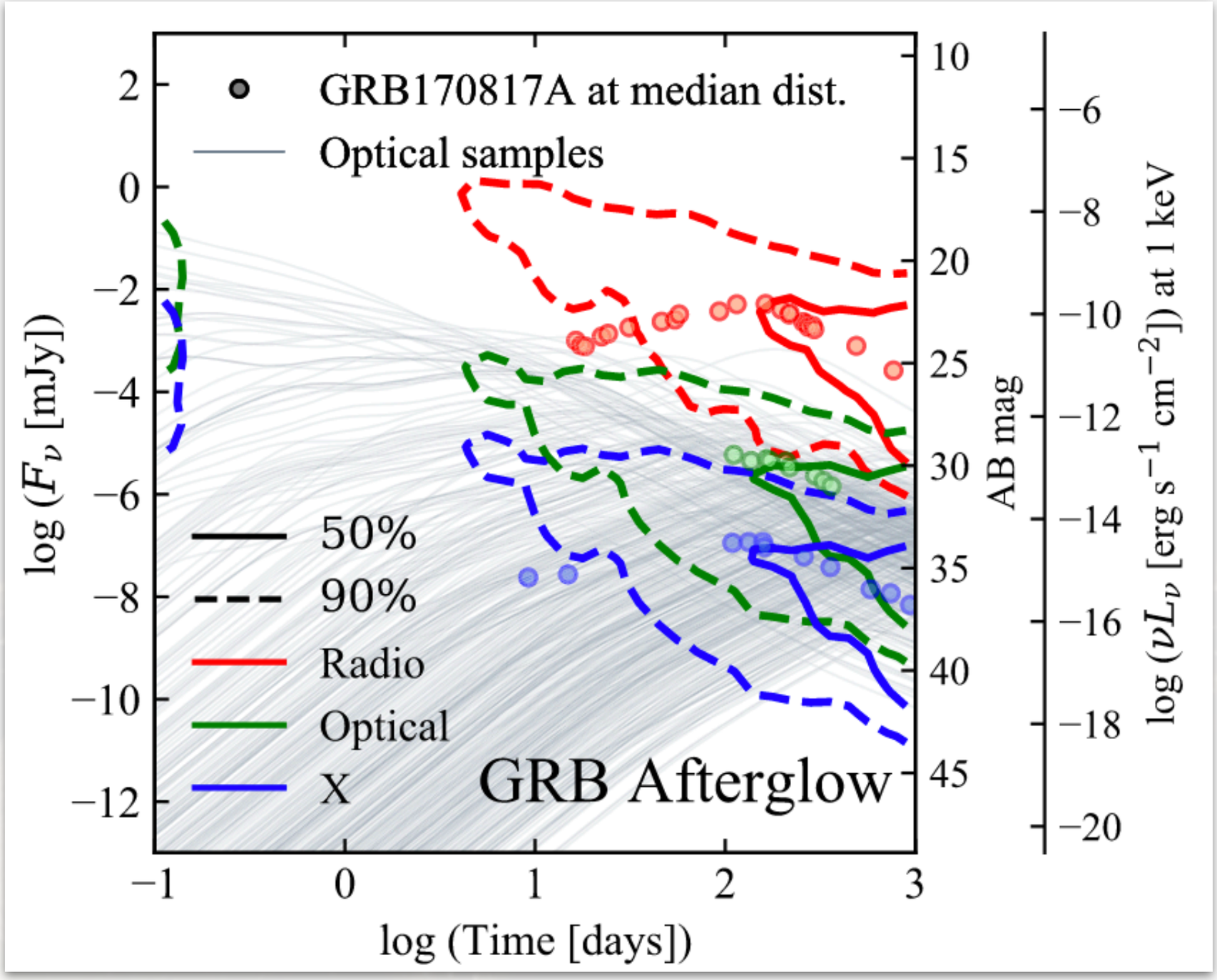
Need of coordination

O4 predictions



Colombo et al. 2022

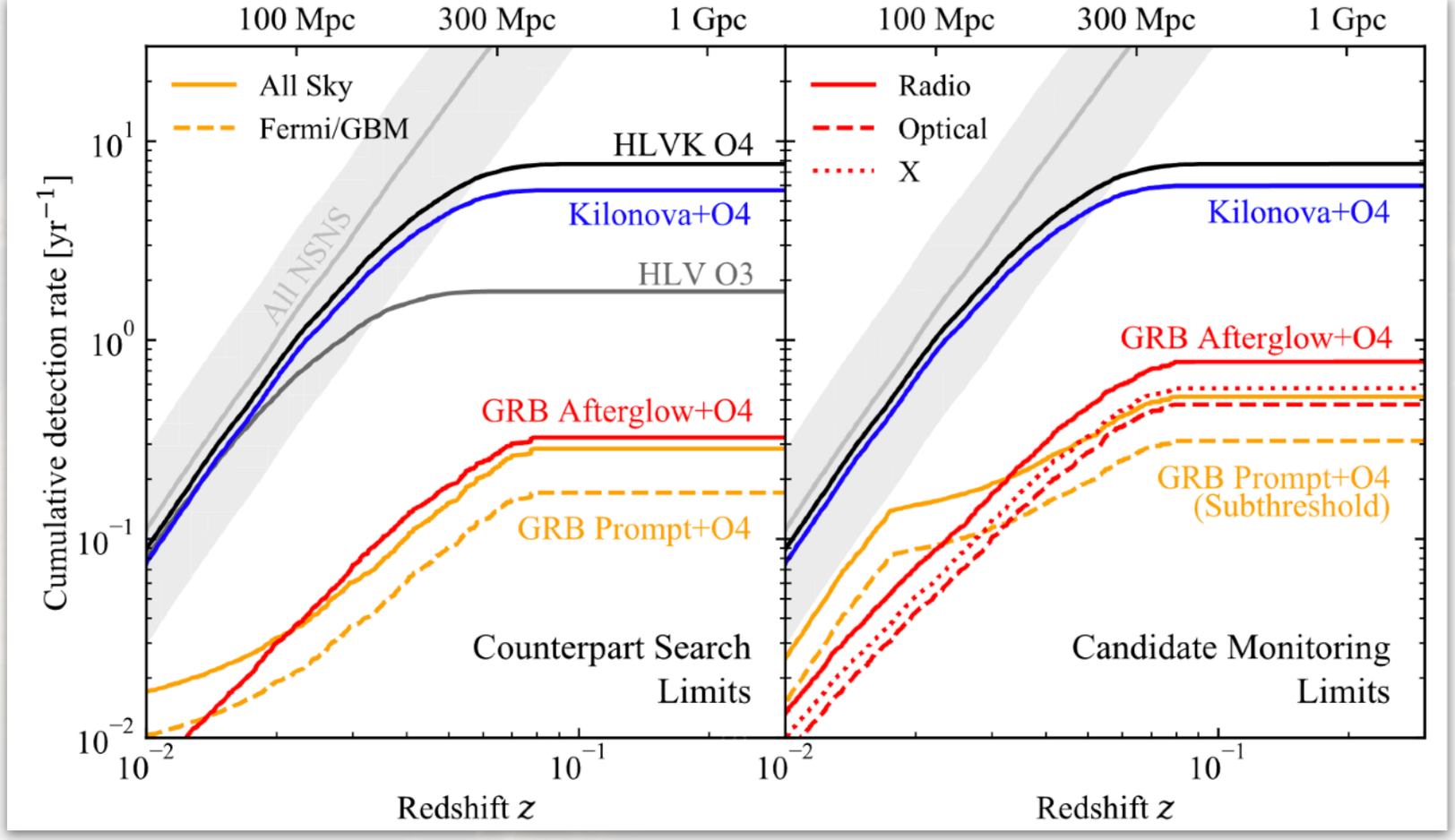
O4 predictions



Colombo et al. 2022

O4 predictions

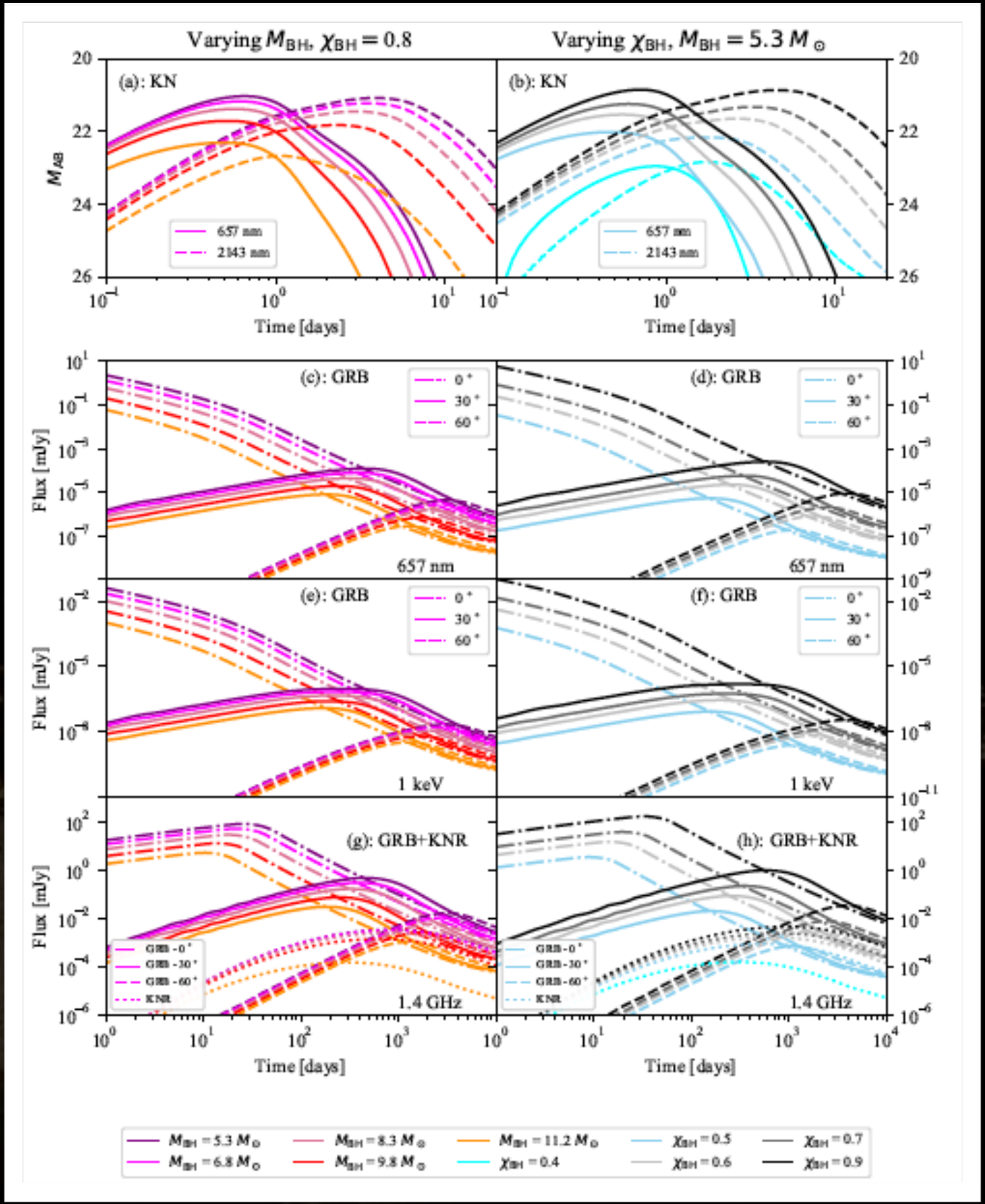
	GW		KN + GW O4			GRB Afterglow + GW O4		
	HLV O3	HLVK O4	J	z	g	Radio	Optical	X-rays
Counterpart search								
Limit	12	12	21	22	22	0.1	22	10^{-13}
Rate	$1.8^{+2.7}_{-1.3}$	$7.7^{+11.9}_{-5.7}$	$2.4^{+3.6}_{-1.8}$	$5.1^{+7.8}_{-3.8}$	$5.7^{+8.7}_{-4.2}$	$0.29^{+0.44}_{-0.22}$	$0.06^{+0.09}_{-0.04}$	$0.32^{+0.51}_{-0.23}$
(% of O4 GW)	(23%)	(100%)	(36%)	(67%)	(74%)	(4%)	(0.8%)	(4%)
Candidate monitoring								
Limit	…	…	28	28	28	0.01	28	10^{-15}
Rate	…	…	$6.0^{+9.2}_{-4.4}$	$6.0^{+9.2}_{-4.4}$	$6.0^{+9.2}_{-4.4}$	$0.78^{+1.21}_{-0.58}$	$0.47^{+0.74}_{-0.35}$	$0.57^{+0.89}_{-0.42}$
(% of O4 GW)	…	…	(78%)	(78%)	(78%)	(10%)	(6%)	(7%)



Colombo et al. 2022

NSBH

Barbieri+2019



z=0.054

$n=10^{-3}cm^{-3}$

O4 predictions

	GW		KN + GW O4			GRB Afterglow + GW O4		
	HLV O3	HLVK O4	J	z	g	Radio	Optical	X-rays
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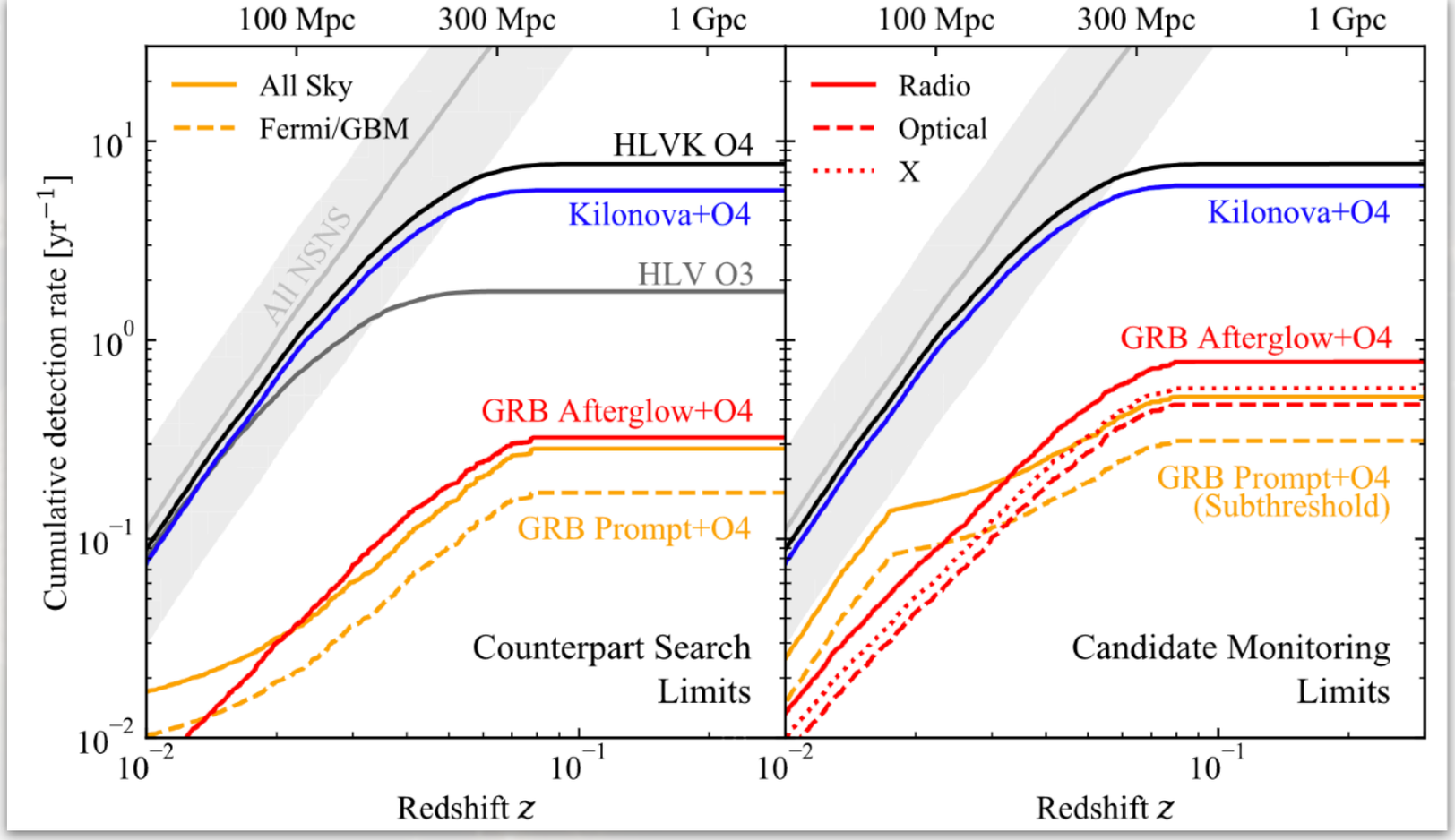


Colombo et al. 2022

O4 predictions

Detect doesn't mean **identify** and study
How many candidates we will have and we will follow?
Spectroscopy needed

5-10 BNS
Without Virgo ~1000 deg2 localization
~100 deg2 with Virgo


Engravé
Electromagnetic counterparts of gravitational wave sources
at the Very Large Telescope
http://www.engrave-eso.org/
ESO

Large Programme @ VLT
~ 200hr to follow-up EM candidate counterparts
photometry, spectroscopy, polarimetry

"Spin-off" radio-mm, HST & JWST awarded programs

Many ENGRAVE members have time
at different facilities to search for the EM counterpart

Governing Council

- Marica Branchesi
- Enzo Brocato
- Paolo D'Avanzo
- Jens Hjorth
- Peter Jonker
- Elena Pian
- Stephen Smartt
- Jesper Sollerman
- Danny Steeghs
- Nial Tanvir **(Chair)**

Executive Committee

- Morgan Fraser
- Andrew Levan **(Chair)**
- Kate Maguire
- Daniele Bjørn Malesani
- Om Sharan Salafia
- Susanna Vergani

~270 members

Observers : expert of spectroscopy, photometry, polarimetry
Transient classification,…
Theoreticians: KN modelling, orphan afterglow modelling
EM outcome from BNS and NSBH,…

- Peter Jonker
- Elena Pian
- Stephen Smartt
- Jesper Sollerman
- Danny Steeghs
- Nial Tanvir **(Chair)**

- Om Sharan Salafia
- Susanna Vergani

~270 members

Weekly on-call Operations Team & Writing Team

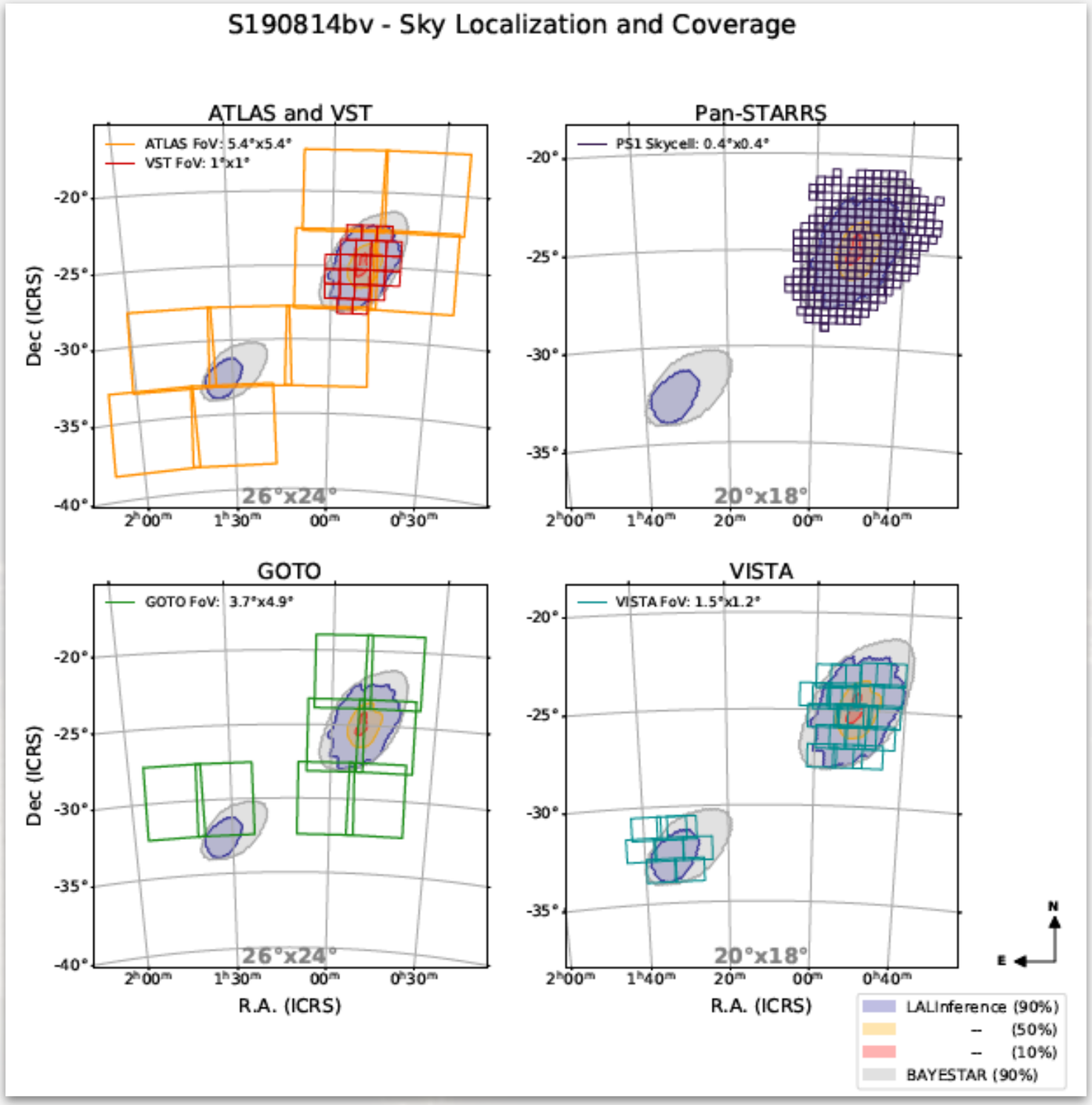
WG: imaging, spectroscopy, polarimetry, theory, infrastructure, epo, external

Two examples :

- Difficulties due to catalogue & observation incompleteness
- Difficulties due to contamination of other transients

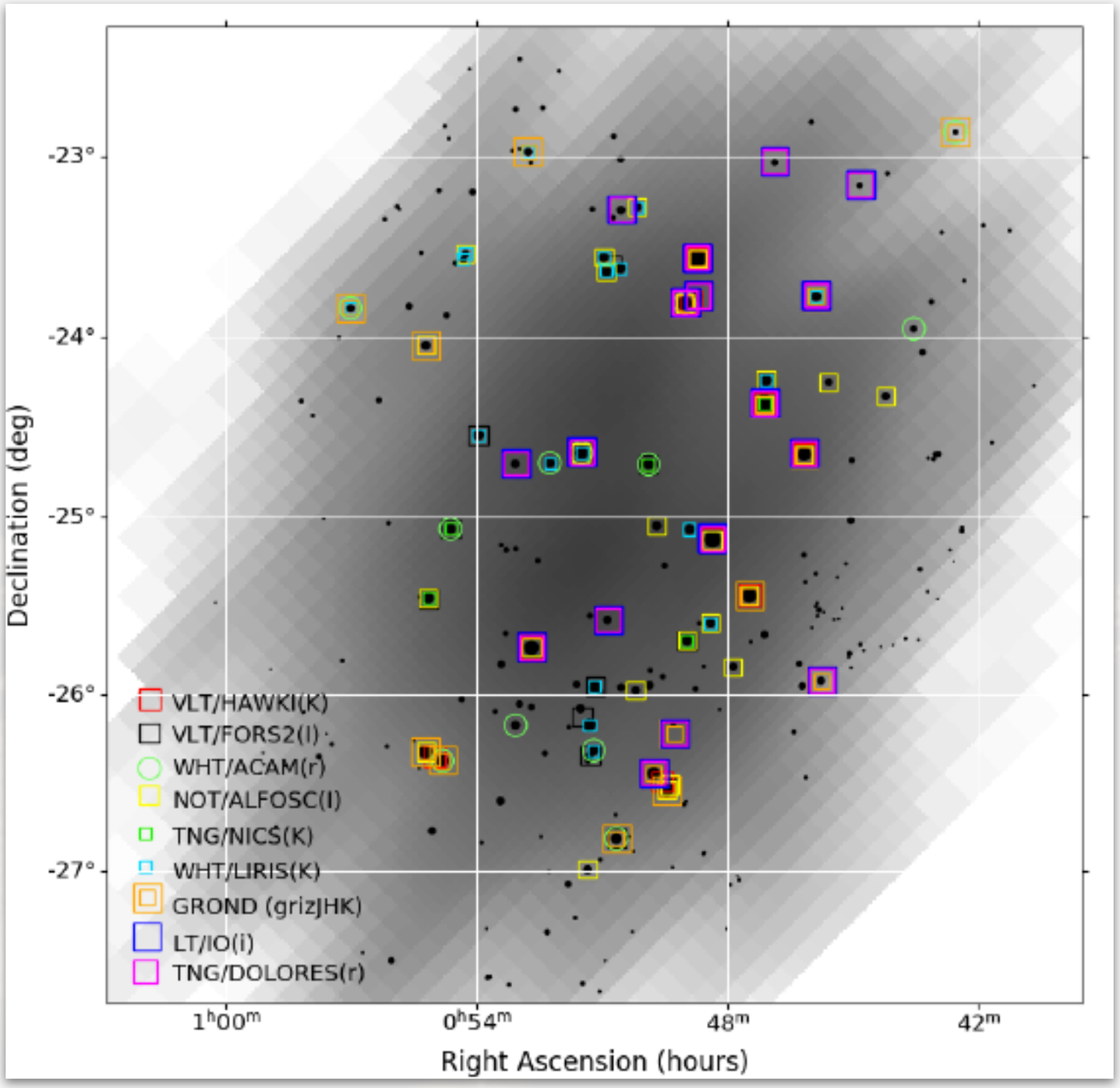
GW190814

Ackley et al. 2020



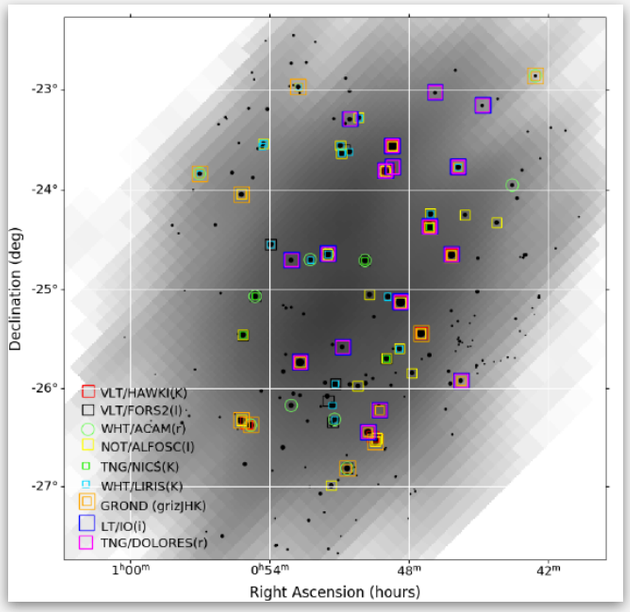
GW190814

Ackley et al. 2020

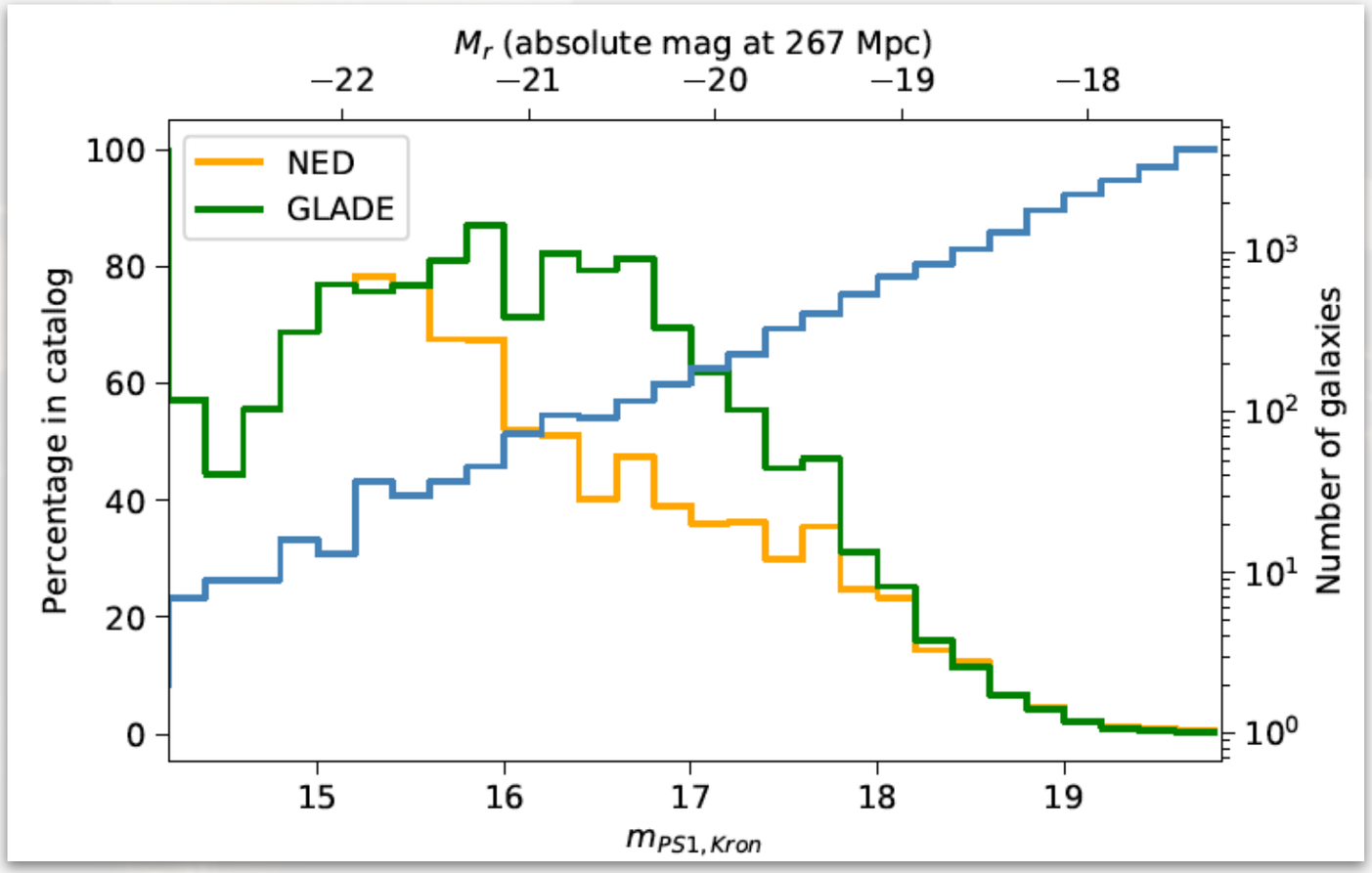


GW190814

Ackley et al. 2020



- catalogue incompleteness
- observation incompleteness



GW190814

Ackley et al. 2020

- catalogue incompleteness
- observation incompleteness

probability proportional to:

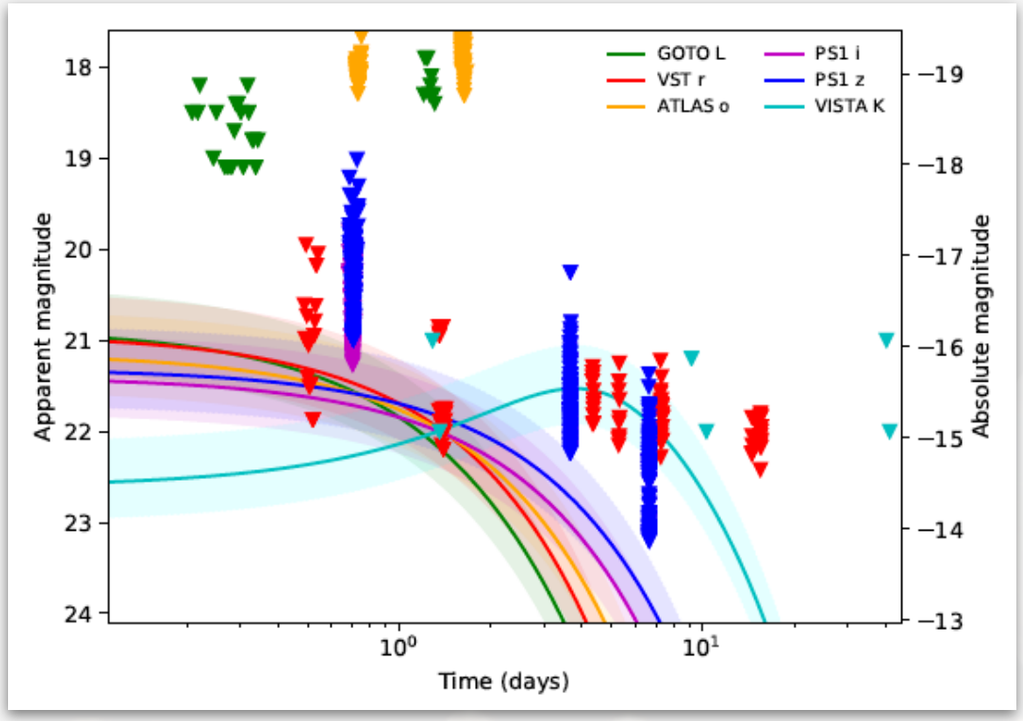
- sky map probability
- NSBH rate —> Stellar Mass —> K-band luminosity

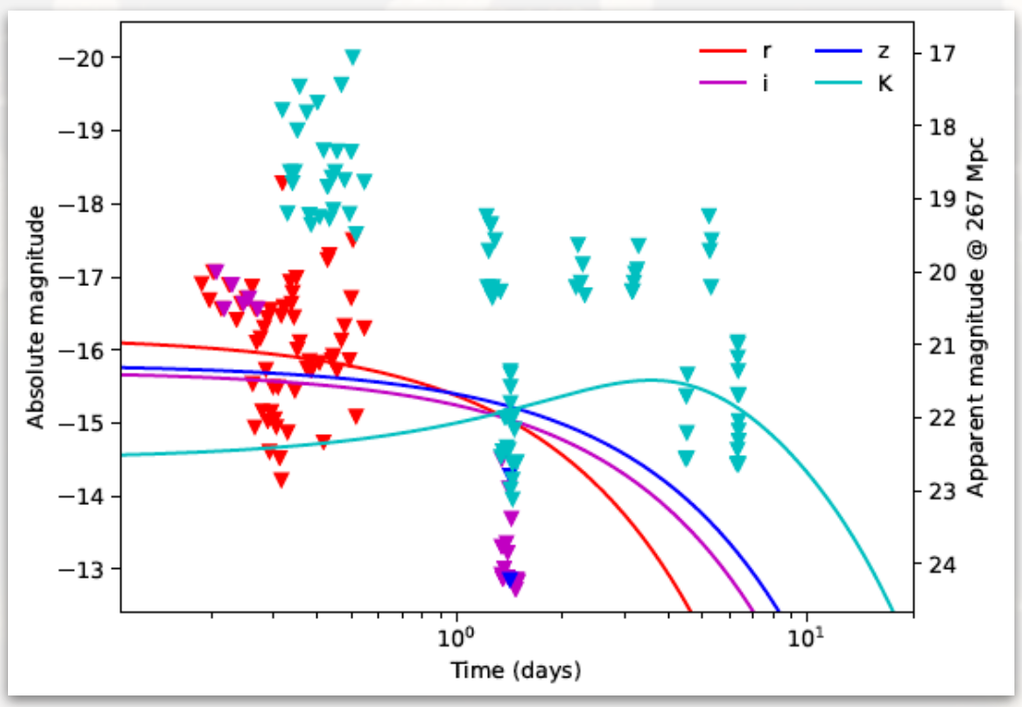
Did we observe the right object ?

Covered probability ~50%

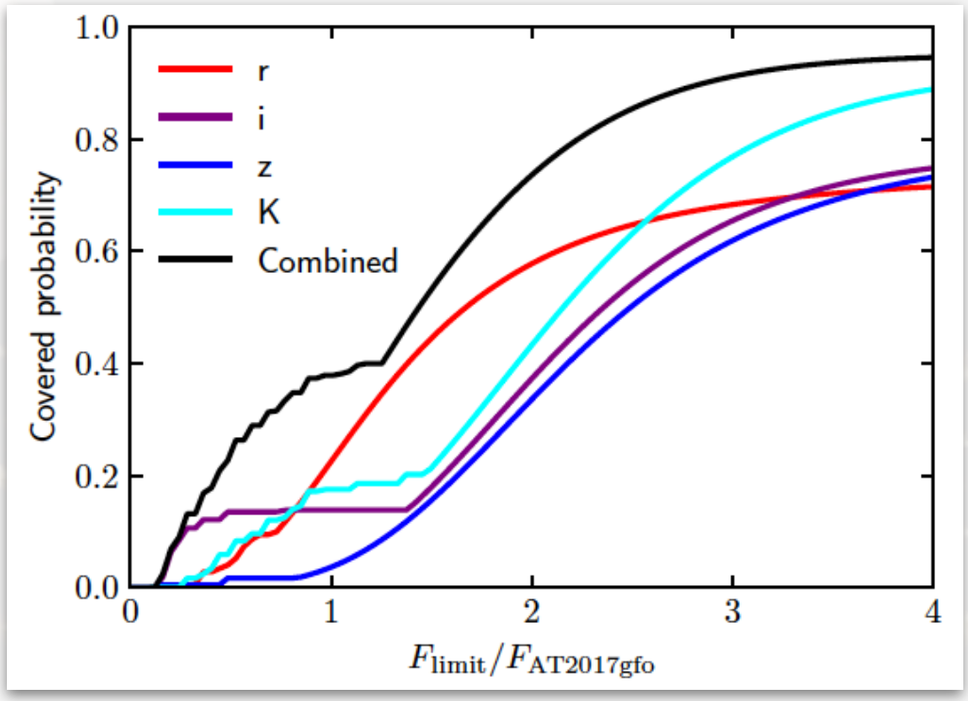
GW190814

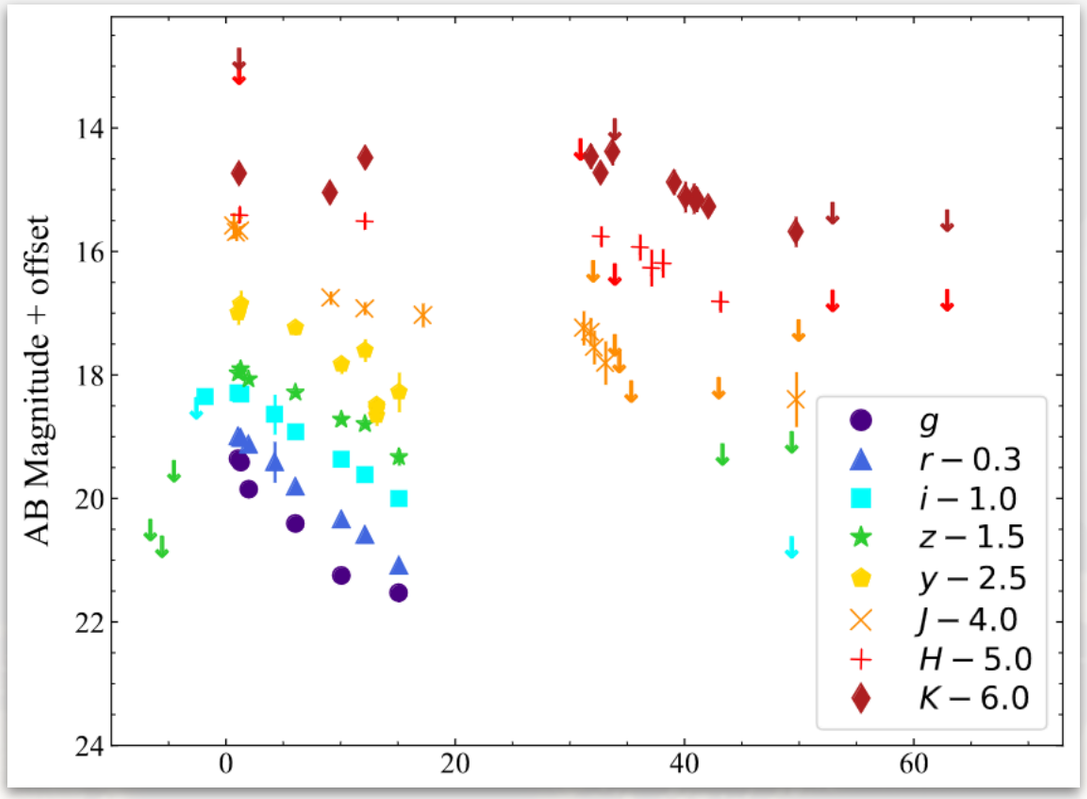
Ackley et al. 2020





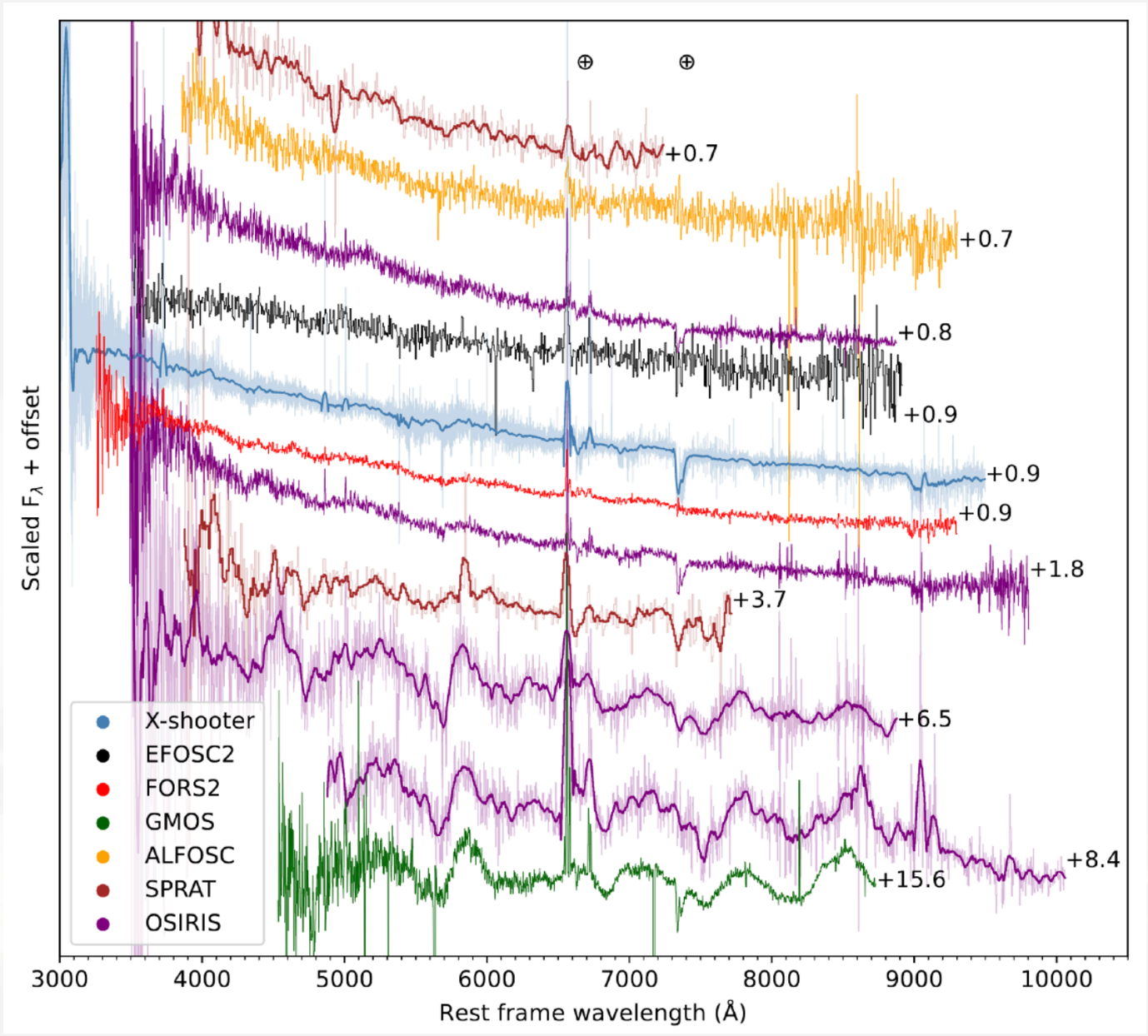
Did we observe deep enough ?



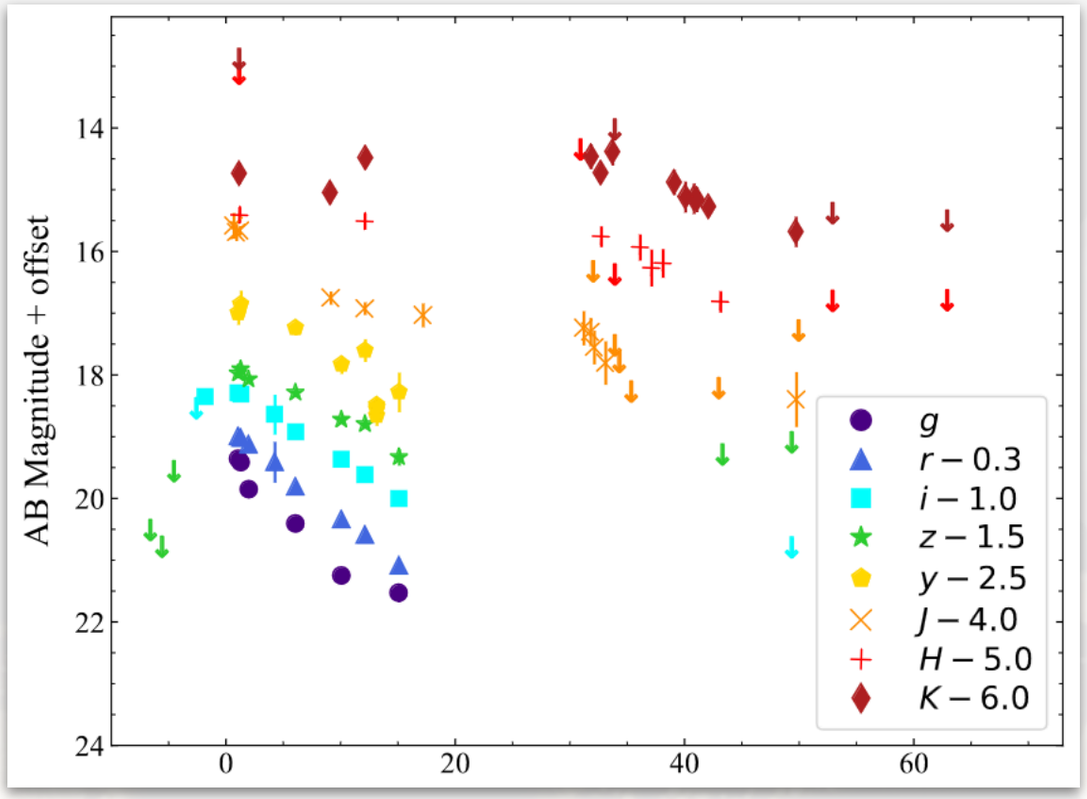


Days

Agudo et al. 2023

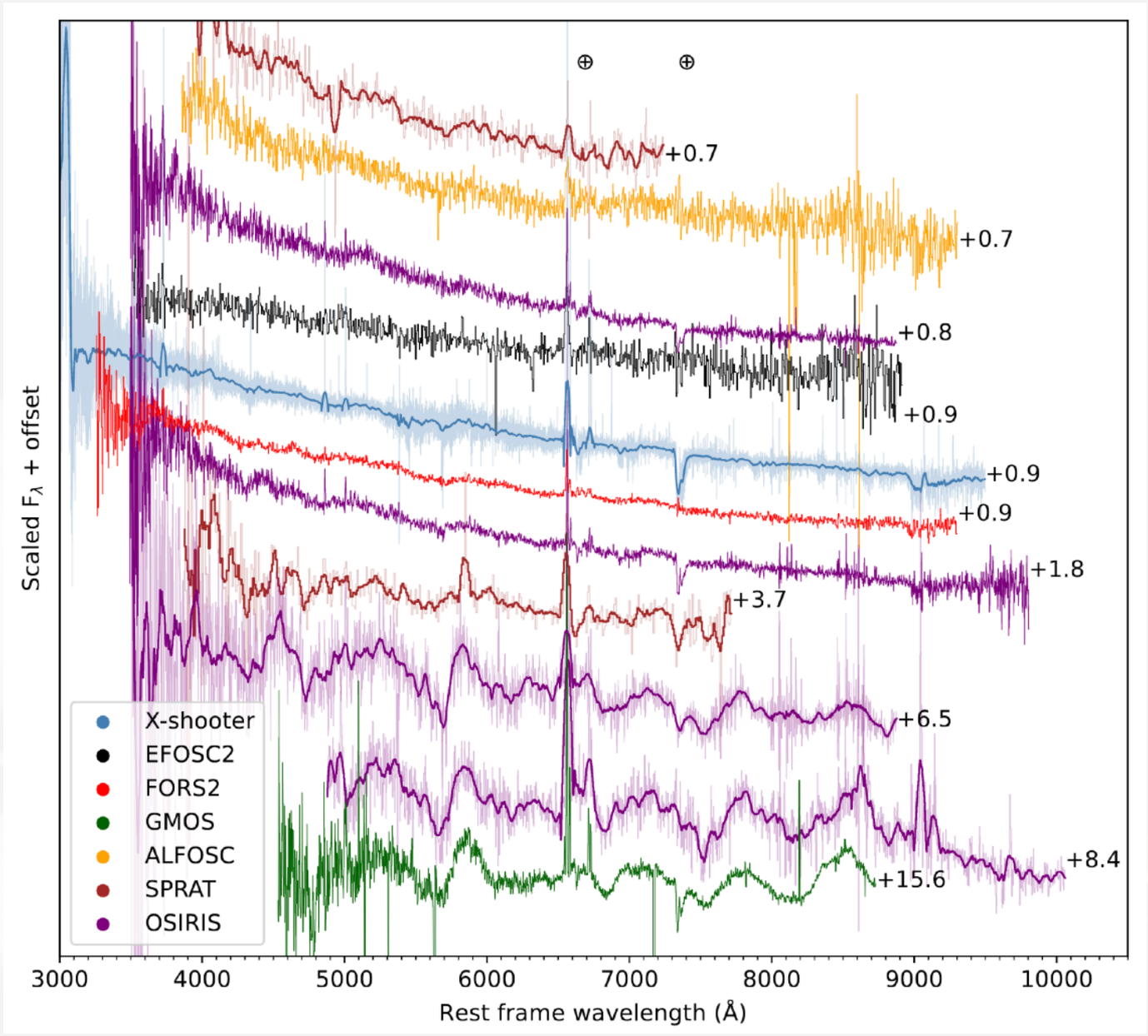


KN ?



Agudo et al. 2023

SN 2019wxt

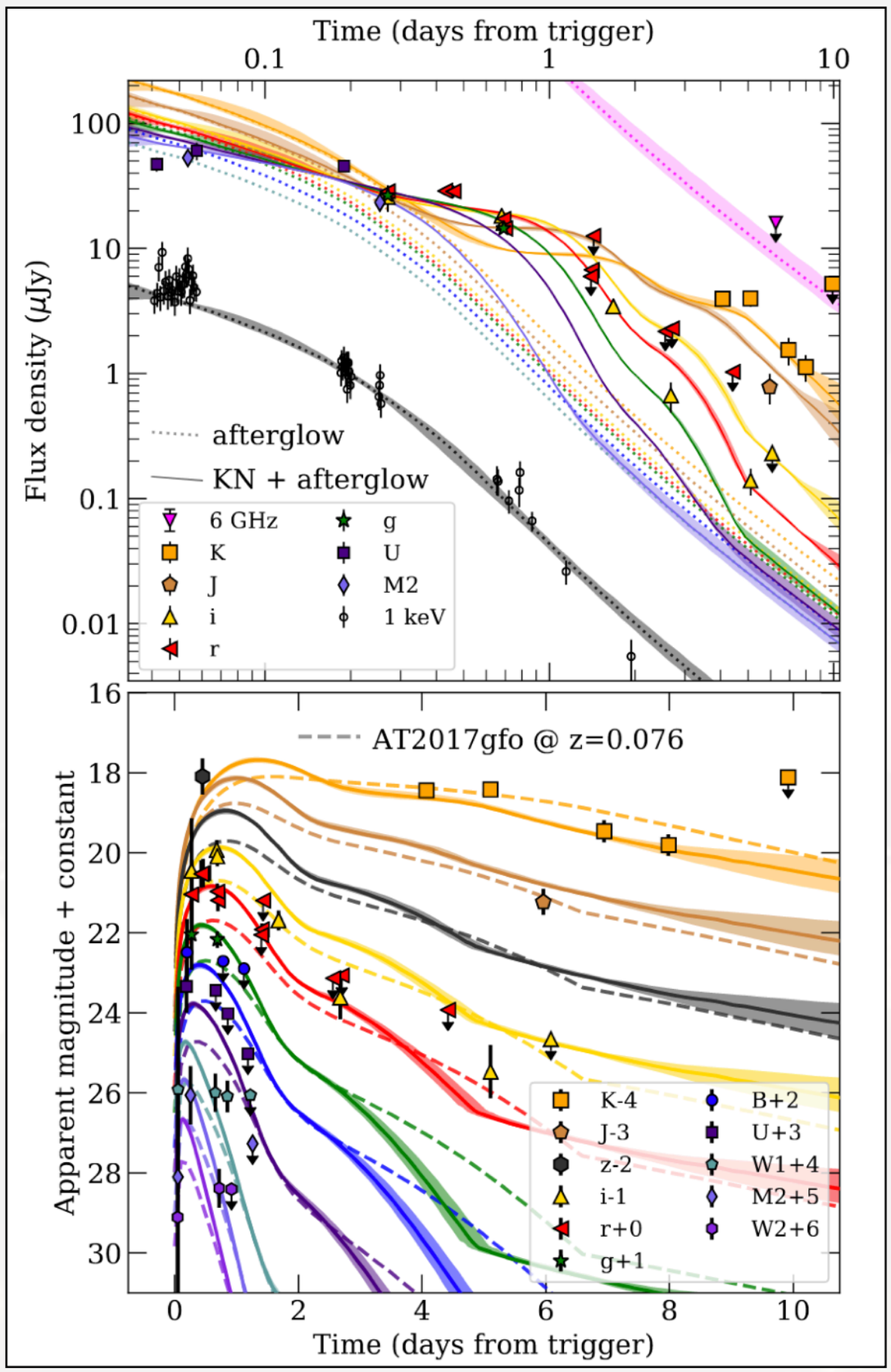


~1/week

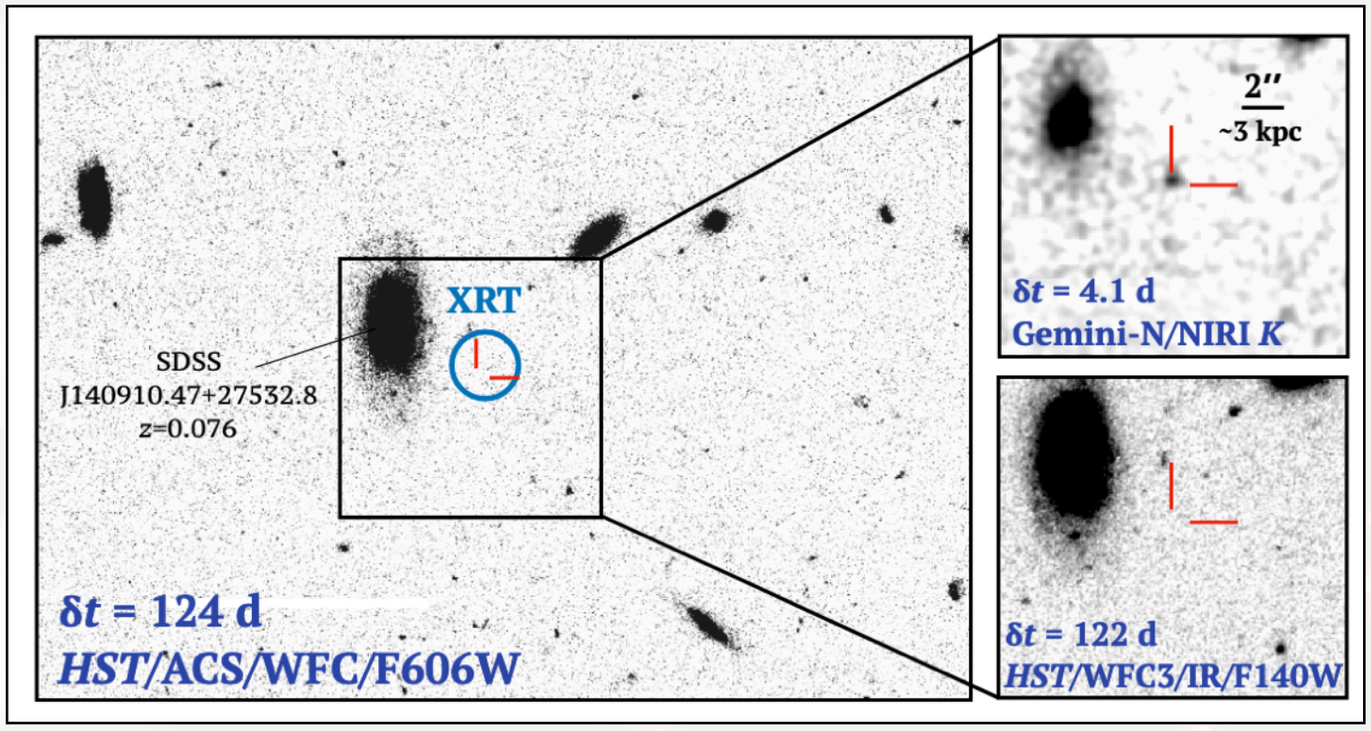
KN ?

No, ultra-stripped SN from a binary system

GRB211211A z=0.076



Rastinejad et al. 2022



04

3rd ENGRAVE meeting

ENGRAVE data reduction workshop

Dry run

Ongravé

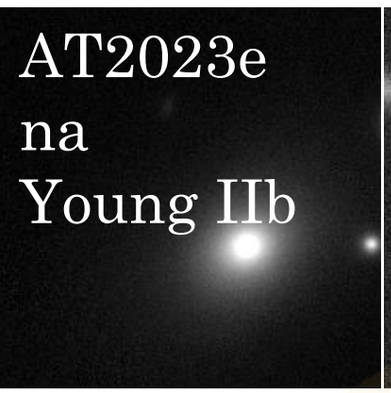
The dry run

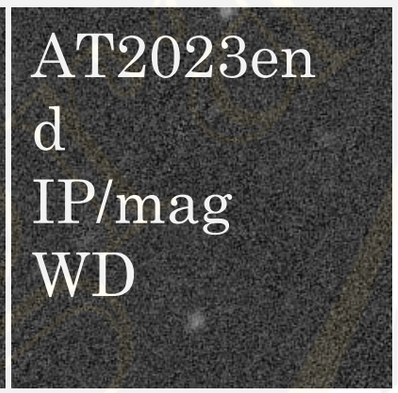
Dry-run idea/set-up

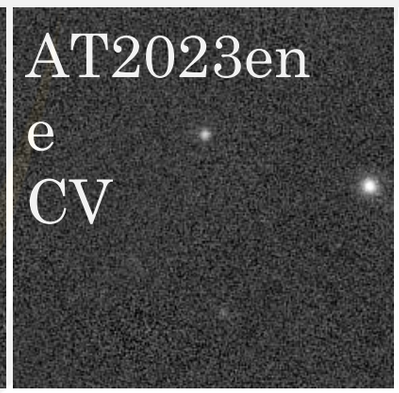
- Dry run intended to;
  - train people in the immediate follow-up of GW triggers (trigger, data reduction, analysis etc).
  - act as a test of ENGRAVE readiness for O4.
  - flag any major issues to be addressed in our operations model.

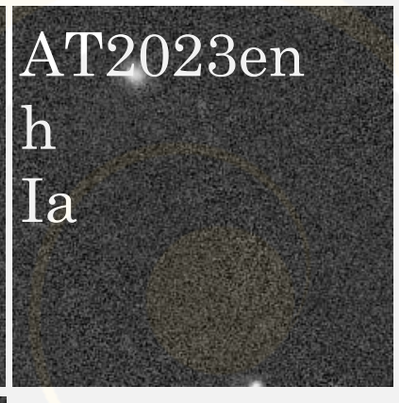
- 6 different teams ~8 people per team, wide range of experience and expertise levels.
- Run in “accelerated” time (no waiting for night to fall, target to rise etc). Dry run lasted ~6 hours, spanning two simulated nights.
- All teams very active (the EC struggled to keep up with all the discussions).

Transient sources



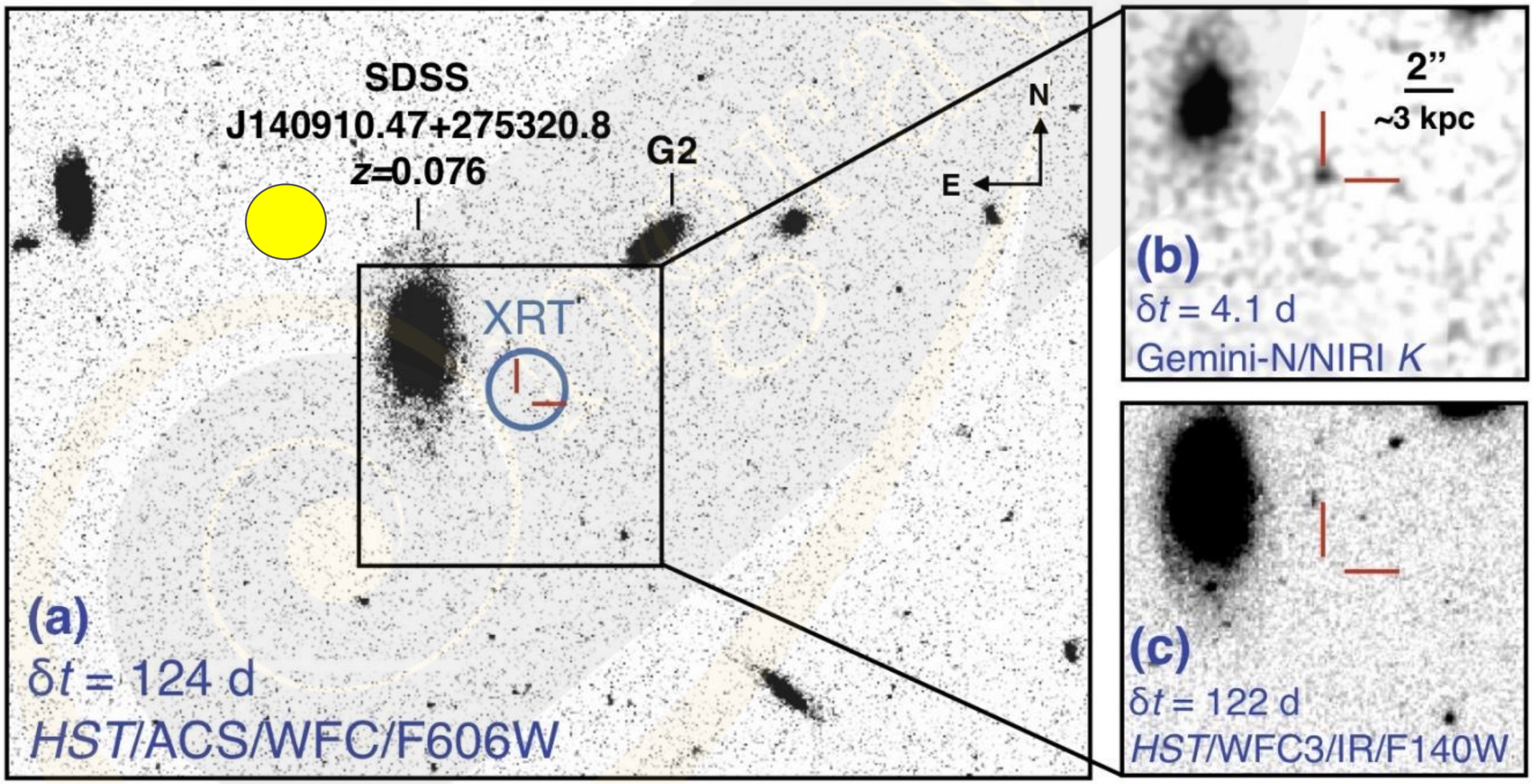






Time	Target	Trigger	OB good	Data recieved	Reduced uploaded	Reduction (min)
10.27	AT2023enb	4800s XSH	Yes	10.45	11.41	56
10.33	AT2023enb	4800s XSH	Yes	10.48	11.52	64
10.35	AT2020enb	4800s XSH	Yes	10.47	11.31	44
10.36	AT2023enb	2400s XSH	Yes	10.51	11.43	52
10.36	AT2023enc	2400s XSH	Yes	11.06	N/A	
10.54	AT2023enb	4800s XSH	Yes	11.07	11.51	44
11.20	AT2023enf	4800s XSH	No			
11.25	AT2023ena	4800s XSH	Yes	11.38	N/A	
11.32	AT2023enf	4800s XSH	Yes	11.46		
12.04	AT2023enf	HAWK-I	Yes	12.15	13.36	81
12.36	**AT2023enk**	**XSH**	**Yes**	**13.52**		
13.09	**AT2023enk**	**3600s FORS2**	**No**			
13.13	**AT2023enk**	**HAWK-I**	**Yes**	**13.30**	**13.58**	28
13.22	AT2023enb	XSH	Yes	13.36	N/A	
13.23	**AT2023enk**	**3600s FORS2**	**Yes**	**13.38**	**14.24**	46
13.29	AT2023enl	2400s FORS2 (300+GG435)	Yes	13.46	14.22	36
13.31	**AT2023enk**	**4800s FORS2 (300V+GG435)**	**Yes**	**13.47**	**13.51**	4
13.36	AT2023enl	1800s FORS2 150I	Yes	13.51		
13.41	AT2020enf	HAWK-I	Yes	-	12.09	
13.48	AT2020enf	FORS2	Yes	14.05	14.32	27
13.58	AT2023enf	4800s XSH	Yes	14.21	14.42	21
13.59	AT2023enf	4800s XSH	Yes	14.22	14.37	15
14.15	AT2023enf	4800s XSH	Yes	N/A	N/A	
14.22	AT2023enl	4800s FORS2 (300V+GG435)	Yes	N/A	N.A	
14.30	**AT2020enk**	**HAWK-I**	**Yes**	**N/A**	**N/A**	
14.55	**AT2023enk**	**bVRIz pol FORS2**	**N/A**	**N/A**	**N/A**	

AT2023enk = GRB 211211A



Host galaxy is in GLADE, but with only a photo-z, which is wrong (z_phot = 0.14)

Suggestions - strategy

- We should eyeball images of all transients reported in GW error-boxes and not just rely on catalog matches etc.
- Photo-z's at very low redshift can be unreliable. Use with caution (but to cut down source numbers for follow-up we may want to use them).
- Make as much use of contextual information as possible (e.g. in this case there was a GRB, so rapidly decaying afterglow was a possibility).
- Teams typically triggered several observations of sources. Need to think carefully about the balance between making sure nothing is missed and running through all our time.
- Teams that made a spreadsheet seemed to have an easier time!
- Don't trust non-detections from other surveys? Things can fall into chip gaps etc.

O4

WE ARE READY

Waiting for LVK significant alerts

Merci