ET-WST synergy for next generation gravitational wave multi-messenger observations

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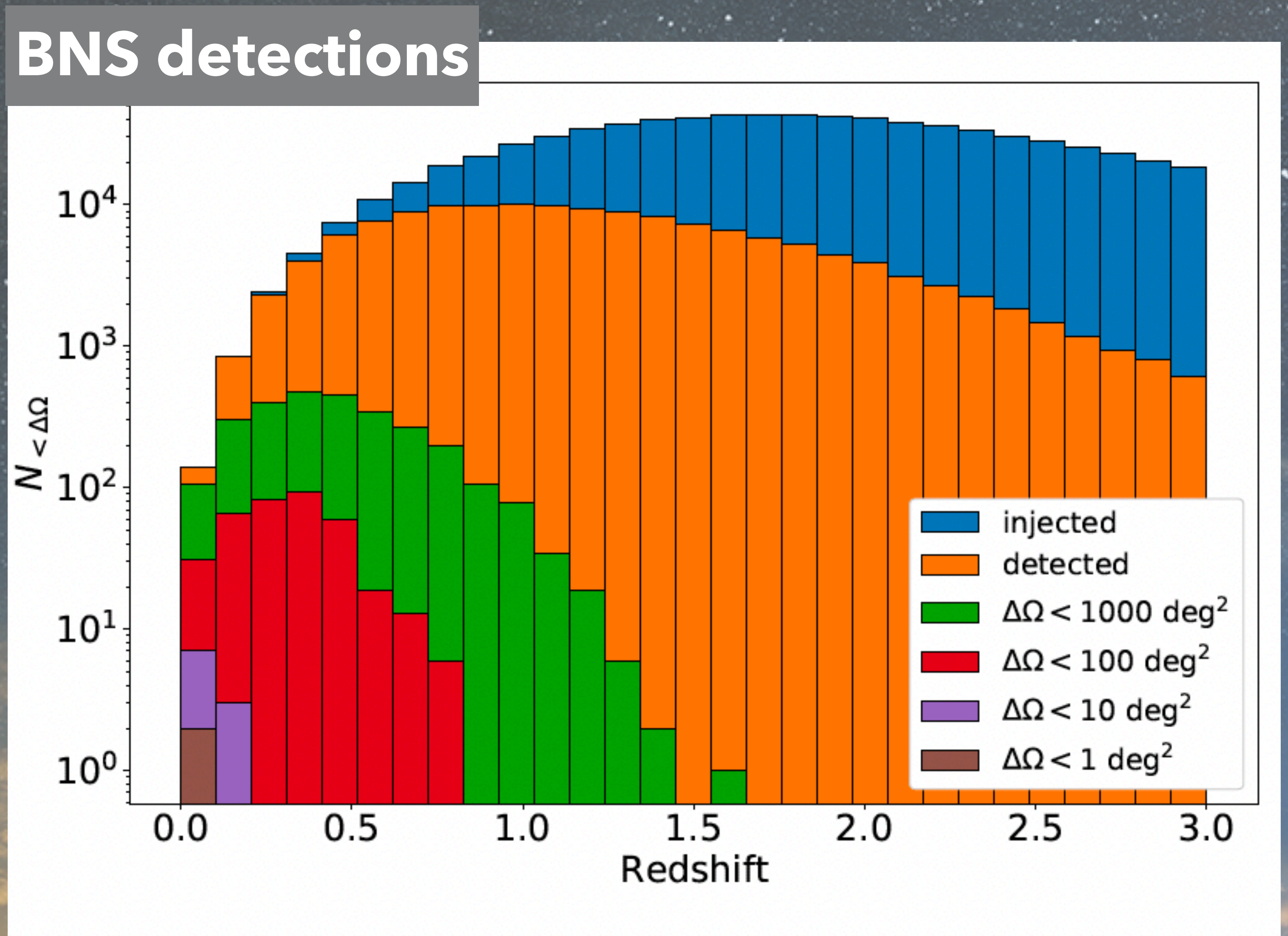
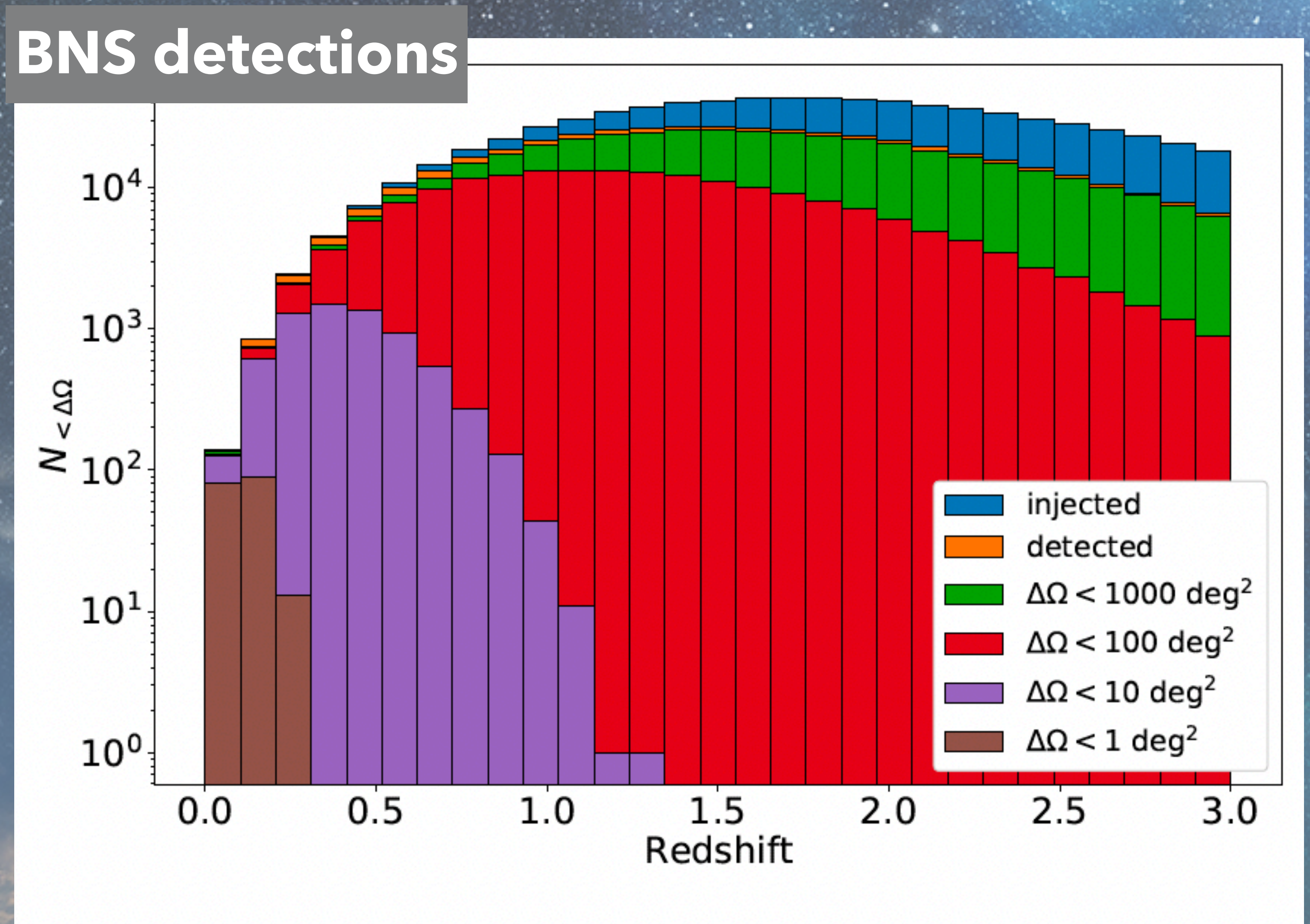
Challenges of the electromagnetic counterpart research



(a) ET, all angles



(c) ET+CE, all angles

Ronchini+22

Larger volume
of the Universe explored

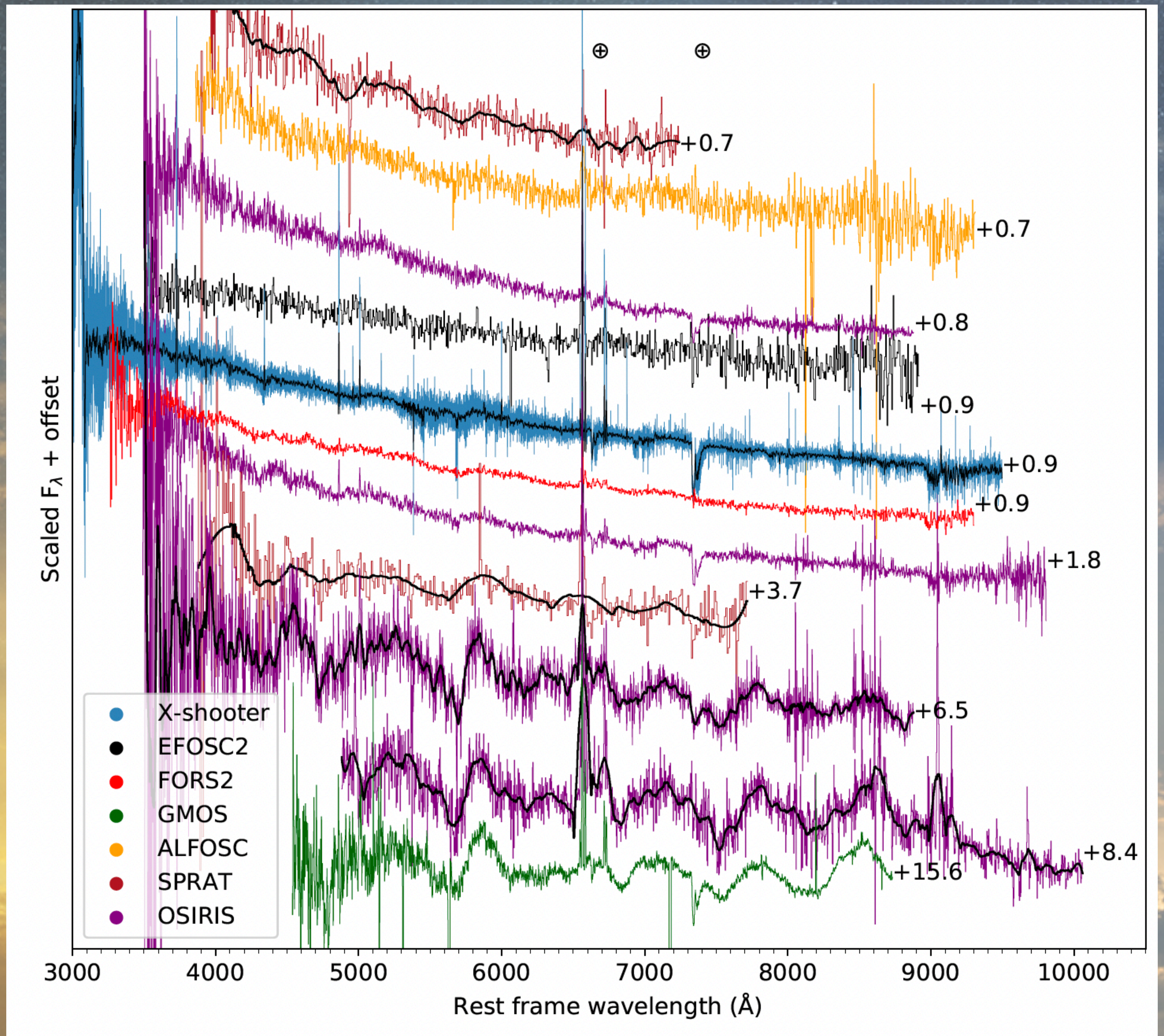
Higher number
of BNS detections

Faint optical-NIR EM counterparts to be found within large error regions among a huge number of contaminants

Large field of views and **high sensitivities** will be necessary for the EM follow-up

Photometric observations with facilities like the Vera C. Rubin Observatory, that will scan the sky with high cadence and unprecedented sensitivities, will provide a lot of **counterpart candidates**

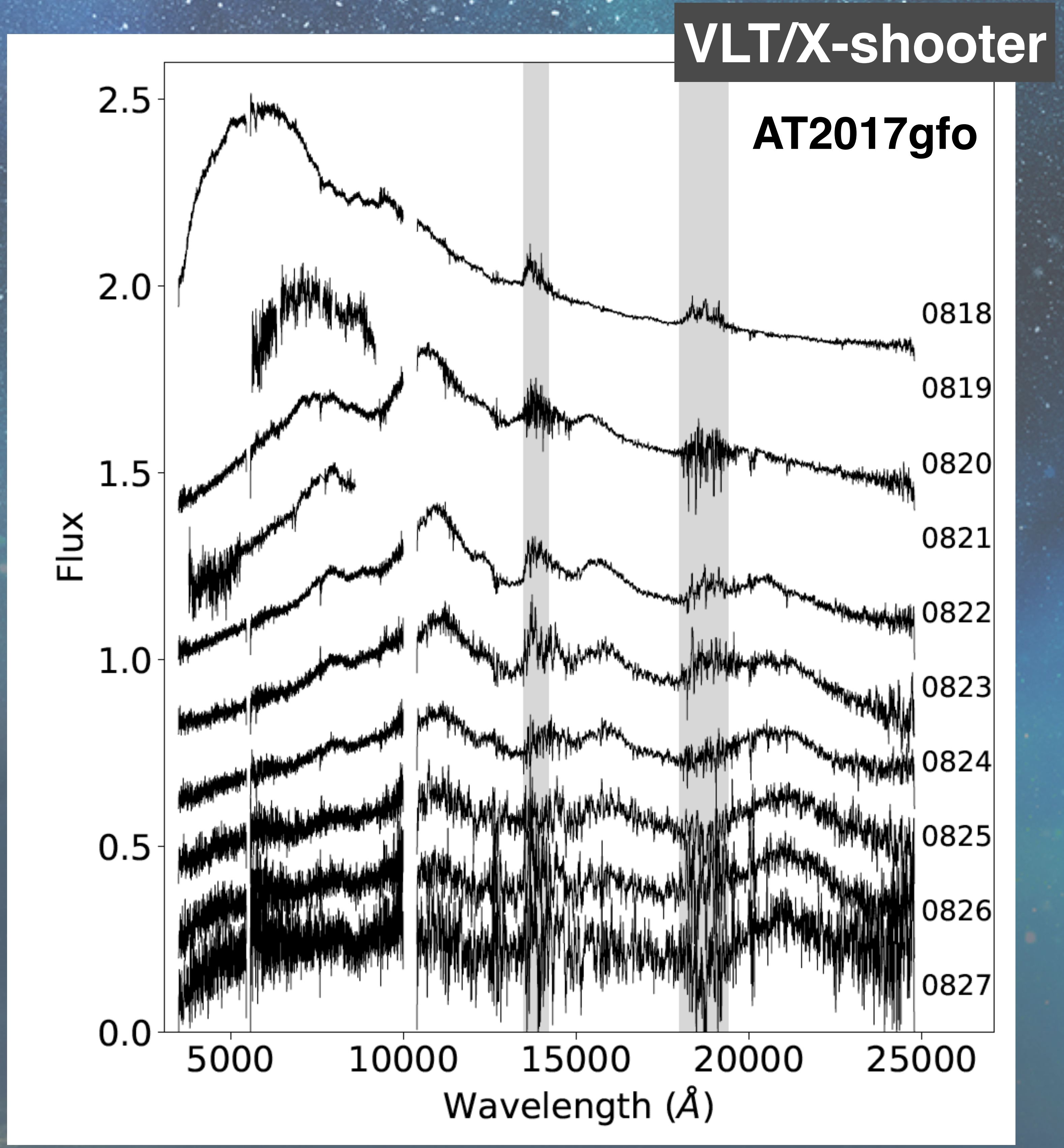
Spectroscopy: the bottleneck of gravitational wave multi-messenger science



Agudo+23

The spectrum of AT2017gfo: important for the study of physics of the phenomenon, the environment, heavy elements nucleosynthesis and for the **KN identification**

The spectrum of SN2019wxt, a GW event counterpart candidate, then classified as SN

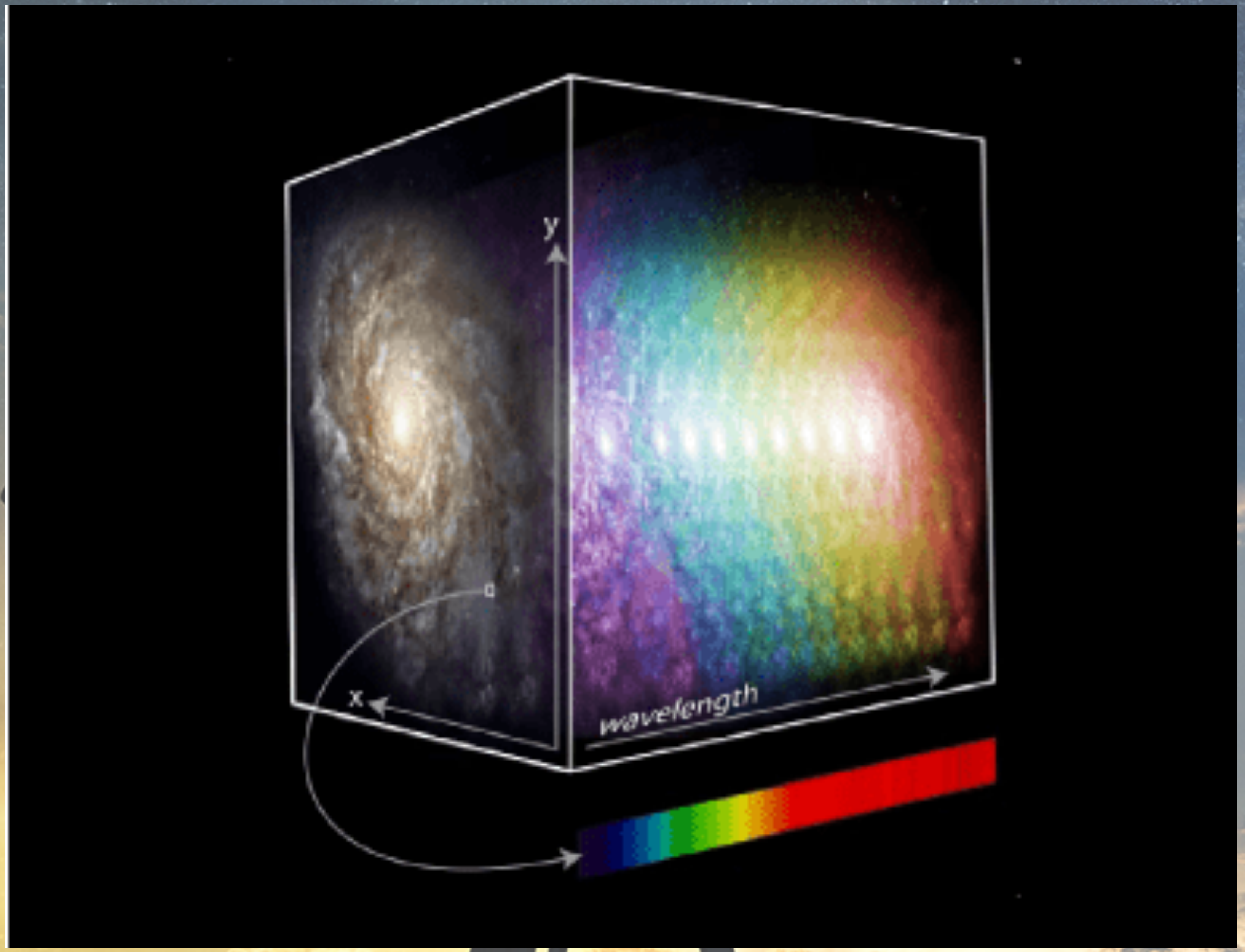


Pian+17

The acquisition of **multiple spectra at the same time** can play a key role in identifying and characterising EM counterparts

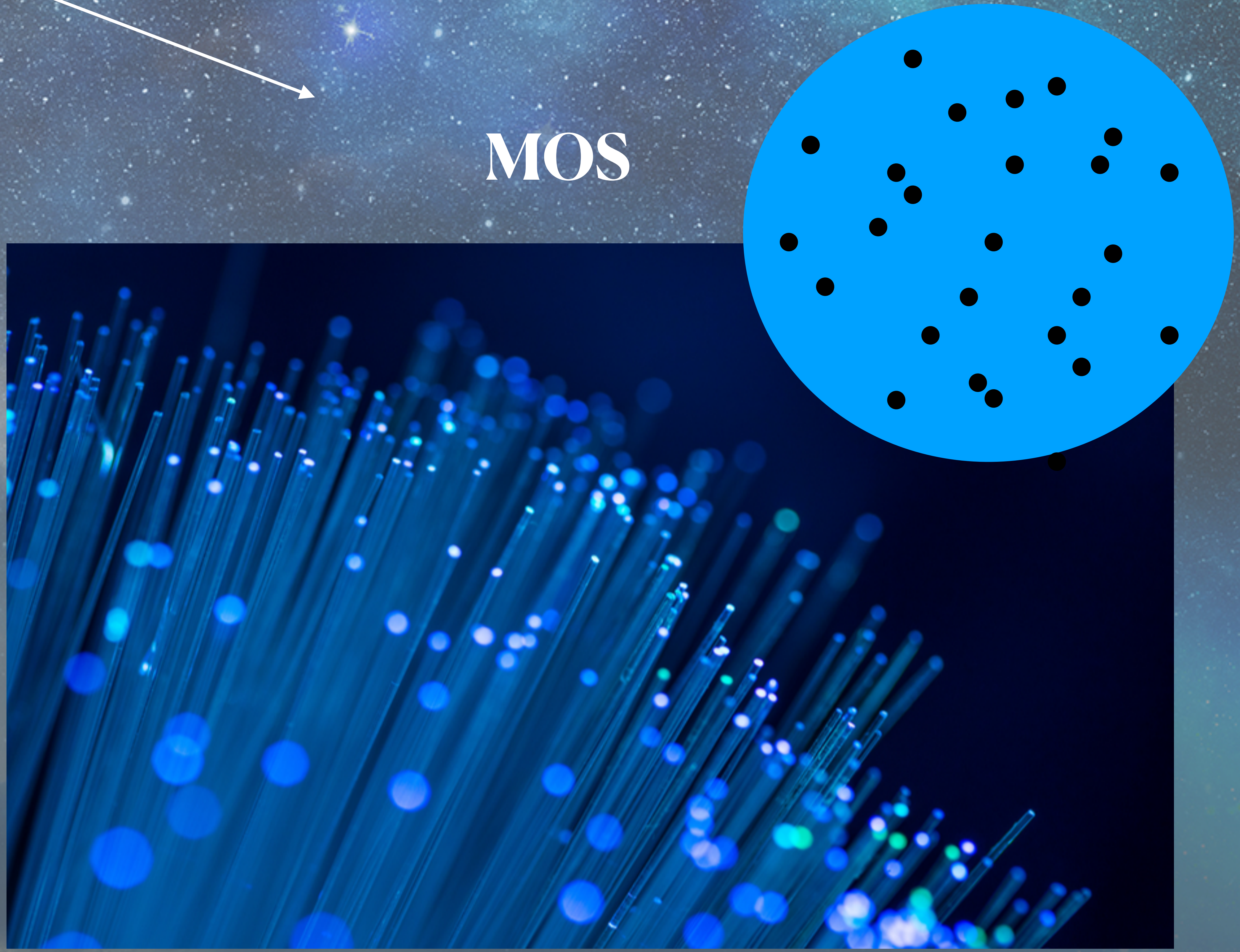
Integral Field and Multi-Object Spectroscopy

IFS



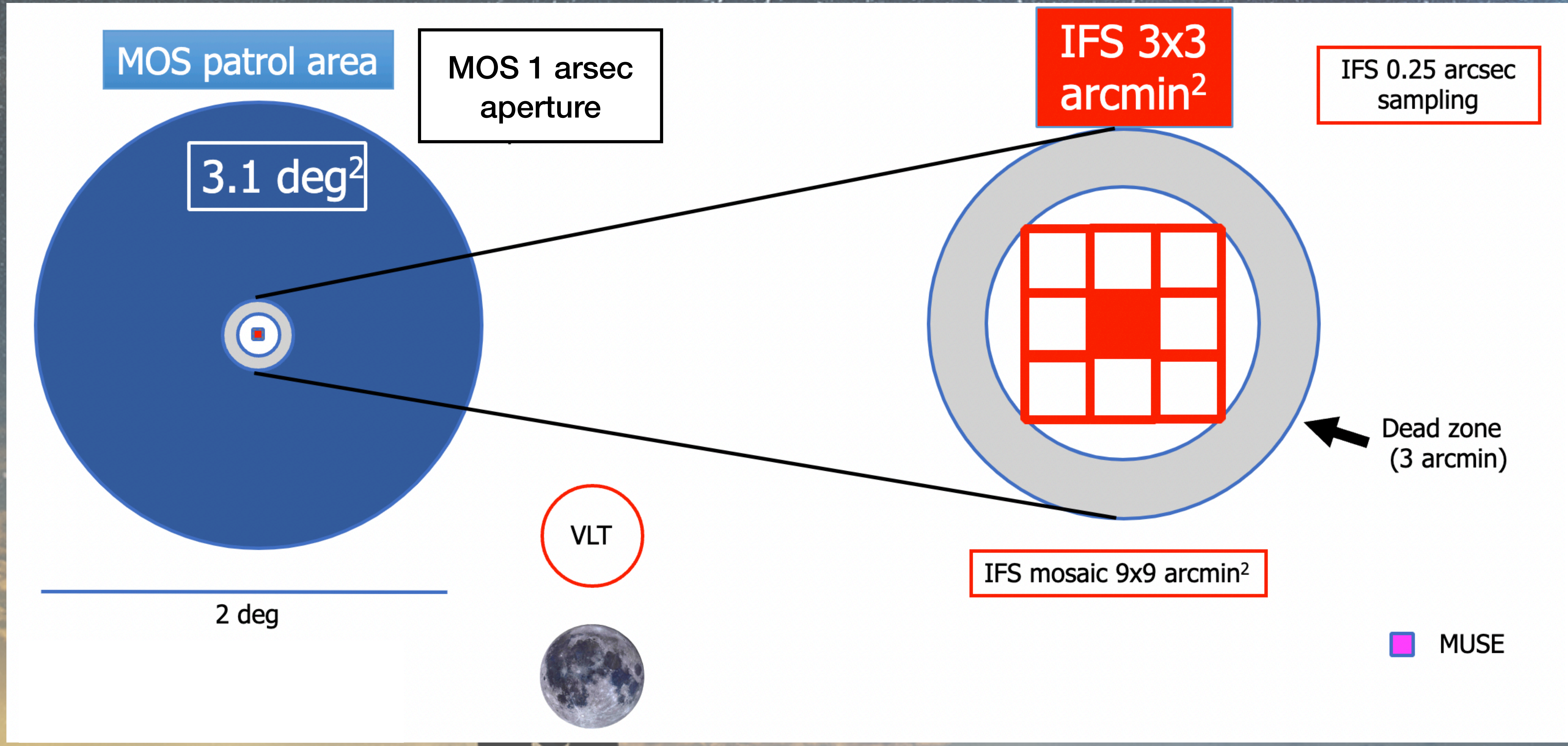
A spectrum for each pixel of the 2D field image

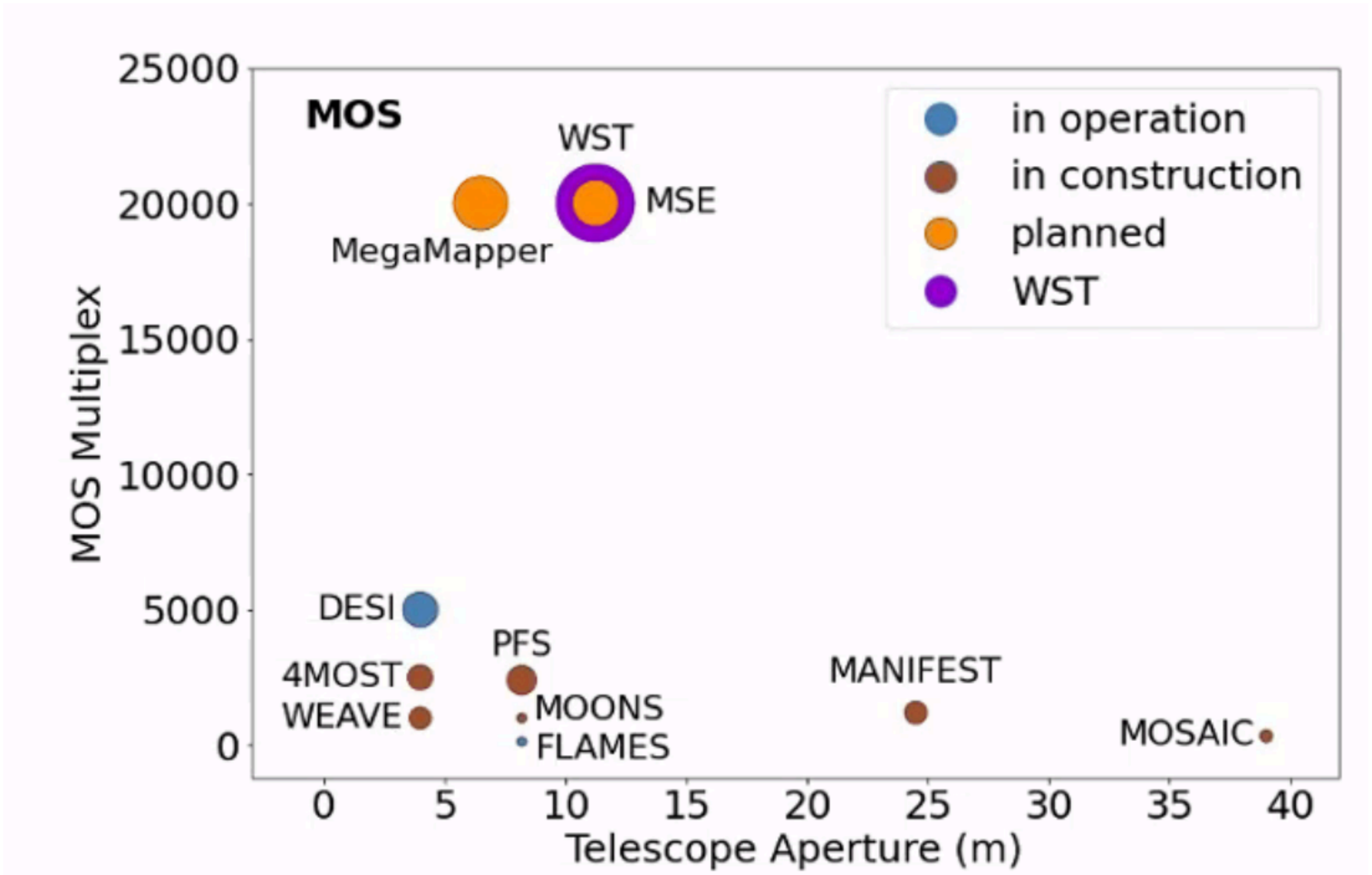
MOS

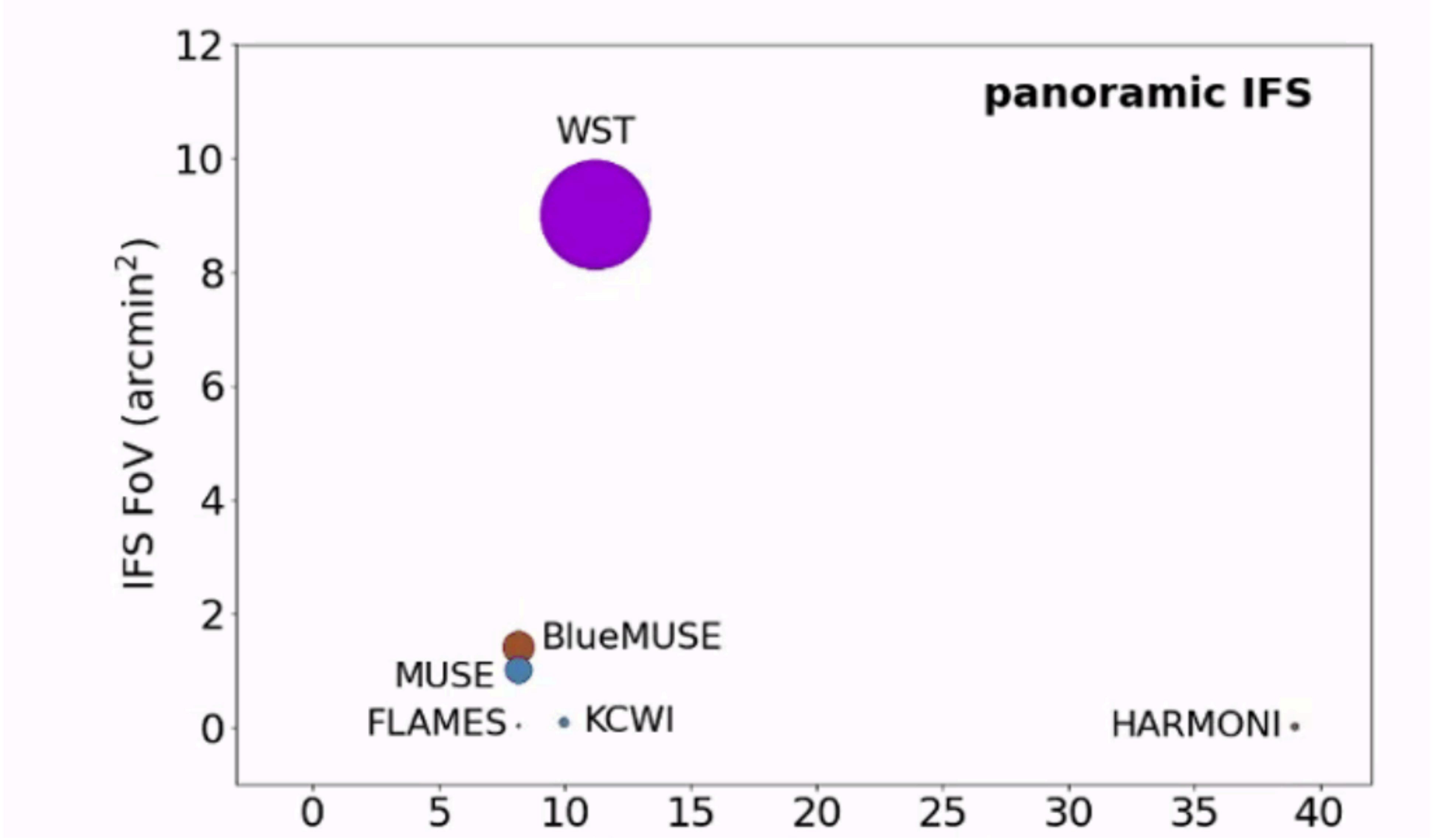


Fibers positioned on the localisation of the sources of interest

IFU and MOS with the Wide-field Spectroscopic Telescope



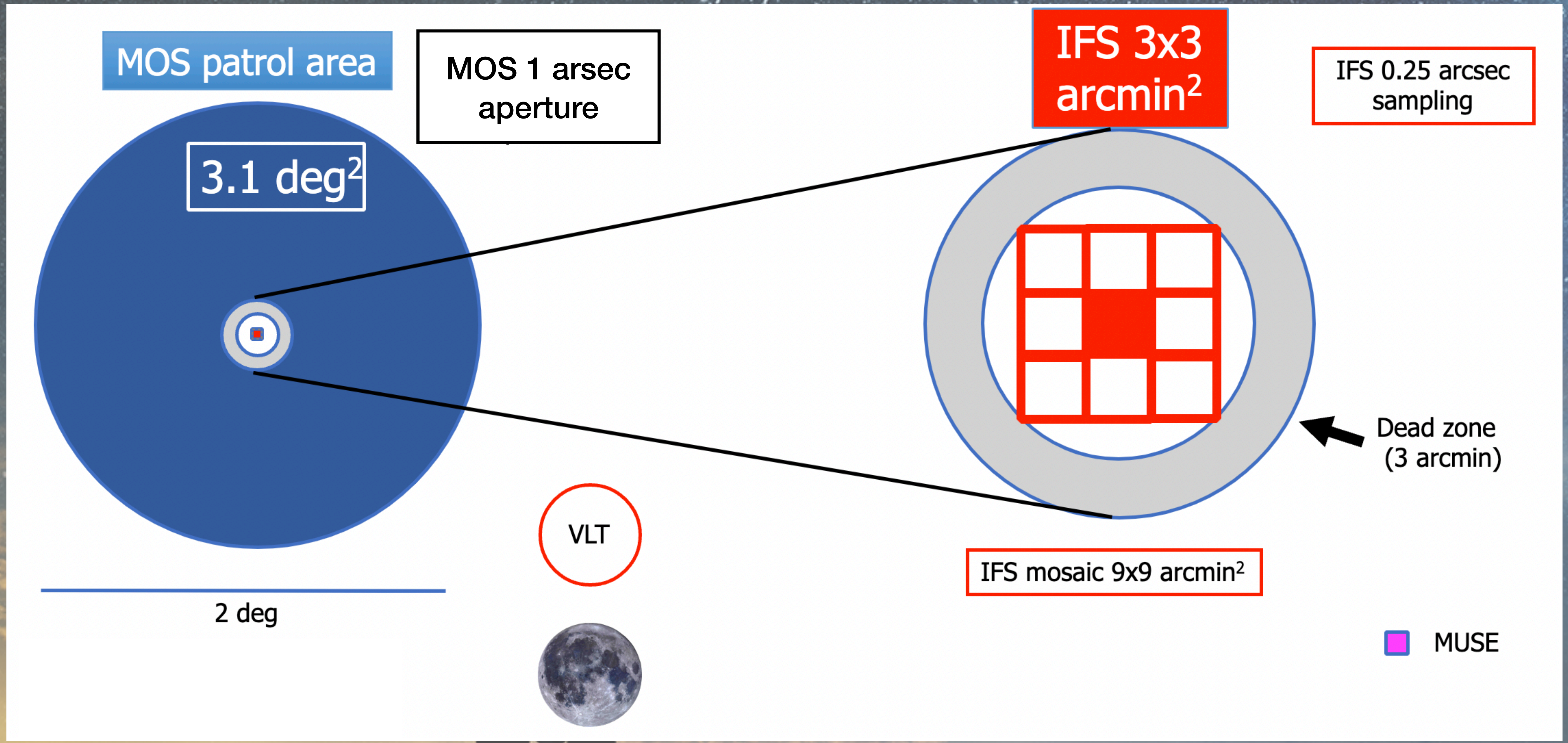


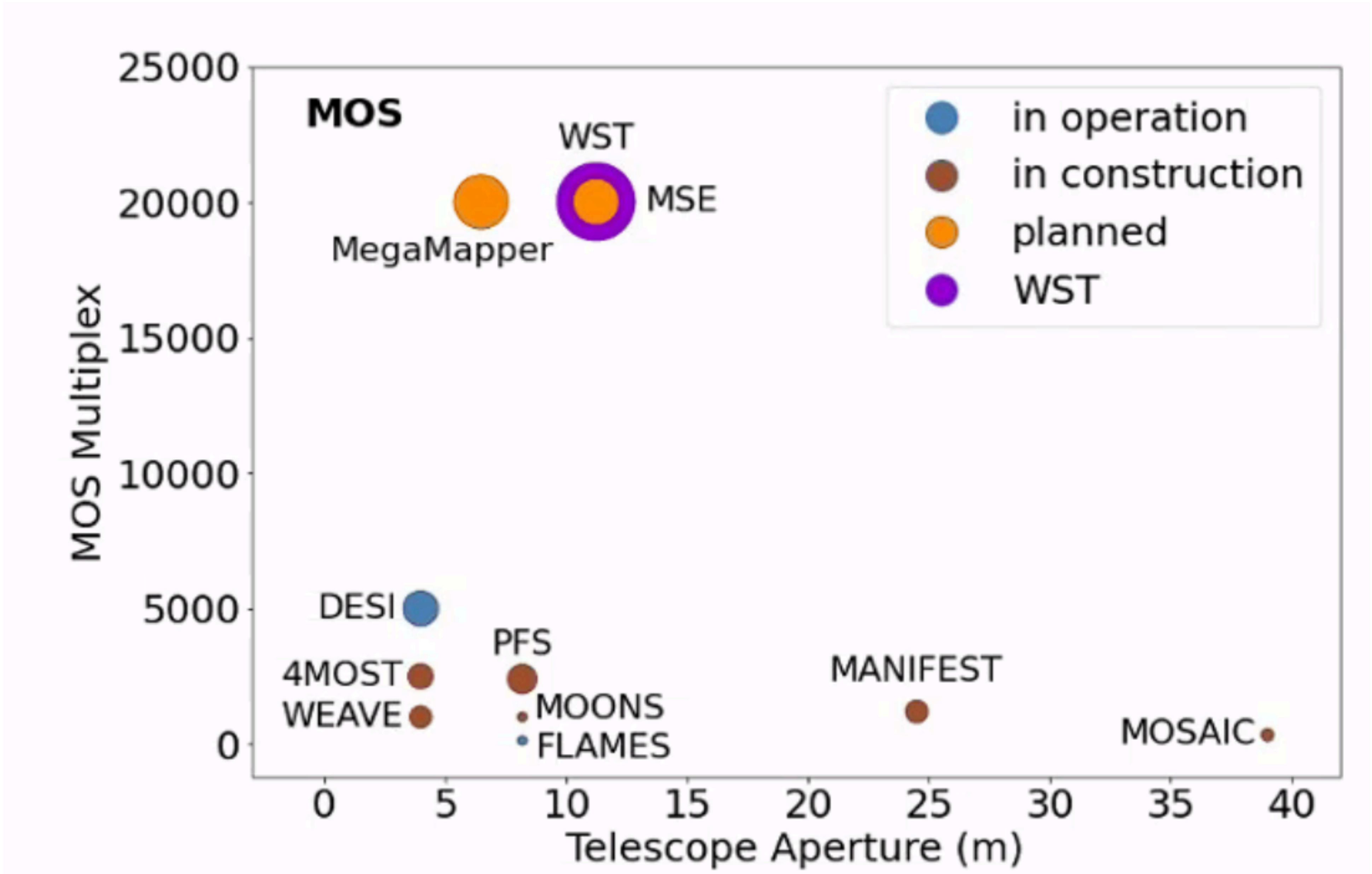


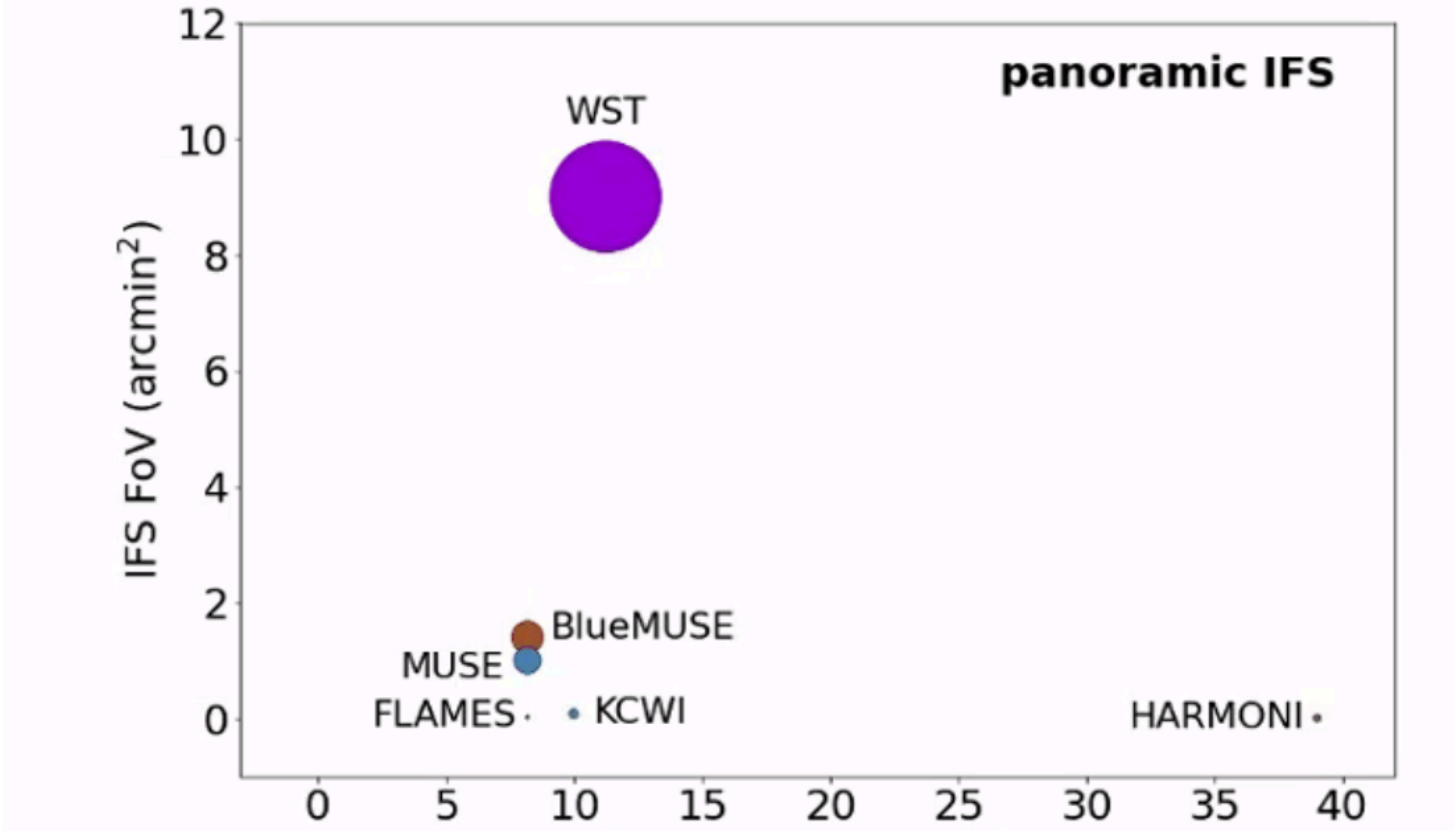
PI: Roland Bacon **(CRAL)**

- **10m** primary mirror
- **Large field of view** and high **multiplexing**
- Simultaneous **IFU** and **MOS**

IFU and MOS with the Wide-field Spectroscopic Telescope







Preparing an observing strategy

Science case within the WST Time Domain Working Group

"WST - ET synergies for BNS multi-messenger observations"

Division 4 of the **ET OSB:**
Multimessenger Observations

IFU and MOS with the Wide-field Spectroscopic Telescope

Preparing the observing strategy

Stand-alone scenario

Galaxy targeted search with IFS and MOS within the GW signal error region

Synergy with optical-NIR photometric observations

IFS and MOS used to target the counterpart candidates found by optical-NIR surveys

IFU and MOS with the Wide-field Spectroscopic Telescope

Preparing the observing strategy

- **Simulations** of WST observations
- Estimating the **number of galaxies** in the **GW signal error volume** of the events that are detectable with WST

  ➡ **galaxies number density** reported in the literature

  ➡ integrating the **luminosity function** $\Phi(M)$ to estimate the number of galaxies for **different magnitude intervals**

Stand-alone scenario
Galaxy targeted search with IFS and MOS within the GW signal error region

Synergy with optical-NIR photometric observations
IFS and MOS used to target the counterpart candidates found by optical-NIR surveys

IFU and MOS with WST: simulations

GSSI group

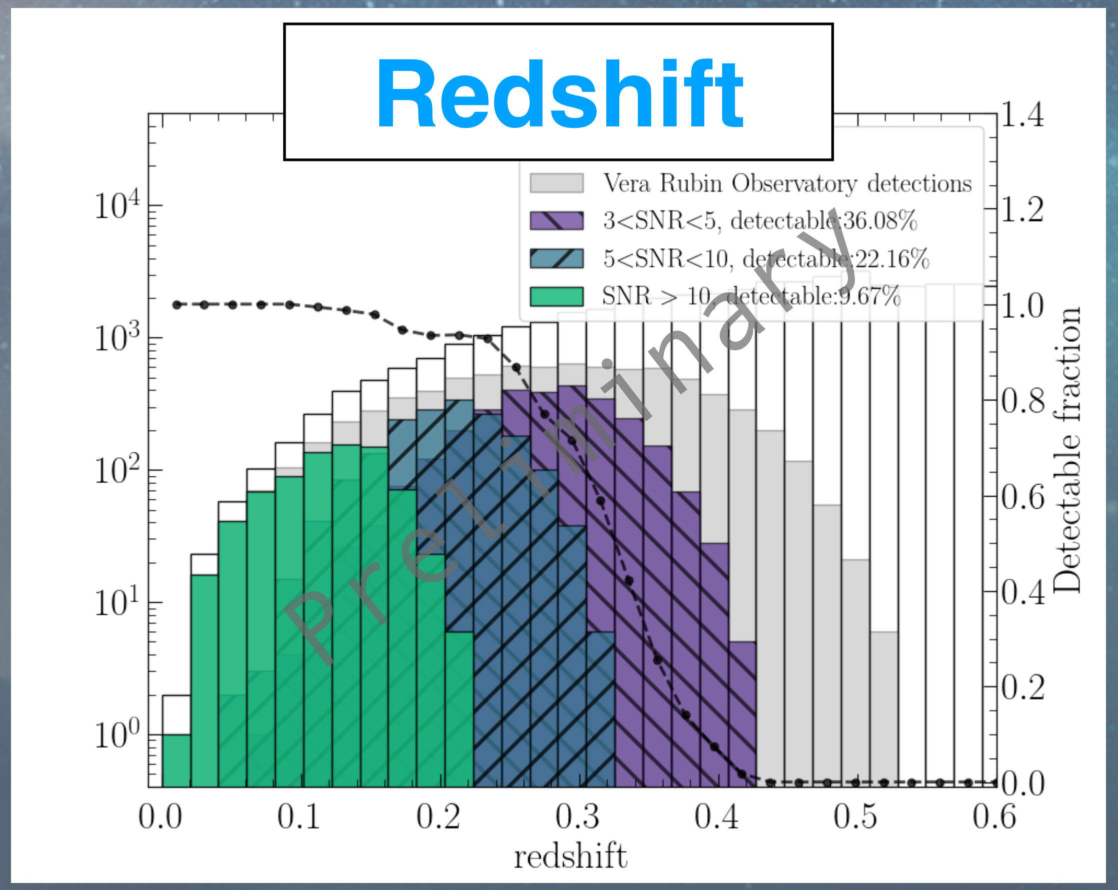
ET BNS populations

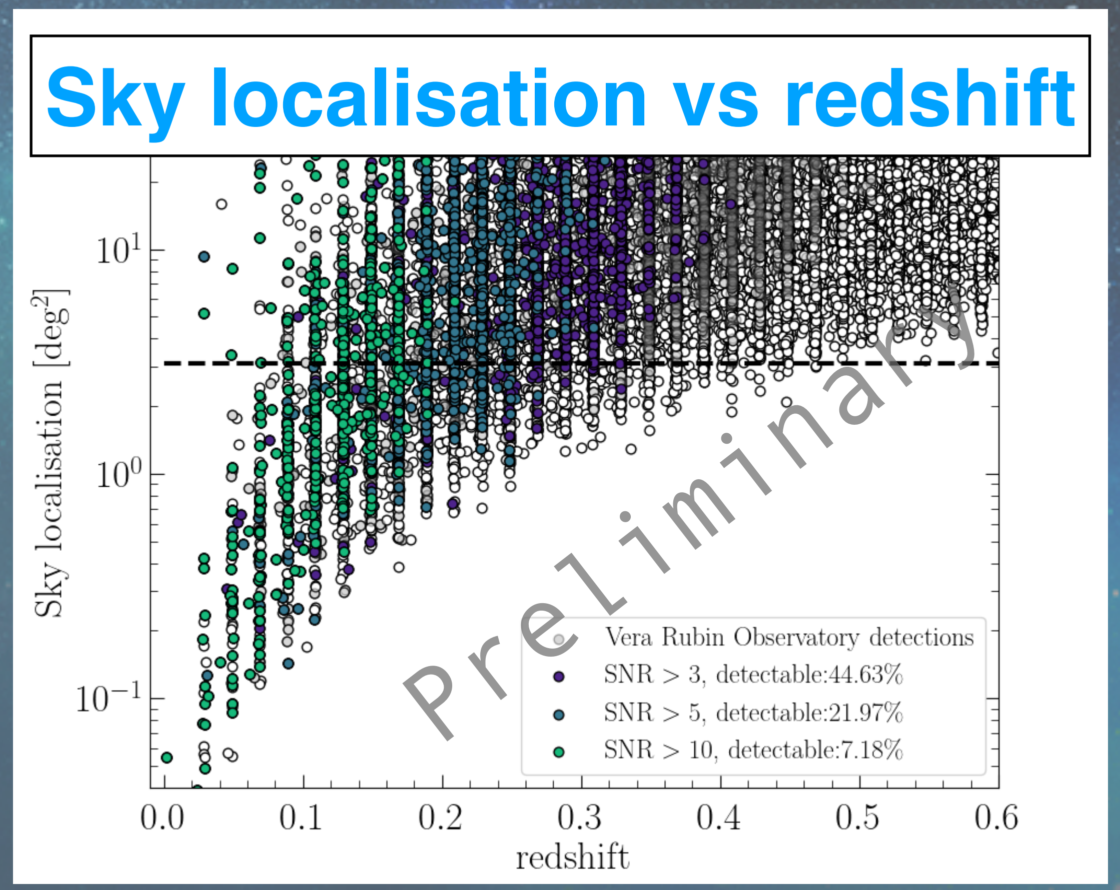
KN + GRB emission

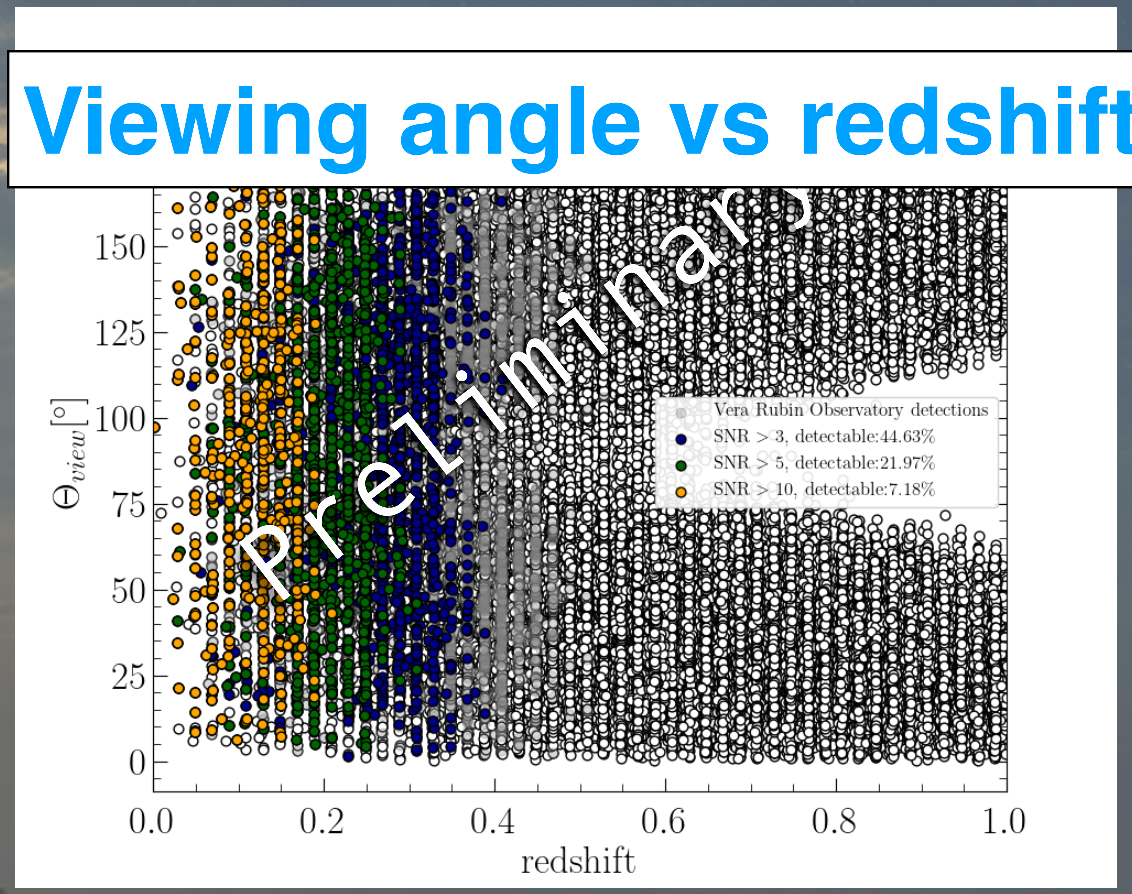
WST

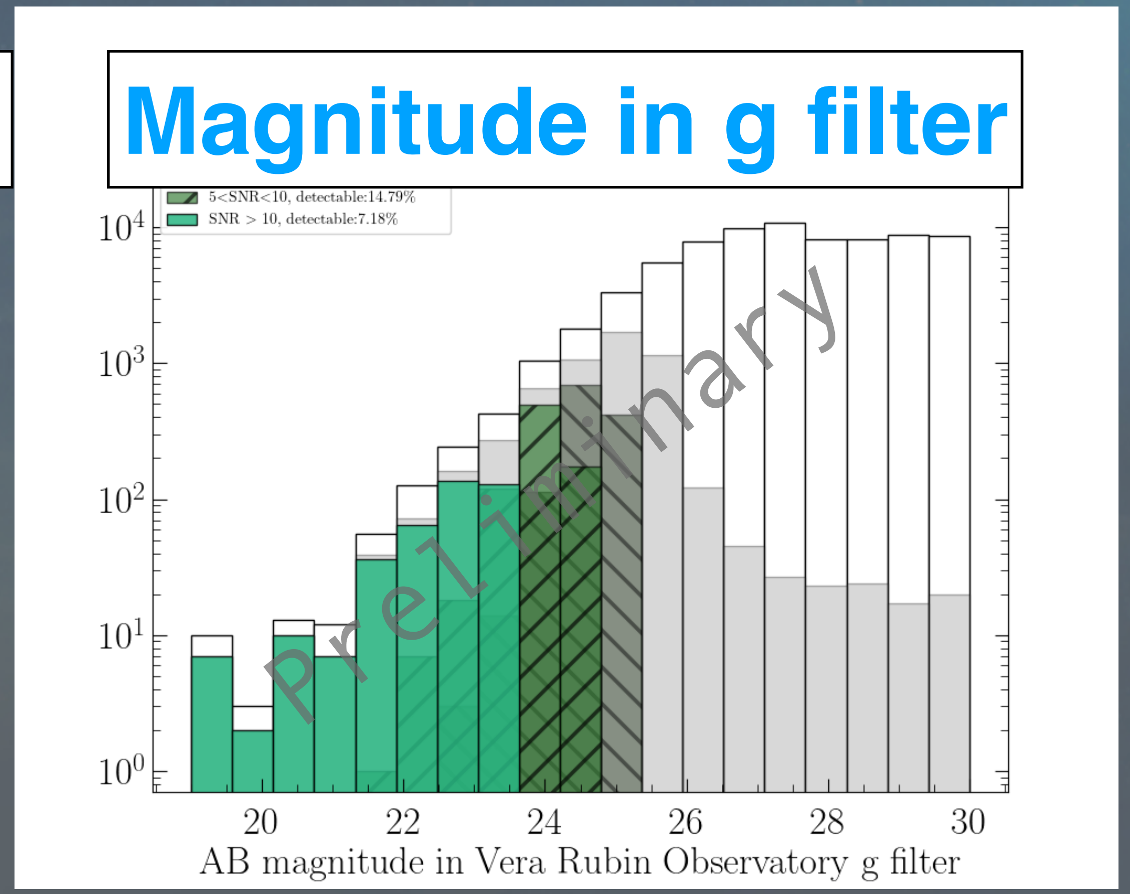
Detectability and **characterisations** of ET BNS counterparts with WST

Analyse how the results depend on the **observable properties** of the BNS population

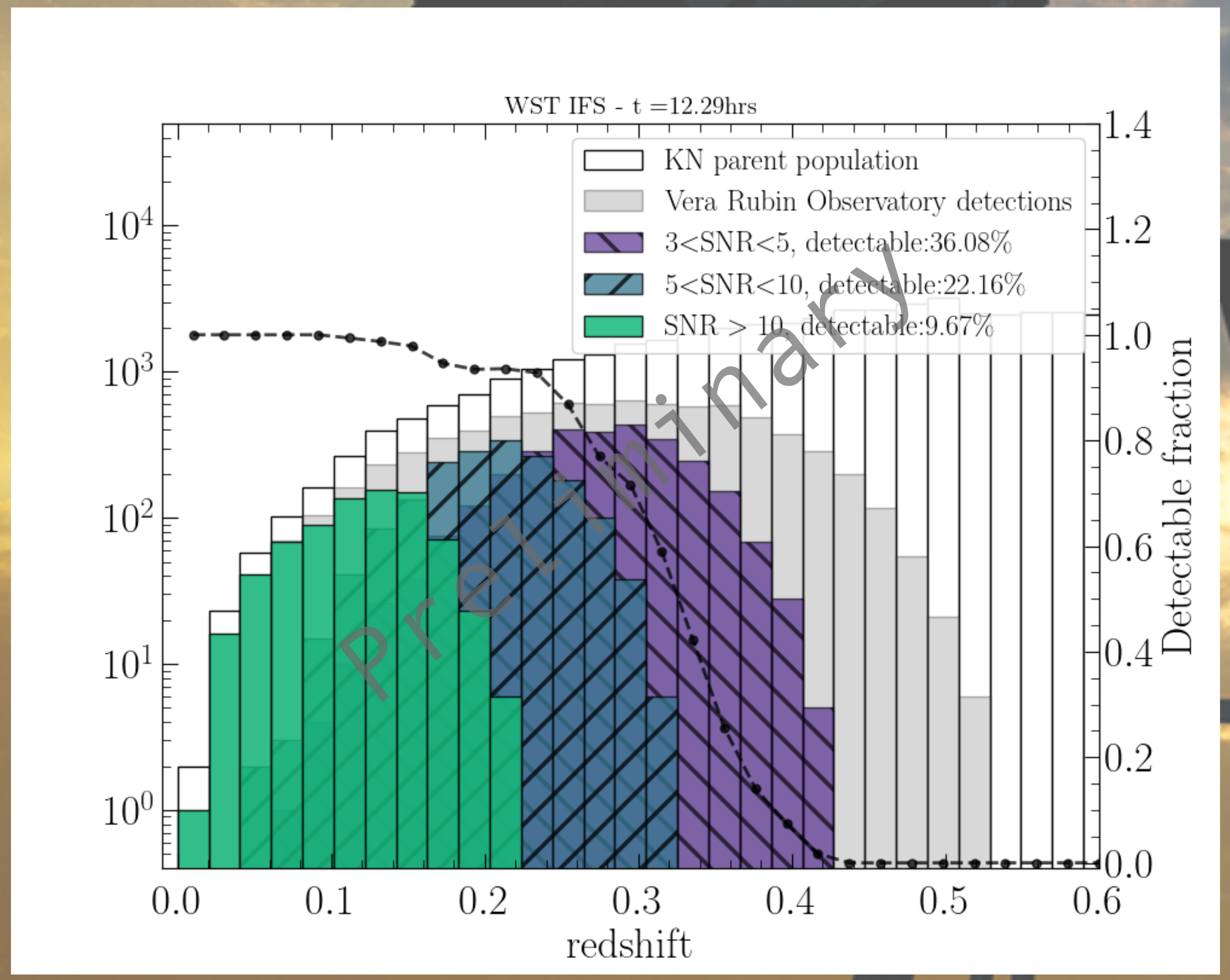


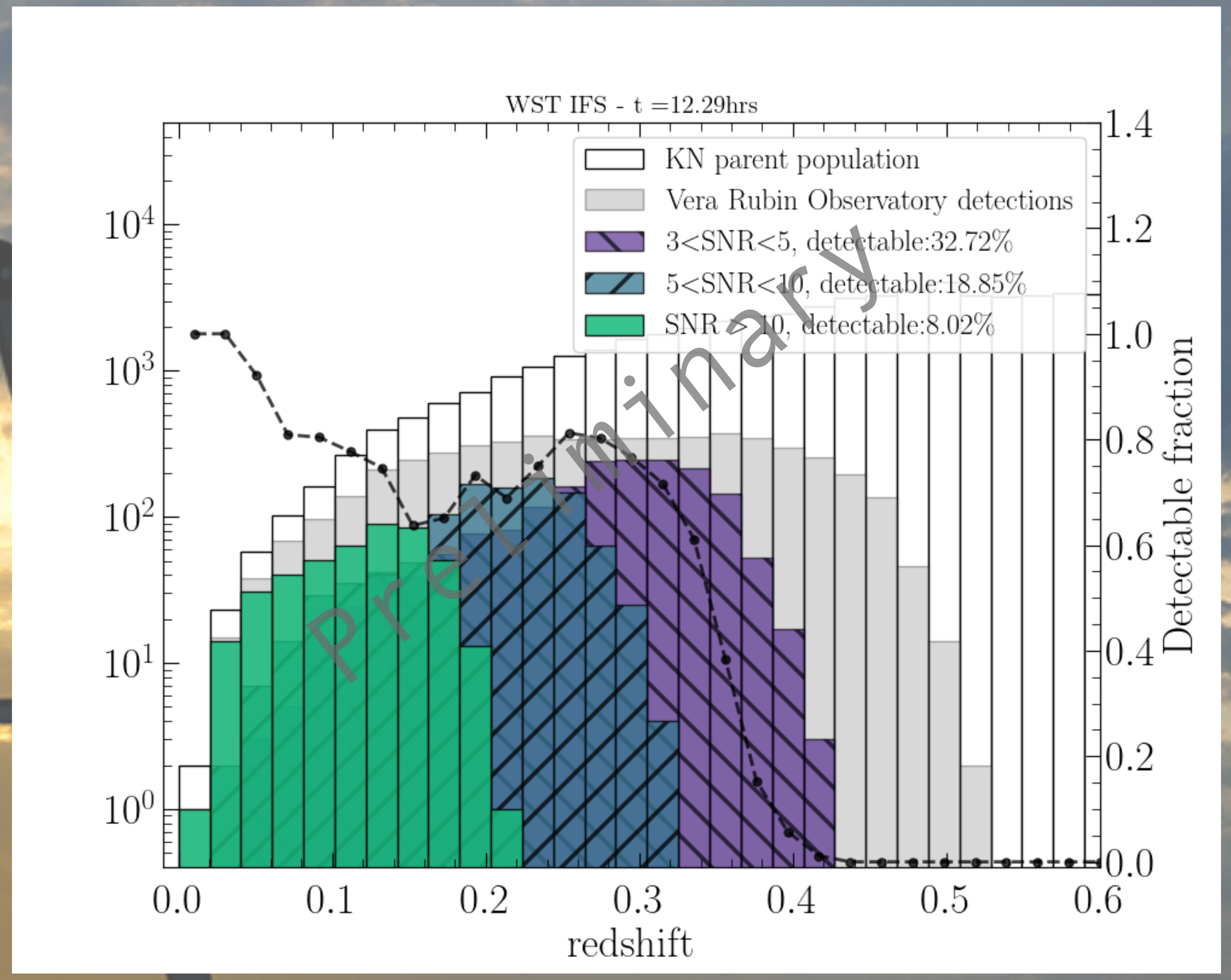






Analyse how the results depend on the **intrinsic properties** of NS

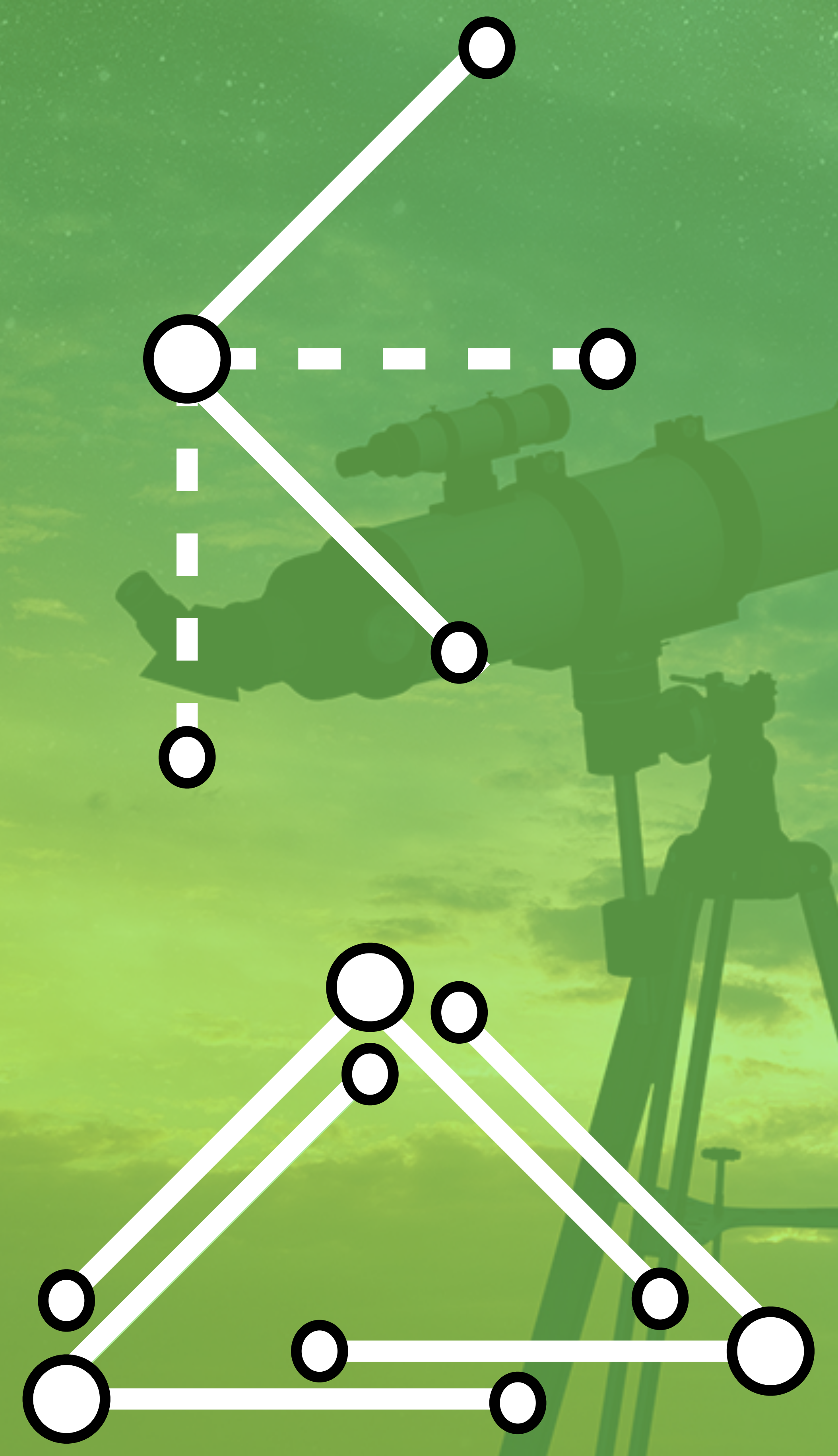




NS EoS:	**BLh**	**APR4**
NS mass distribution:	**gaussian**	**uniform**

ET-WST synergy

BNS population



sky localisation < $100 deg^2$

EM counterparts

- AT2017gfo-like KN
- theoretical KN
- GRB afterglows

light curves: AB magnitudes in Rubin g r i and z filters as a function of time (obs. frame)

WST ETC

ETC version 0.31

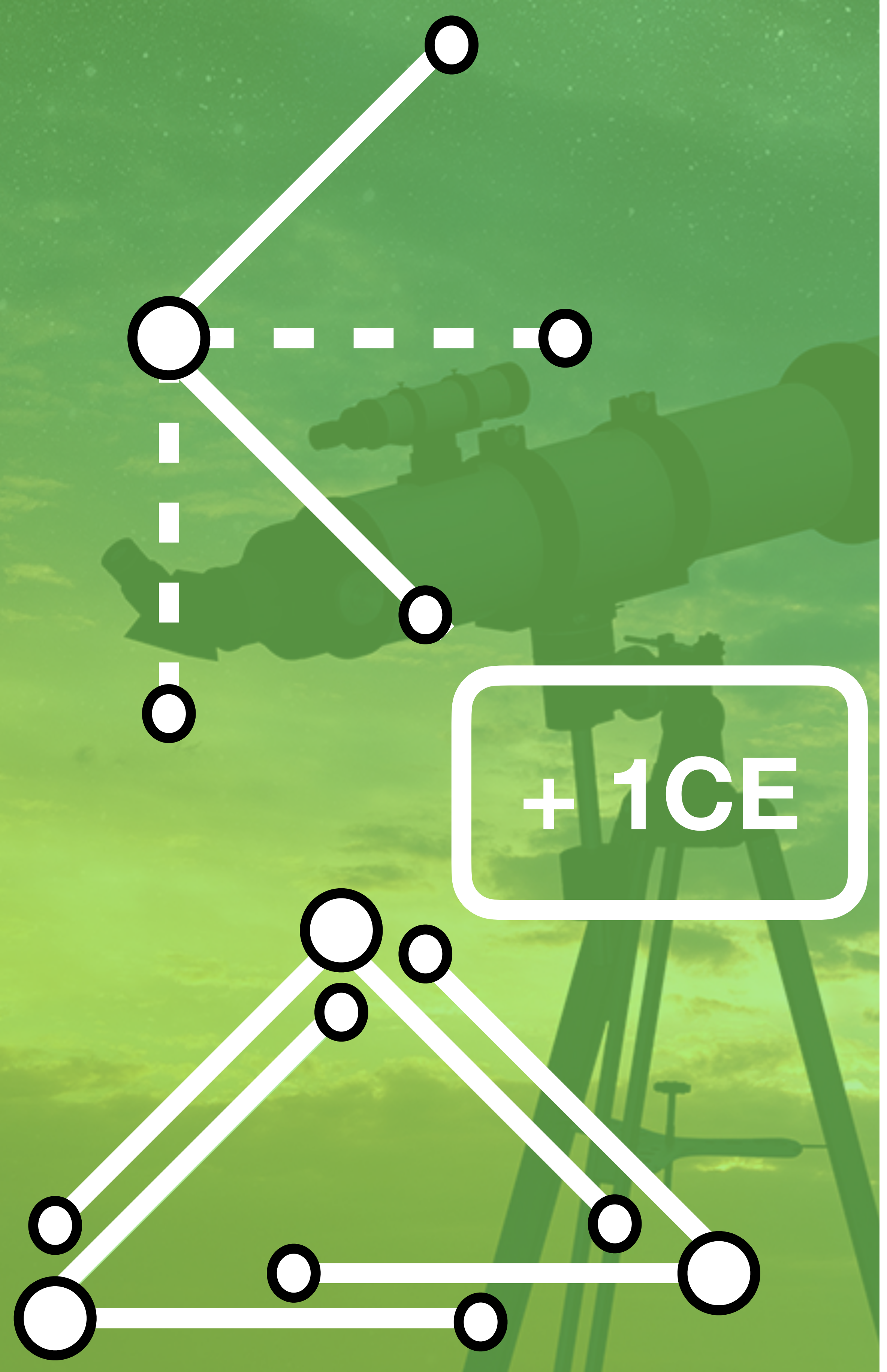
IFS → MOS

- Blue
- Orange (MOS)
- Red

30 minutes and 60 minutes exposures

ET-WST synergy

BNS population



sky localisation < $40\mathrm{deg}^2$

EM counterparts

- AT2017gfo-like KN
- theoretical KN
- GRB afterglows

light curves: AB magnitudes in Rubin g r i and z filters as a function of time (obs. frame)

WST ETC

ETC version 0.31

IFS → Blue / Red

MOS → Blue / Orange (MOS) / Red

30 minutes and 60 minutes exposures

ET-WST synergy

Preliminary results

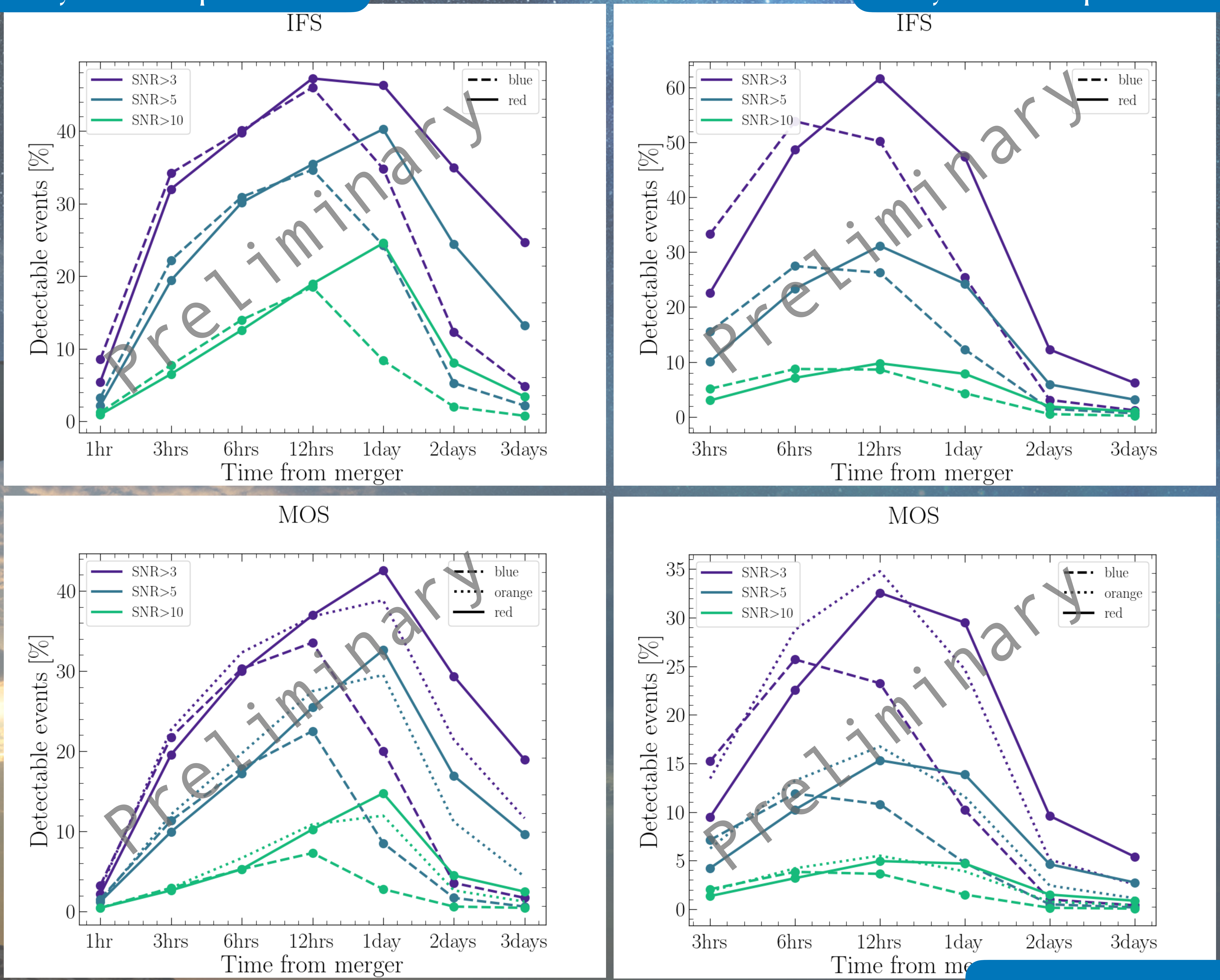
1 year of ET operations

10 years of ET operations

AT2017gfo KN model

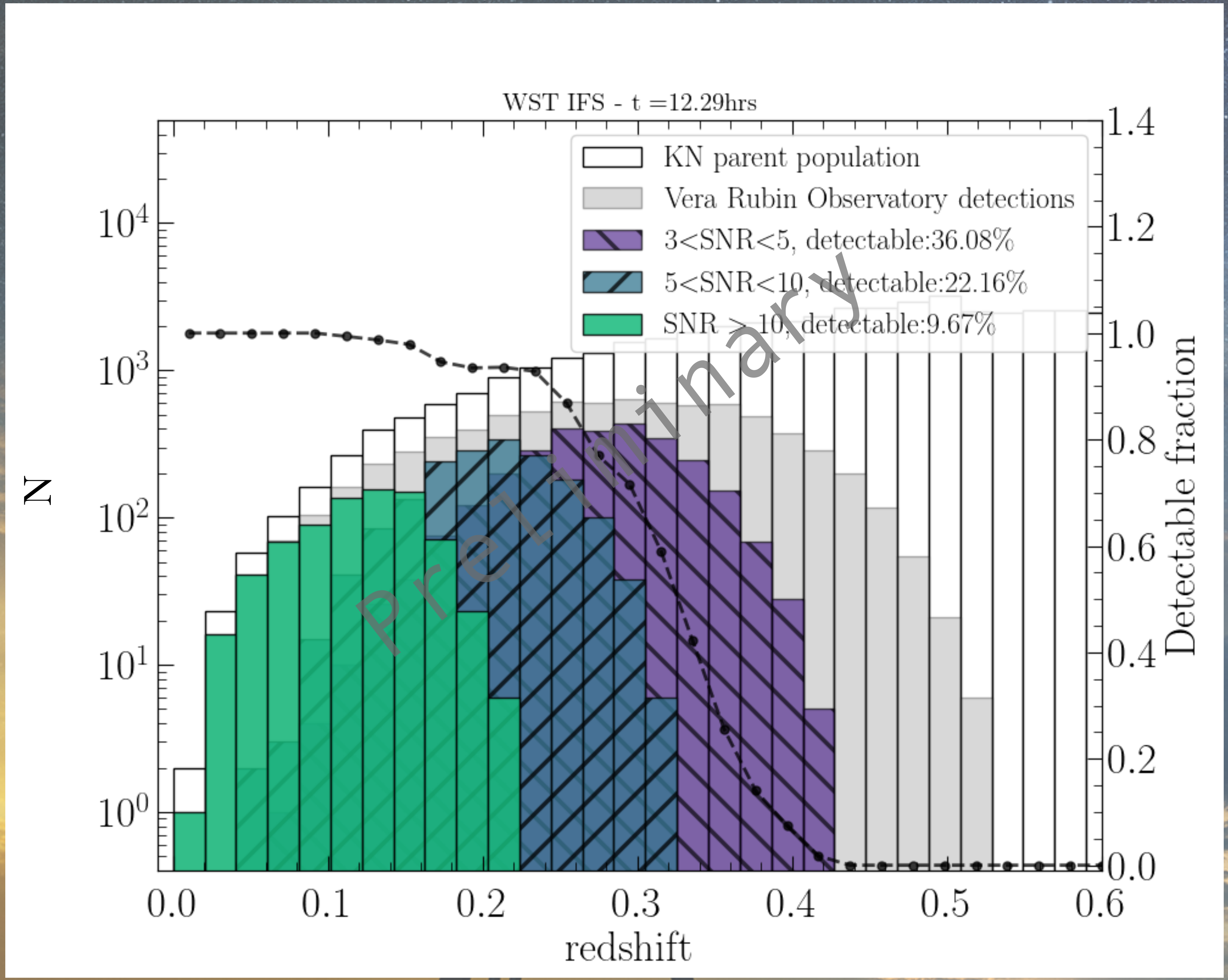
KN theoretical models

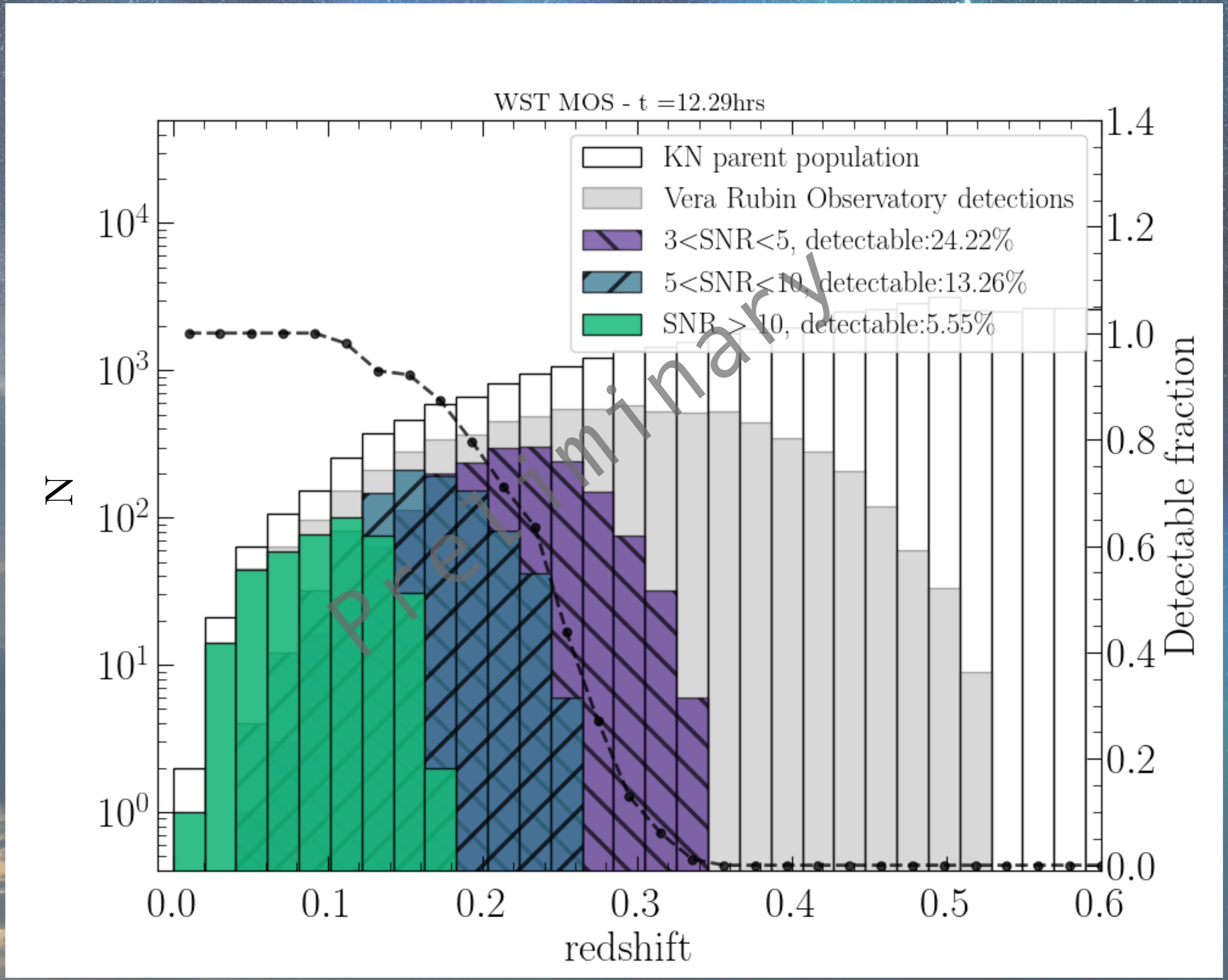
BLh gaussian



ET-WST synergy

Preliminary results

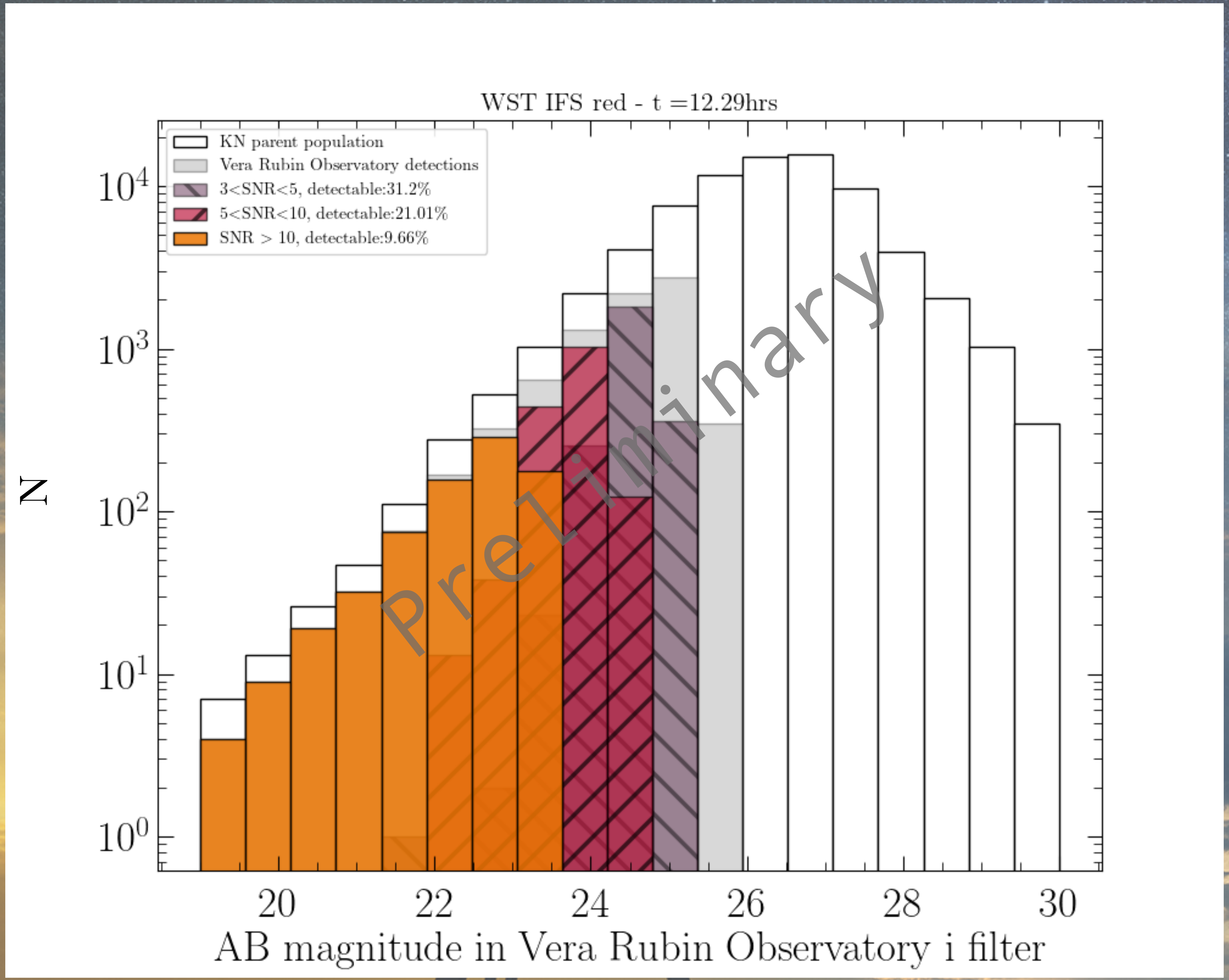


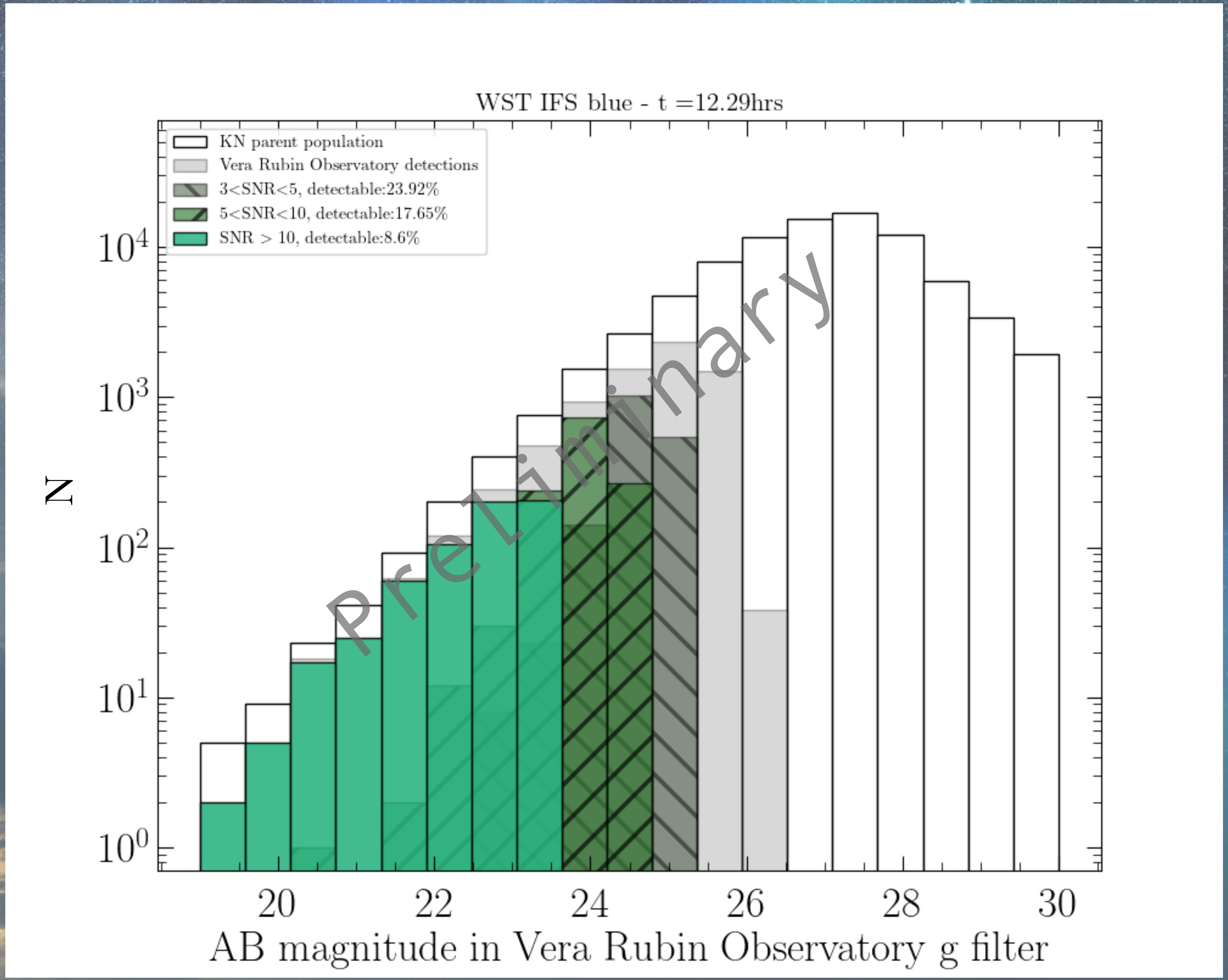


White: ET+CE **BNS** detections in **10 years** of operations
Grey: Vera Rubin Observatory **KN** detections
Colored: WST **KN** detections

ET-WST synergy

Preliminary results





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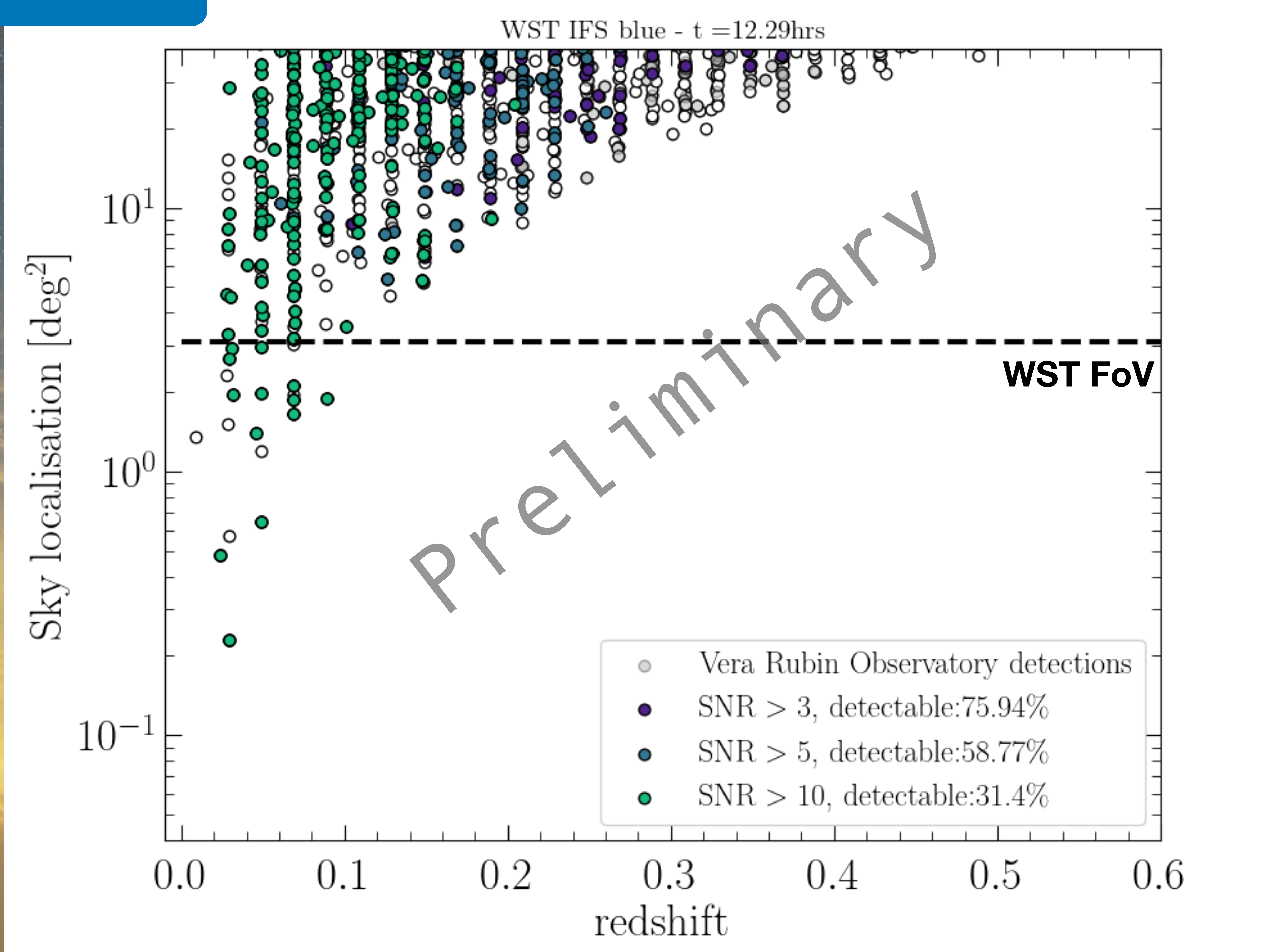
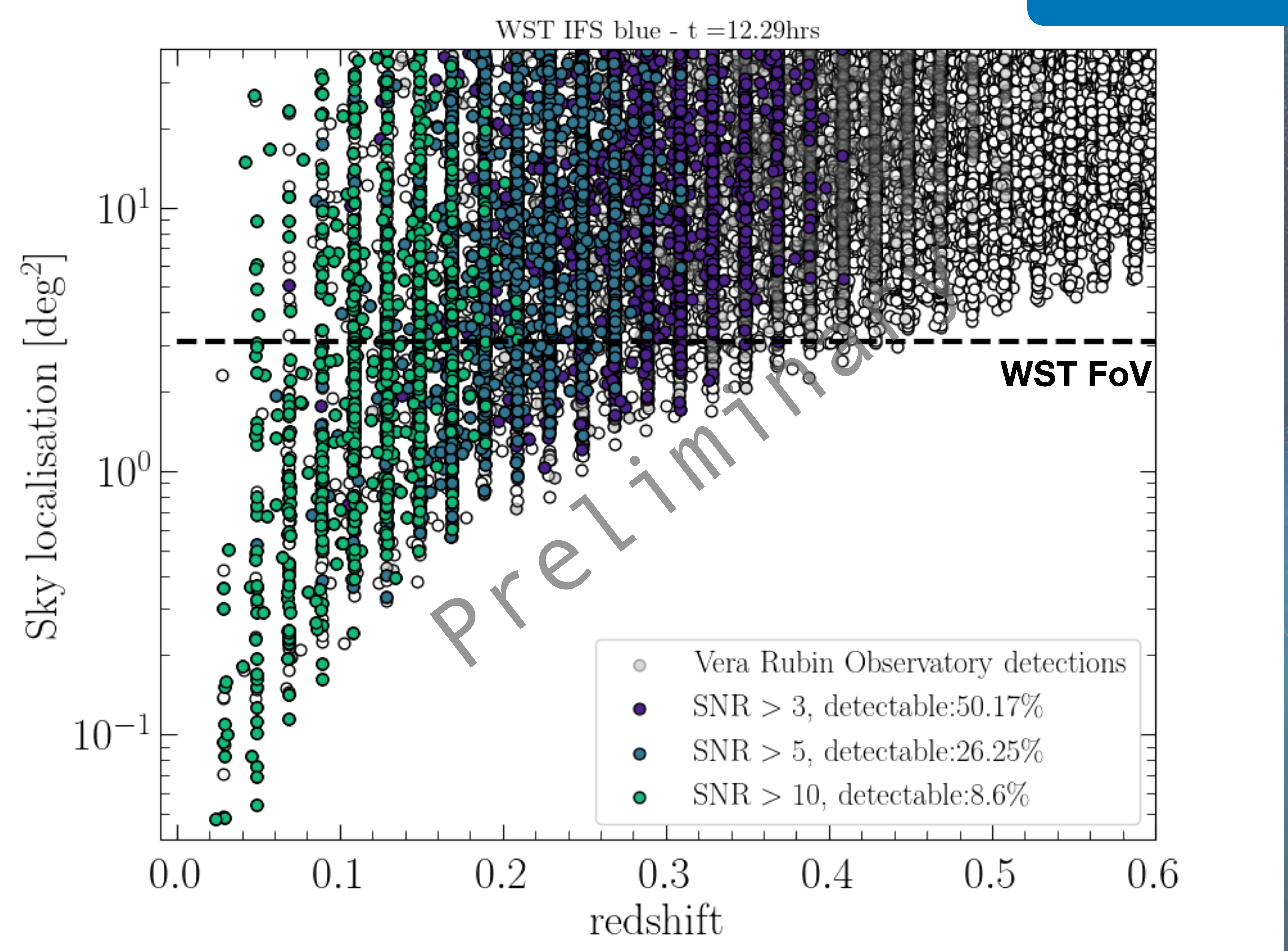
ET-WST synergy

Preliminary results

ET



ET+CE



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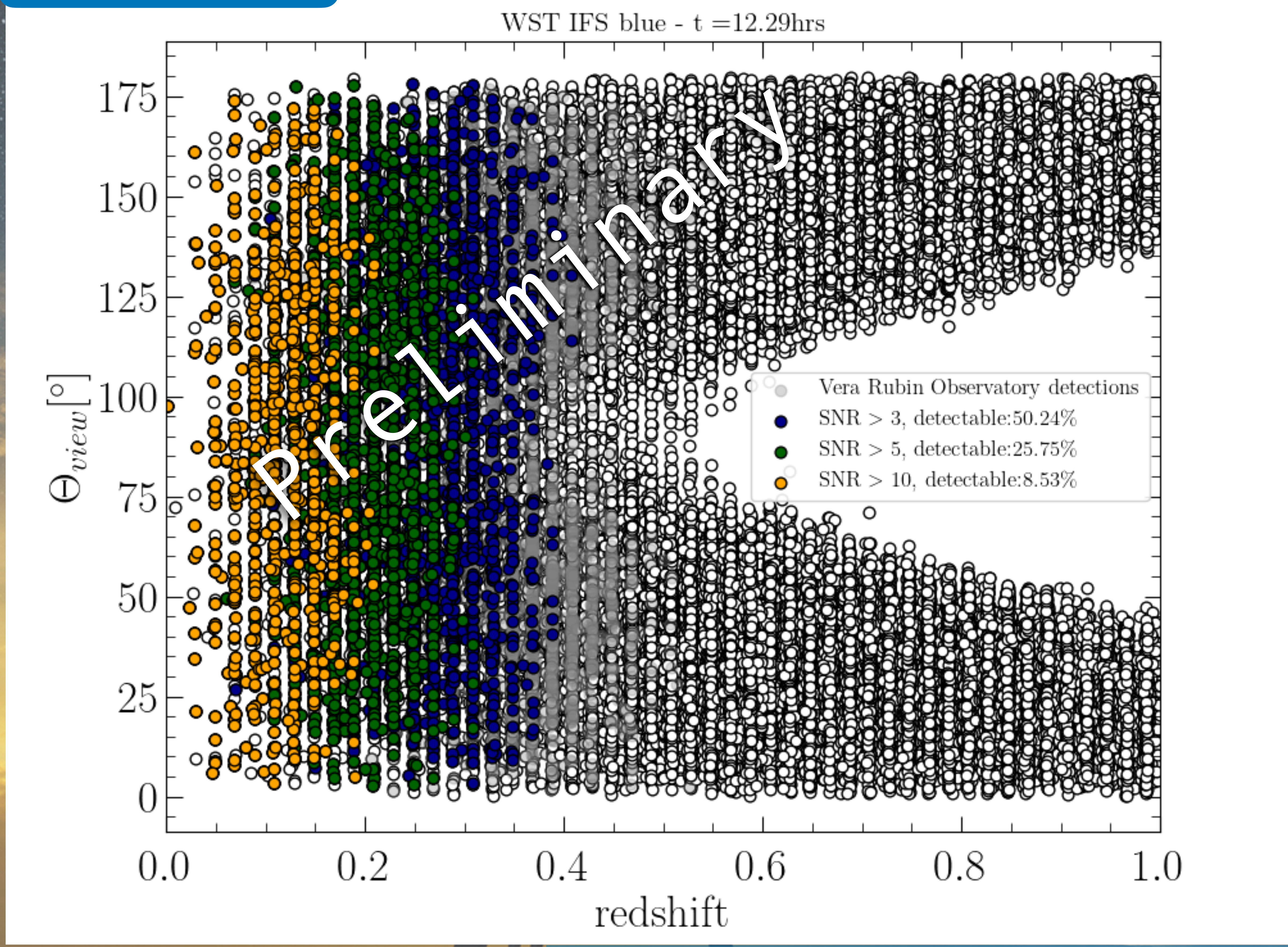
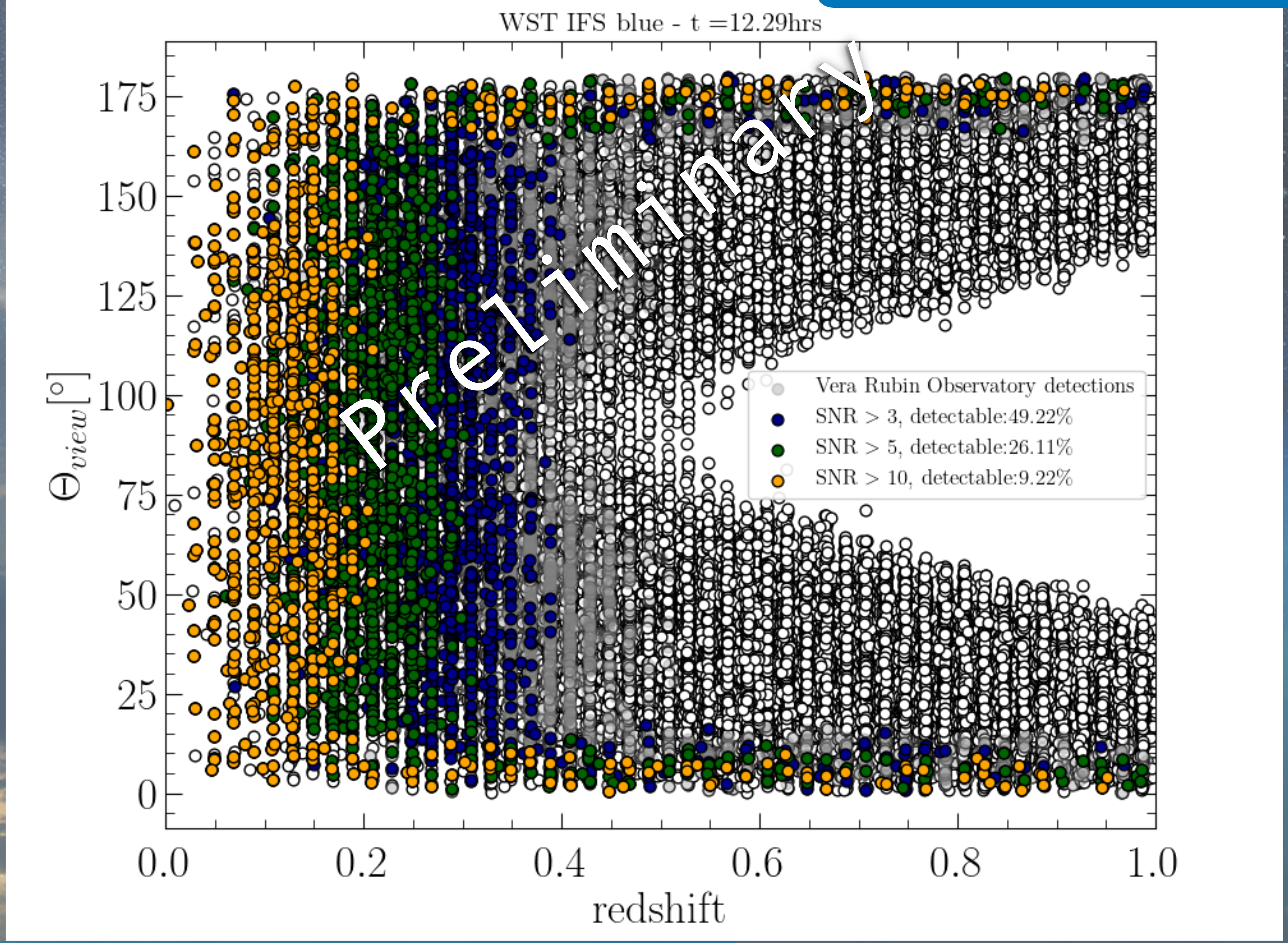
ET-WST synergy

Preliminary results

KN only



KN+GRB afterglow



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Conclusions and future prospects

- **IFS** and **MOS** with **WST** are well suited for the **identification** and **characterisation** of **EM counterparts of next generation GW detections**

- With WST, **KN** can be unveiled up to **z~0.4** and **AB magnitude ~25**
- **GRB afterglows** contribution is observable at **high redshift** for systems with small viewing angle, up to **~15°**

- An optimised **observing strategy** is necessary and it has to be prepared well in advance of ET operations: we consider to use WST in a **stand alone scenario** and in **synergy** with **optical-NIR photometric observations**

- This work can be adapted to make predictions for **LVK O5**, with IFS and MOS facilities available at the time of O5 operations

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Thank you!

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