ET-WST synergy for next generation multi-messenger observations
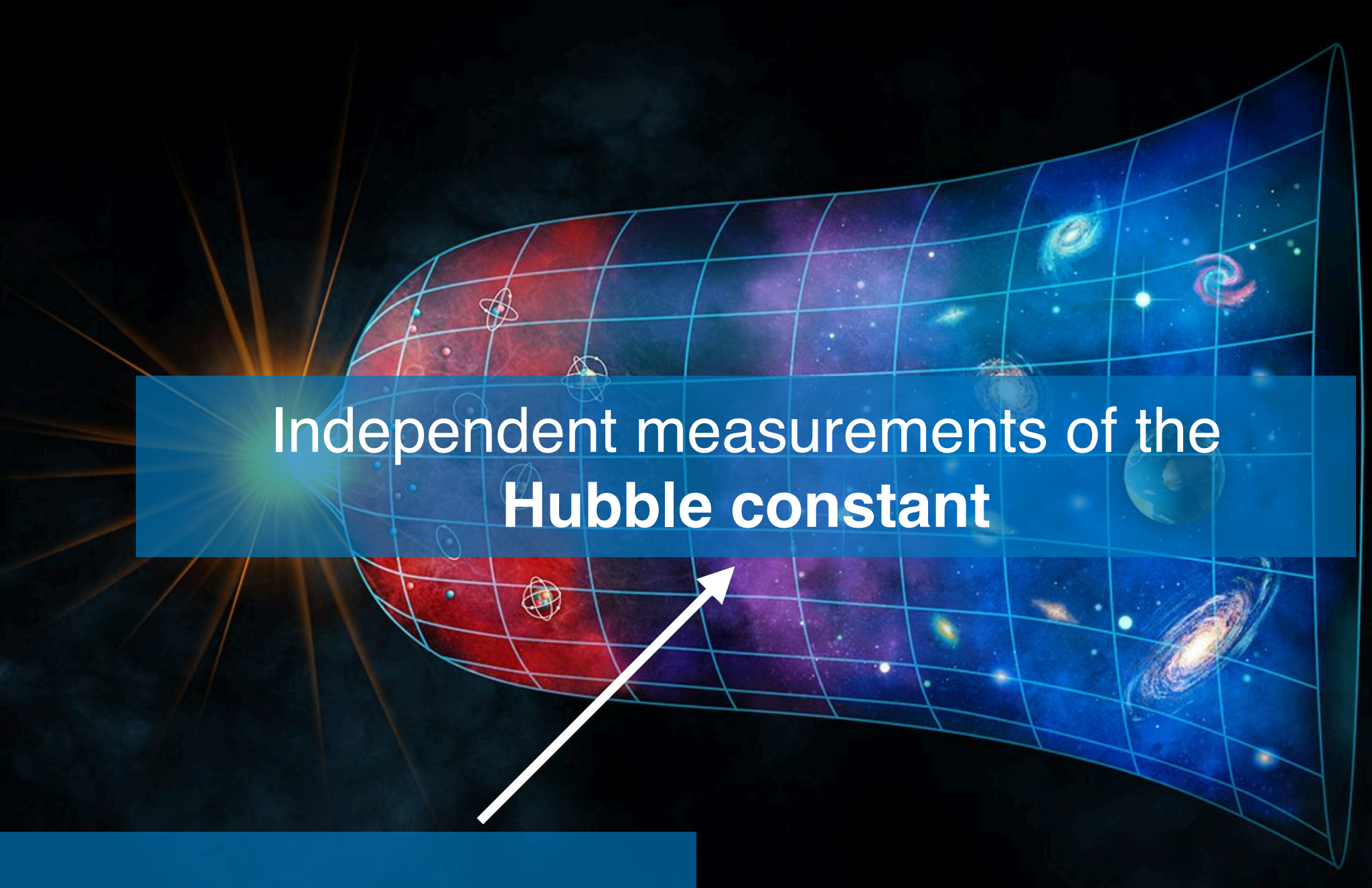
Sofia Bisero
Supervisor: Susanna Vergani

GEPI, Observatoire de Paris

Image credit: Claudio Ventrella

Sofia Bisero - Atelier API - November 17th, 2023

Researching EM counterparts of GW events

Understanding **BNS population** and **massive stars evolution**

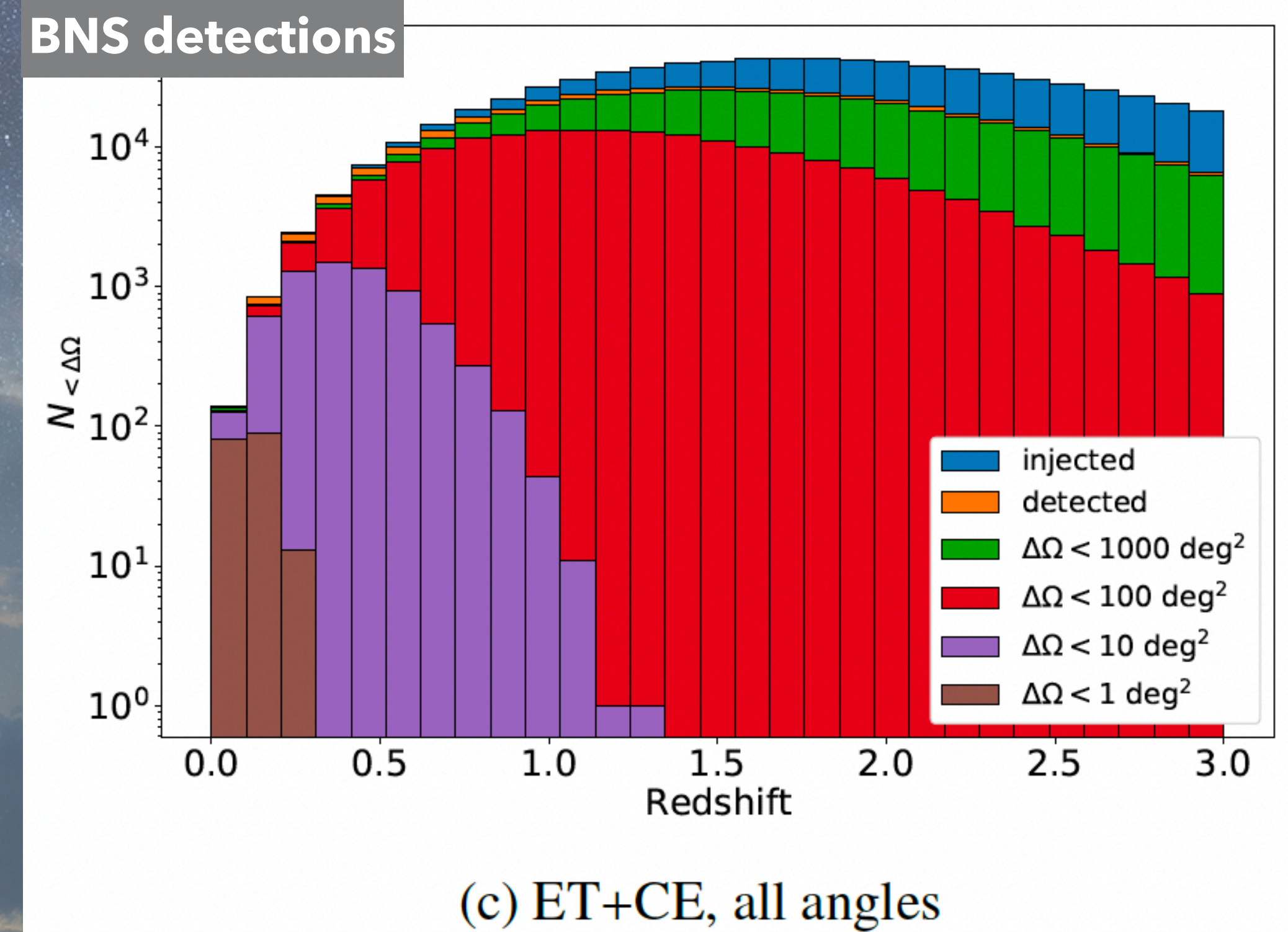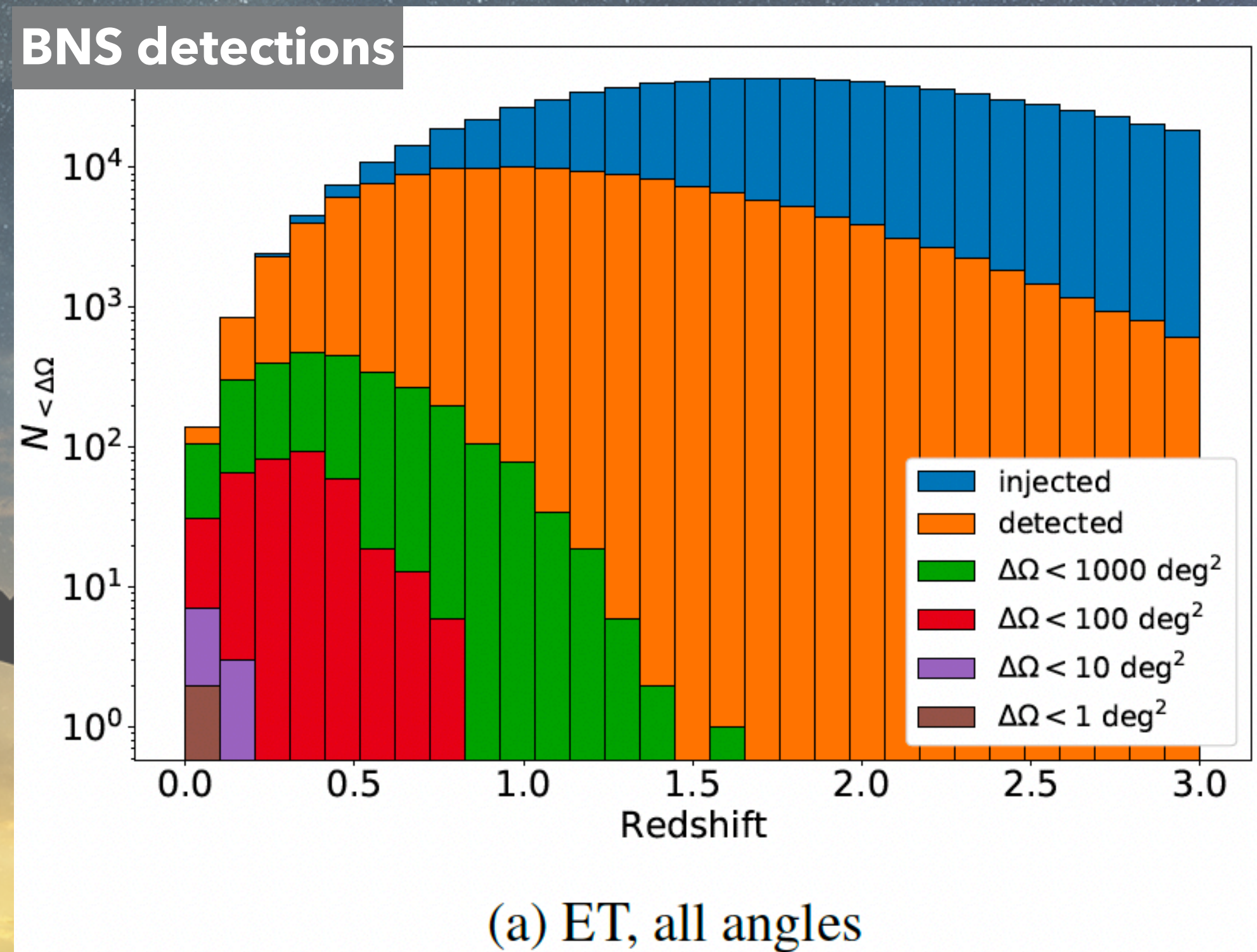Independent measurements of the **Hubble constant**

Studying **KN** and their contribution to **heavy elements nuclesynthesis**

Investigating **GRB jet structure**

BNS beyond the Local Universe with ET

Ronchini+22
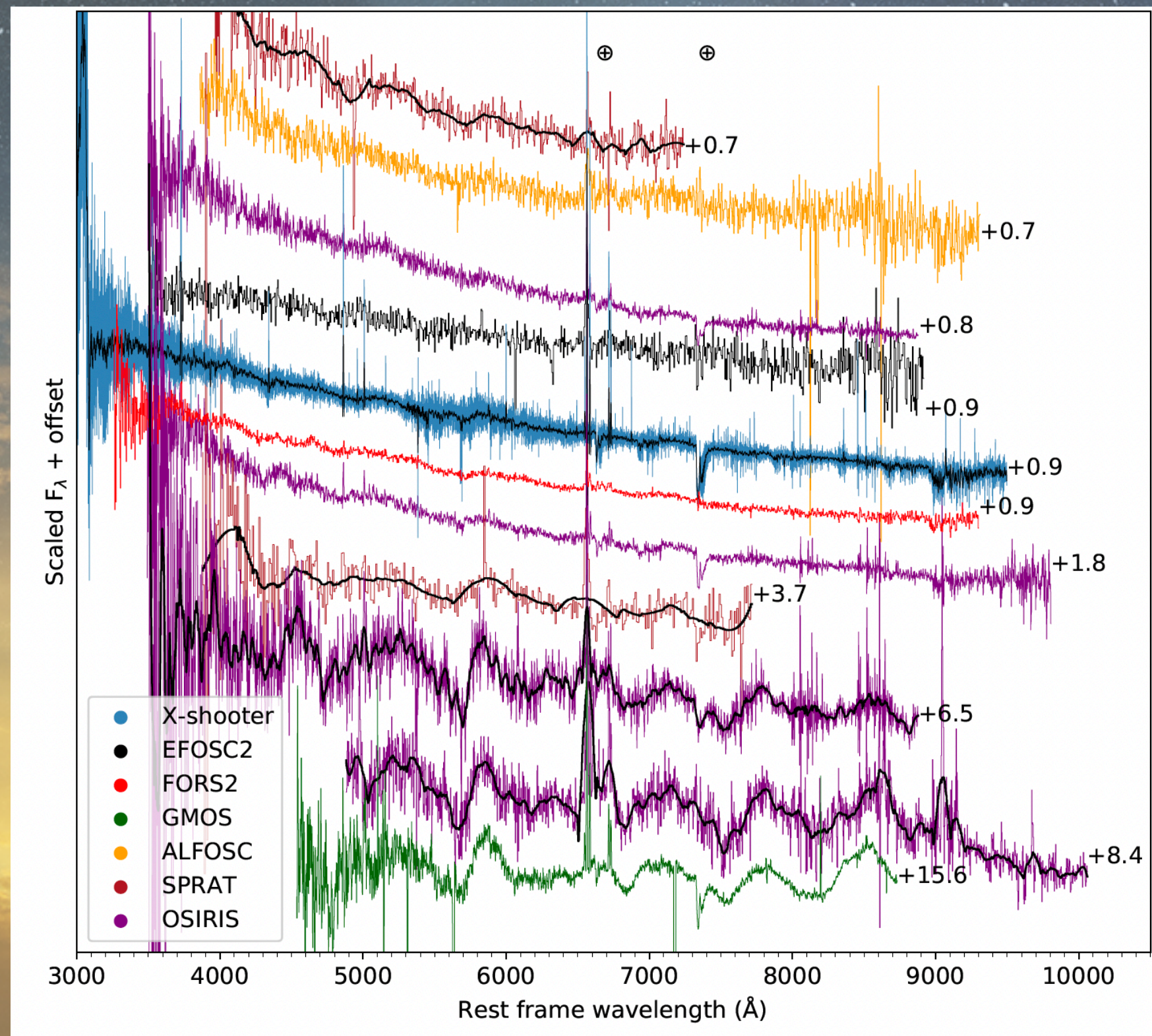

(a) ET, all angles

(c) ET+CE, all angles

Larger volume of the Universe explored
Higher number of BNS detections

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

Sofia Bisero - Atelier API - November 17th, 2023

Spectroscopy: the bottleneck of gravitational wave multi-messenger science

Agudo+23

VLT/X-shooter

AT2017gfo
Pian+17

The spectrum of AT2017gfo: important for the study of **physics of the phenomenon,** the **environment**, **heavy elements nucleosynthesis** and for the **KN identification**
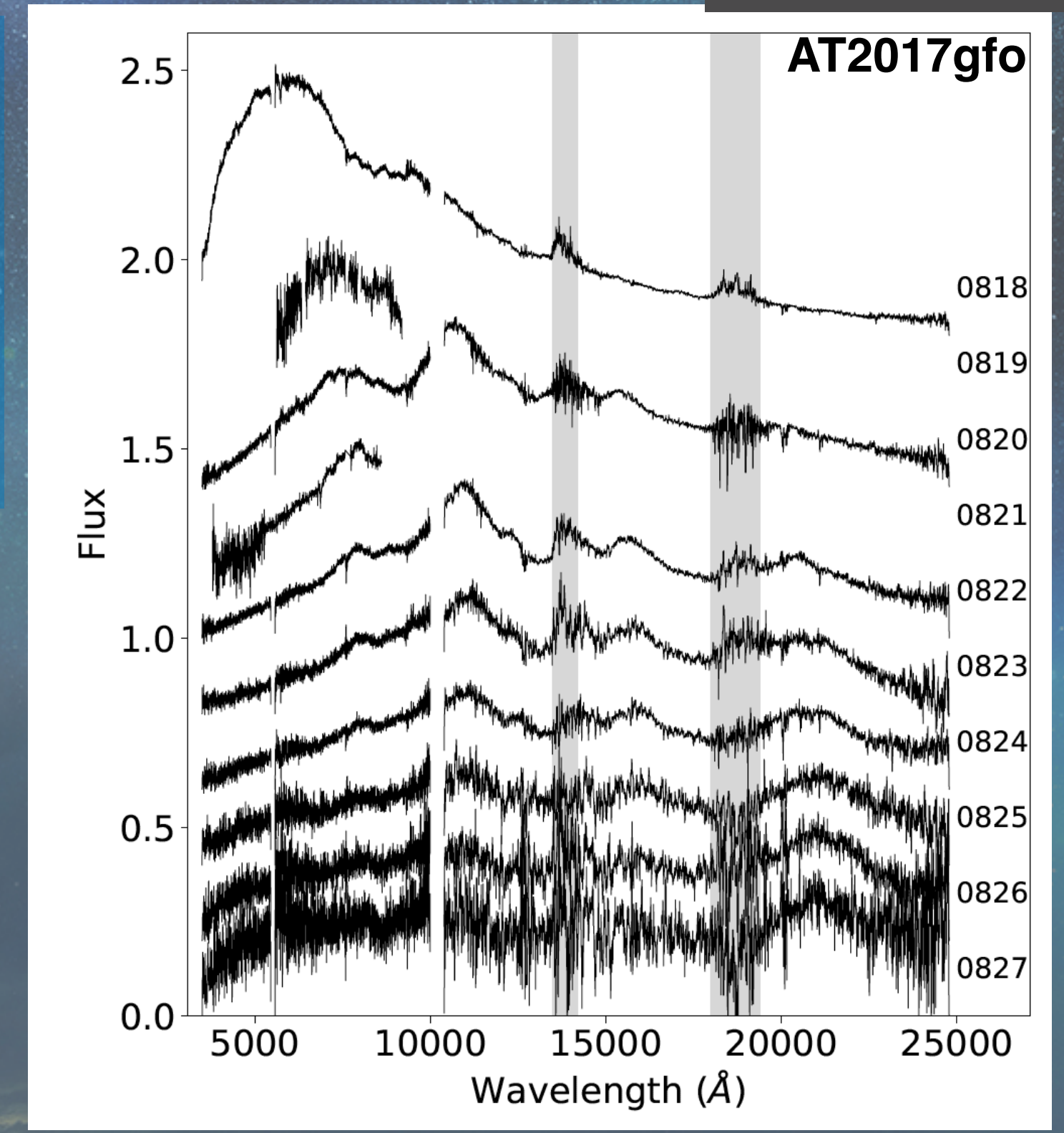
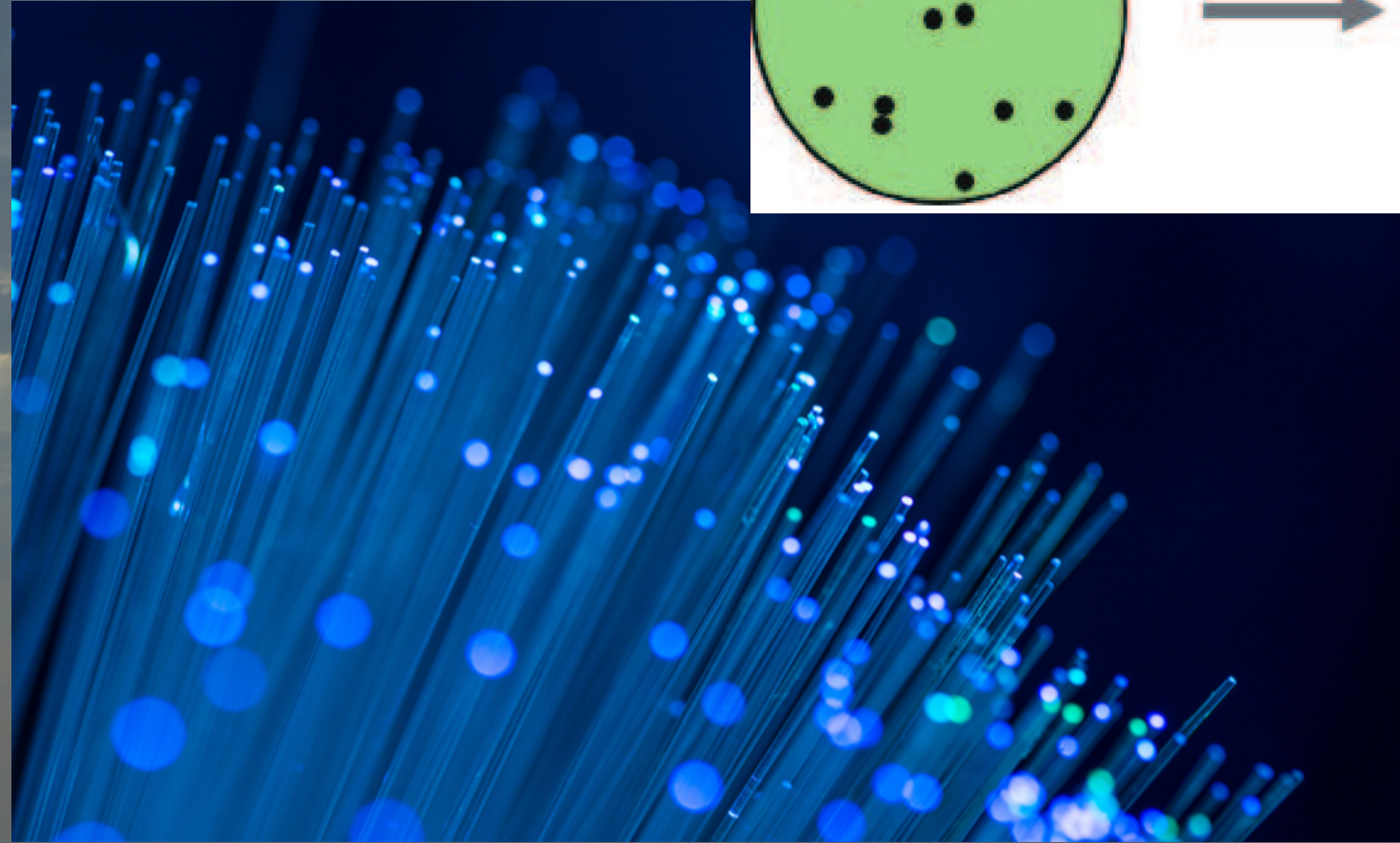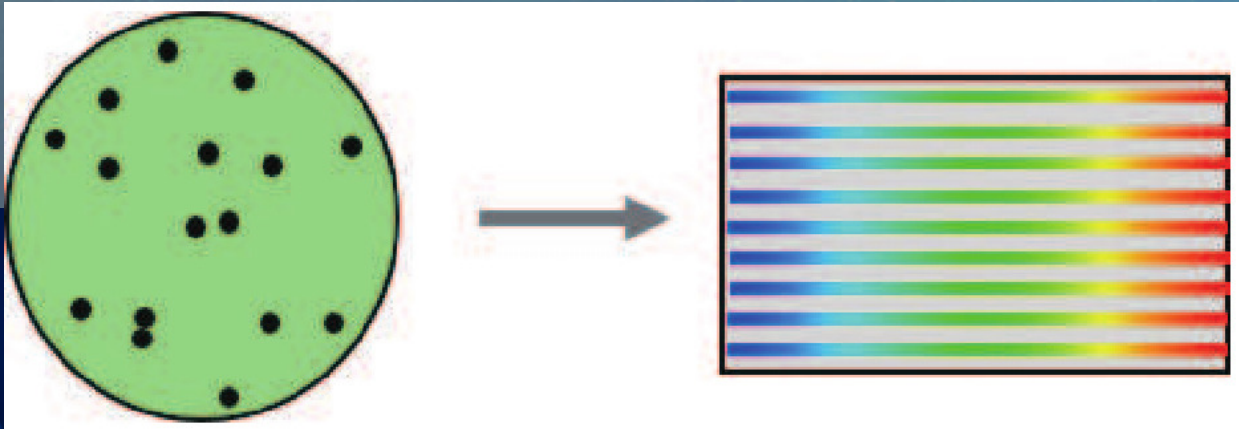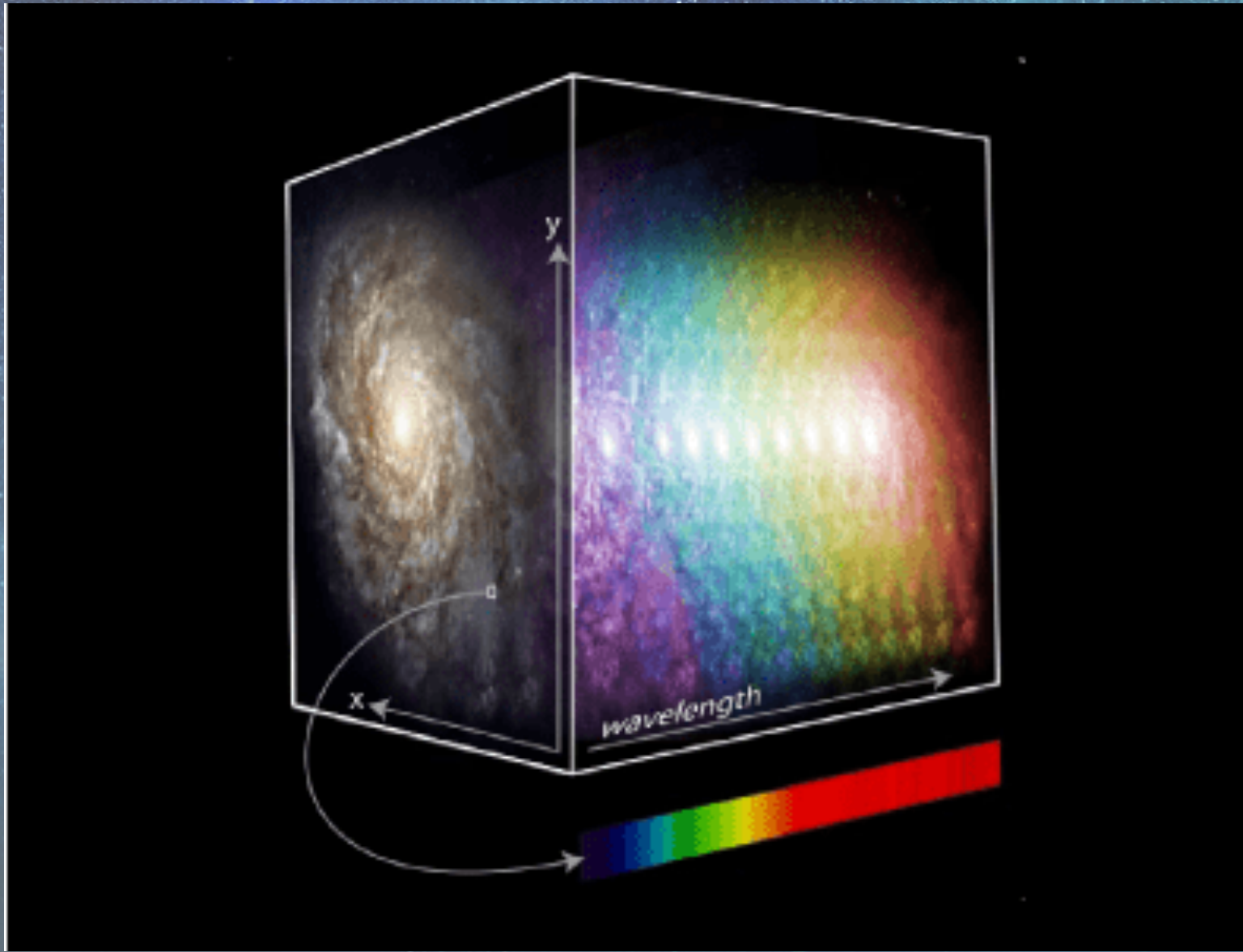The spectrum of **SN2019wxt**, a GW event counterpart candidate, then classified as SN

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

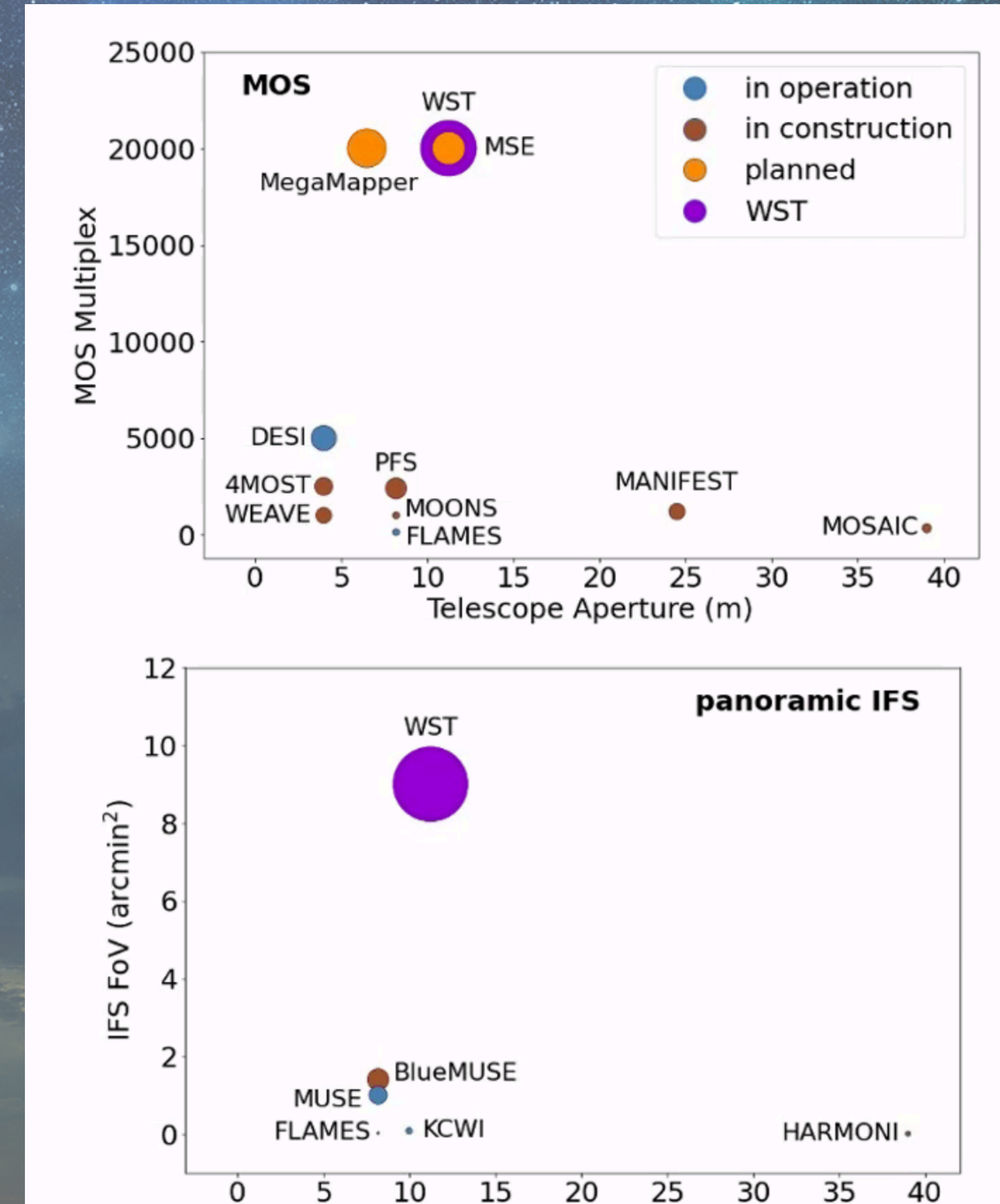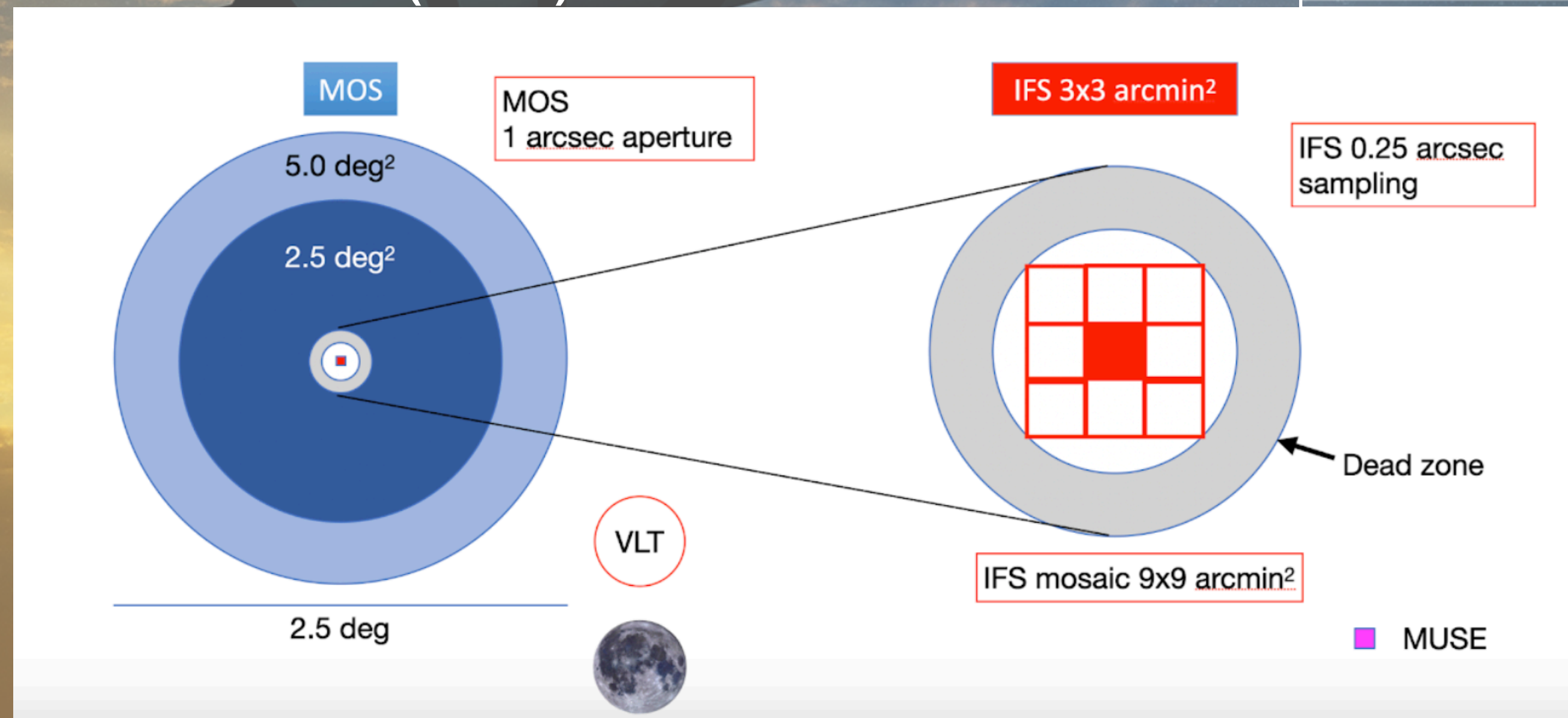**MOS**: fibres to acquire multiple spectra simultaneously

Hang-xin +19

IFS and MOS with the Wide-field Spectroscopic Telescope

Large field of view and high **multiplexing**

Equipped with both **IFU** and fibres (**MOS**)
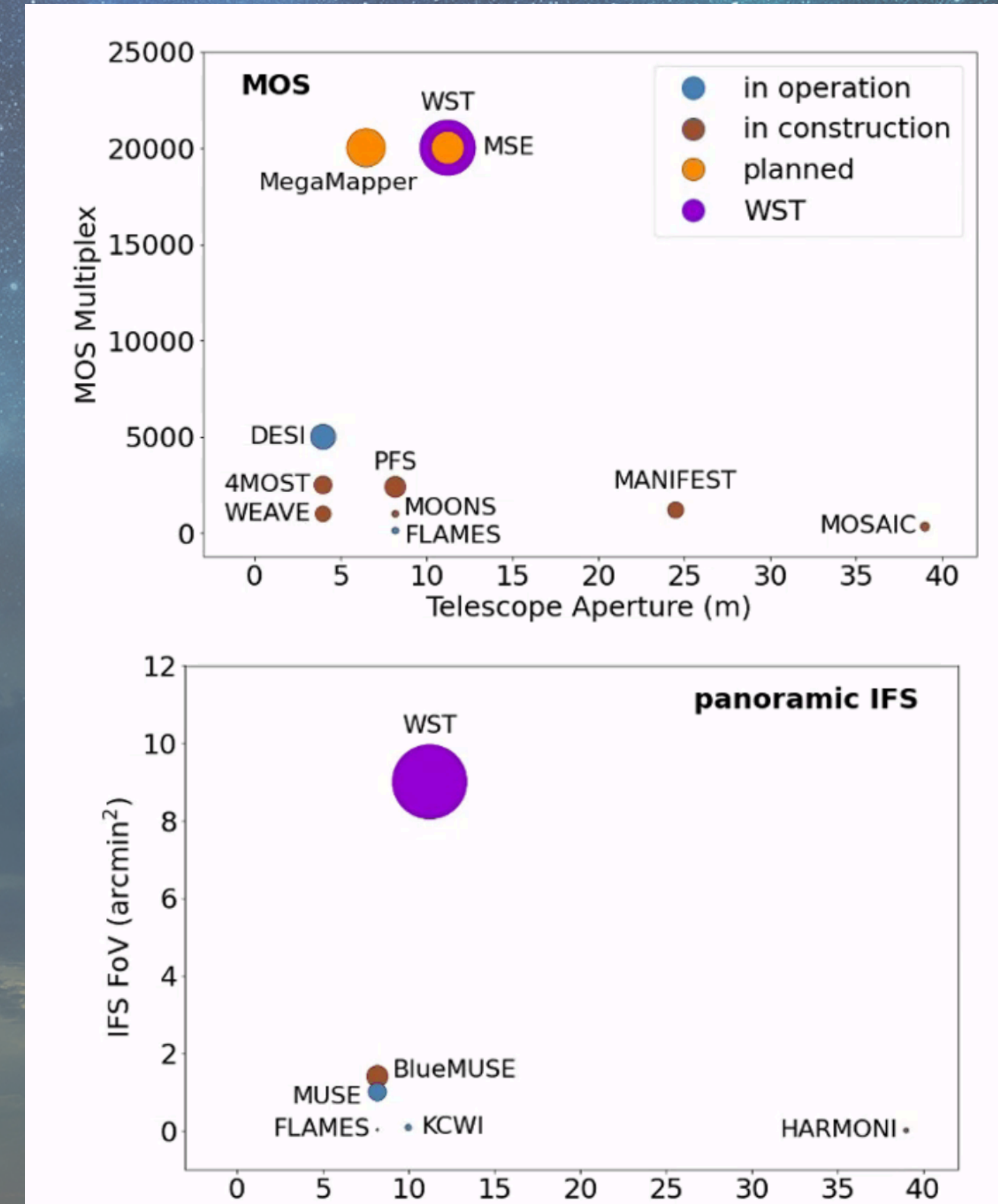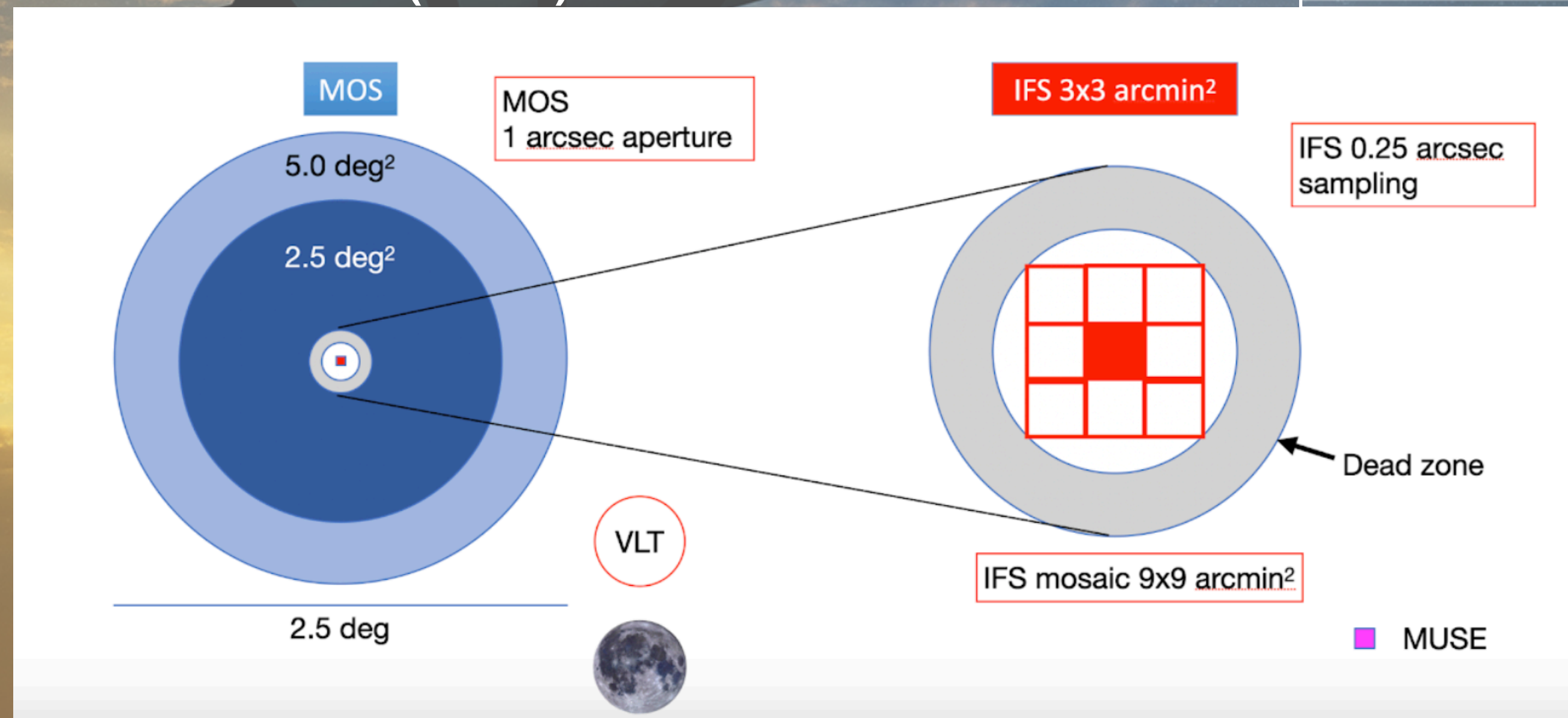
PI: Roland Bacon **(CRAL)**

IFS and MOS with the Wide-field Spectroscopic Telescope

Science case "**WST - ET synergies for BNS multi-messenger observations**" within the WST Time Domain Working Group

Division 4 of the ET OSB: Multimessenger Observations
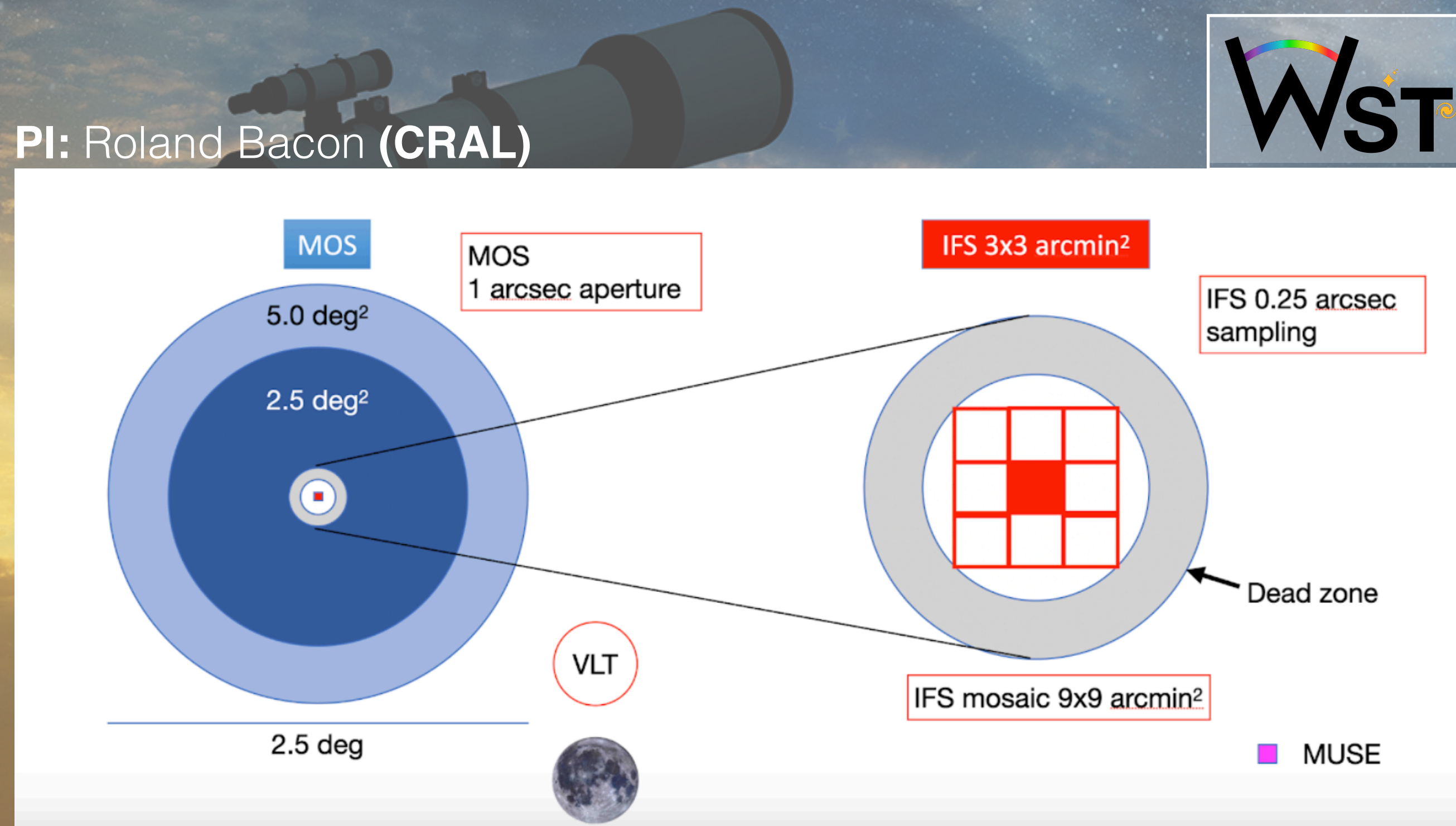
PI: Roland Bacon **(CRAL)**

IFS and MOS with the Wide-field Spectroscopic Telescope

Two ways to use **WST** for EM **counterpart detection**, **characterisation** and **identification**

PI: Roland Bacon **(CRAL)**

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

ET-WST synergy
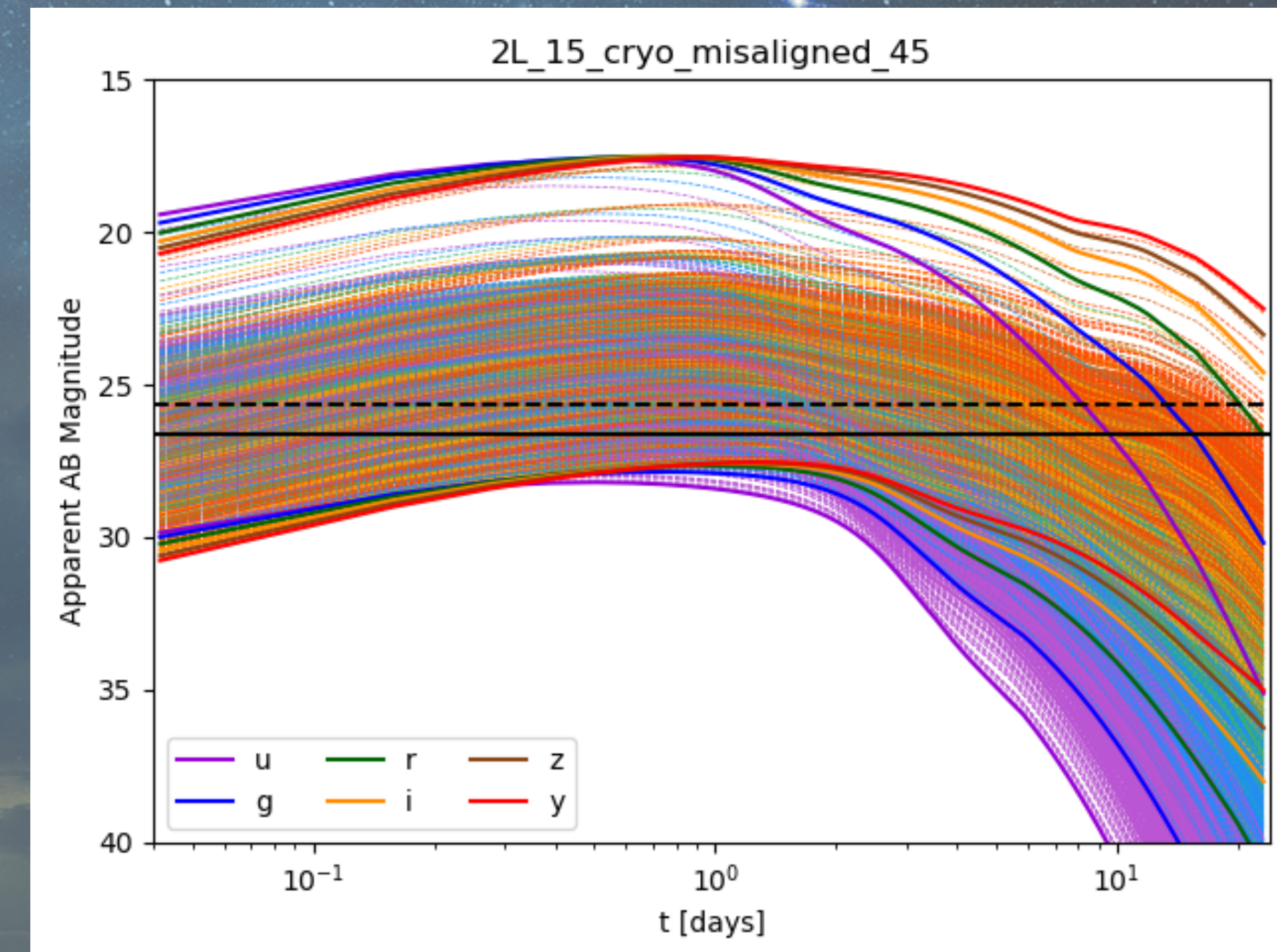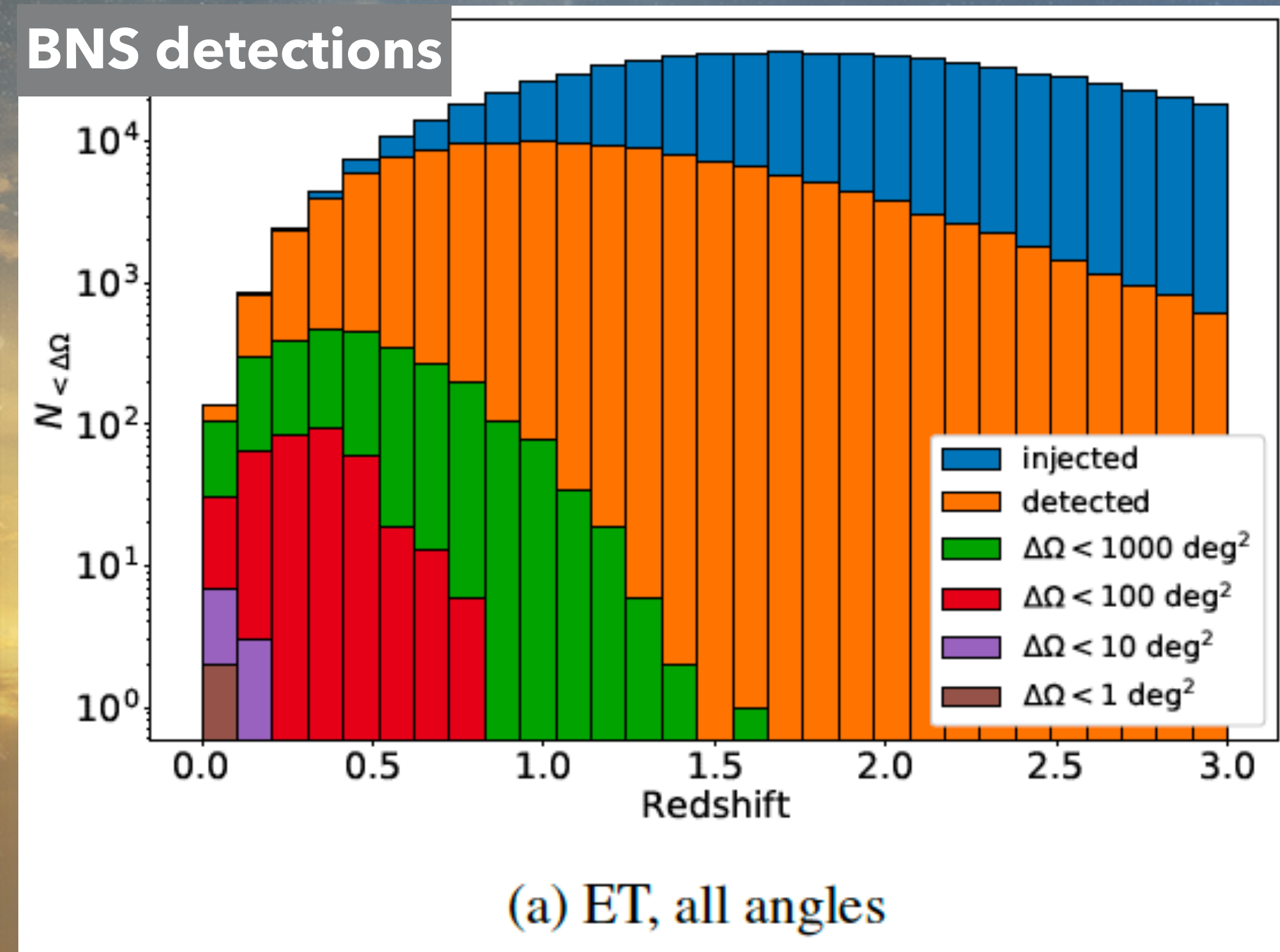
ET simulations

KN + GRB simulations

GSSI group (& Milano Bicocca PROMETEO group)

BNS detections

(a) ET, all angles

Ronchini +22

WST simulator

2L_15_cryo_misaligned_45

ET-WST synergy

ET simulations

KN + GRB simulations
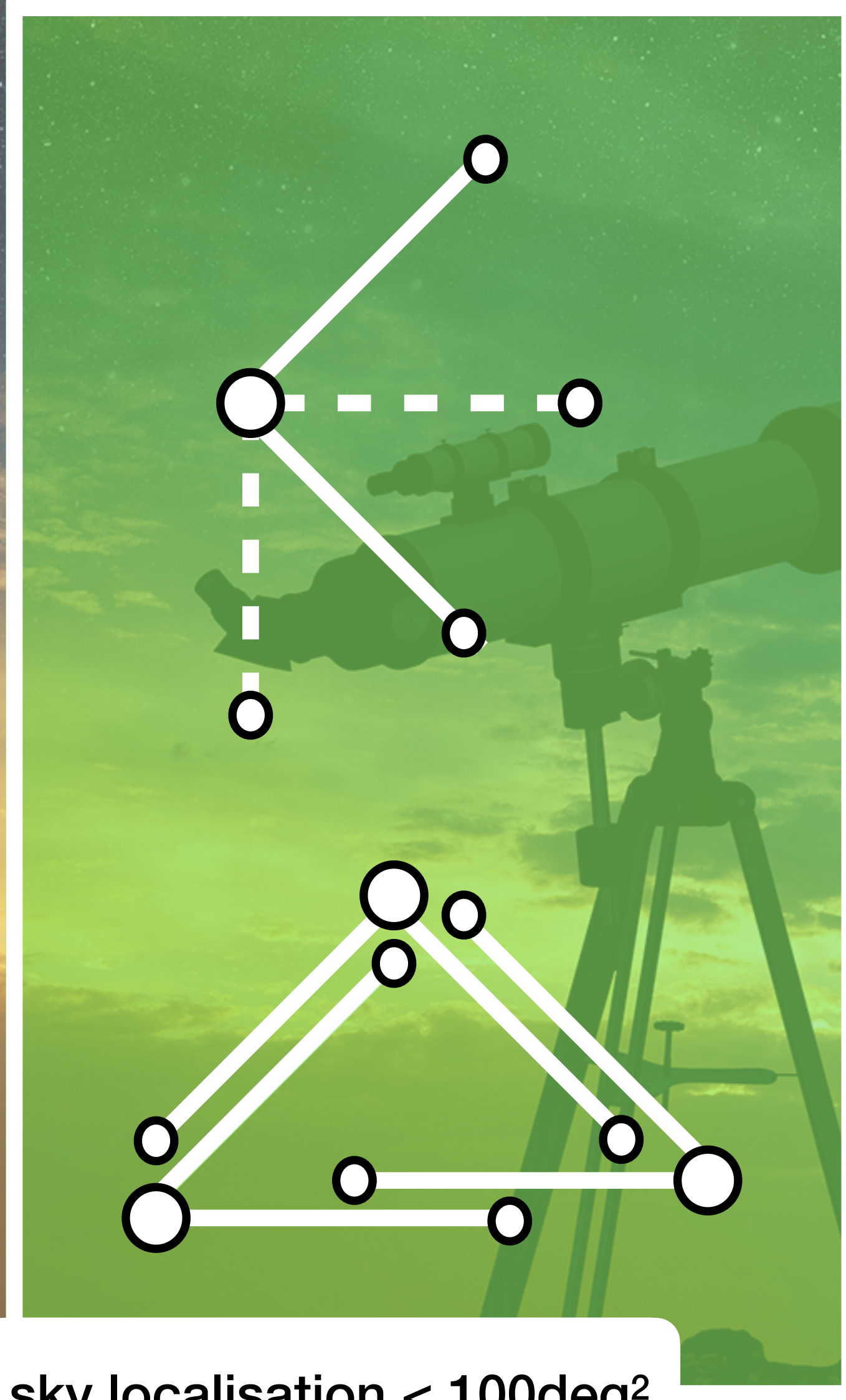
GSSI group (& Milano Bicocca PROMETEO group)

WST simulator

- explore the **detectability** and **characterizations** with WST of the EM counterparts of ET BNS

- analyse how the results depend on the **observable properties** of the population of **ET BNS**, such as their distribution in **redshift**, **viewing angle** or sky **localisation uncertainty**

- analyse how the results depend on the **intrinsic properties** of ET BNS, such as NS **EoS** and the component **mass distribution**
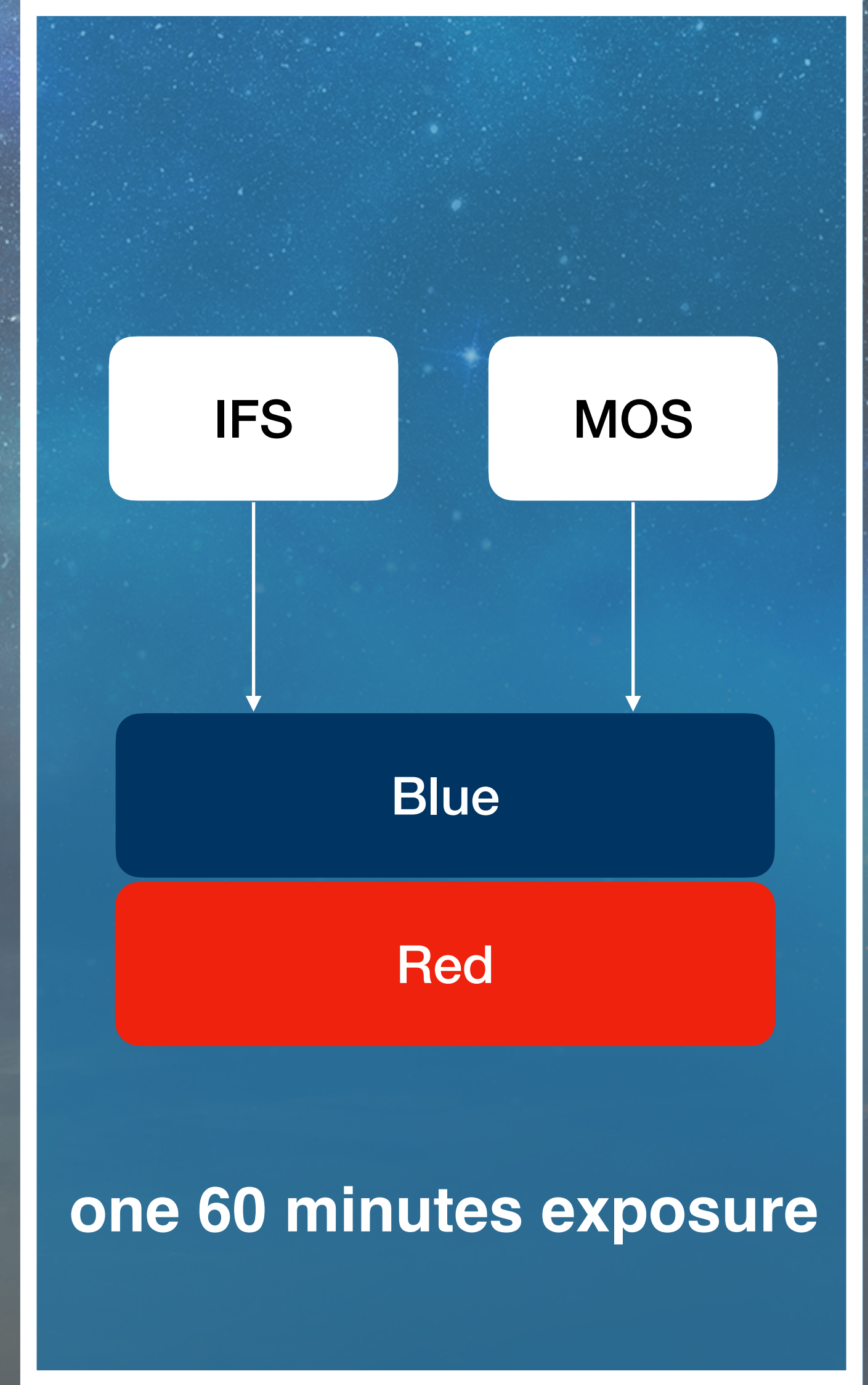
ET-WST synergy

BNS population

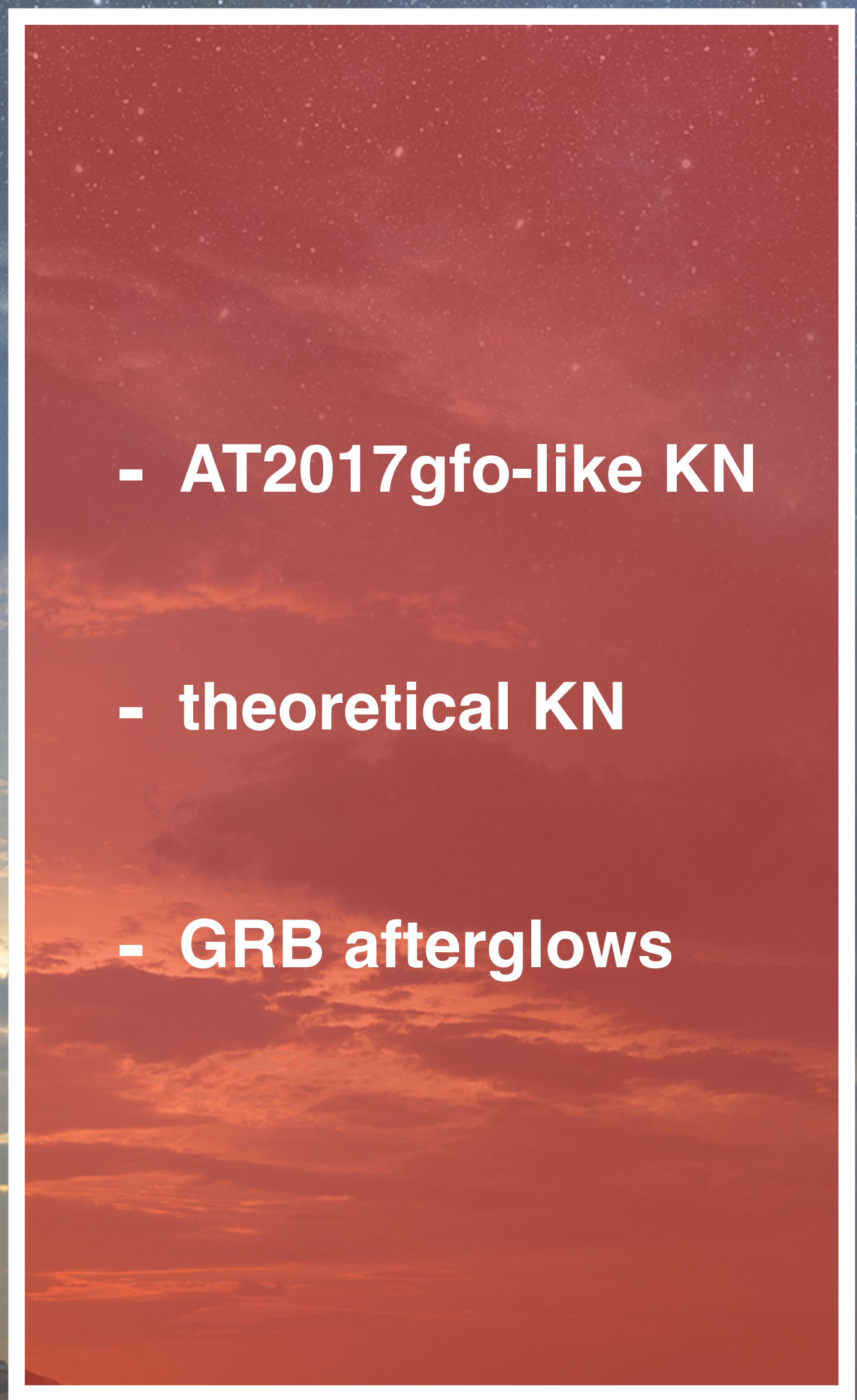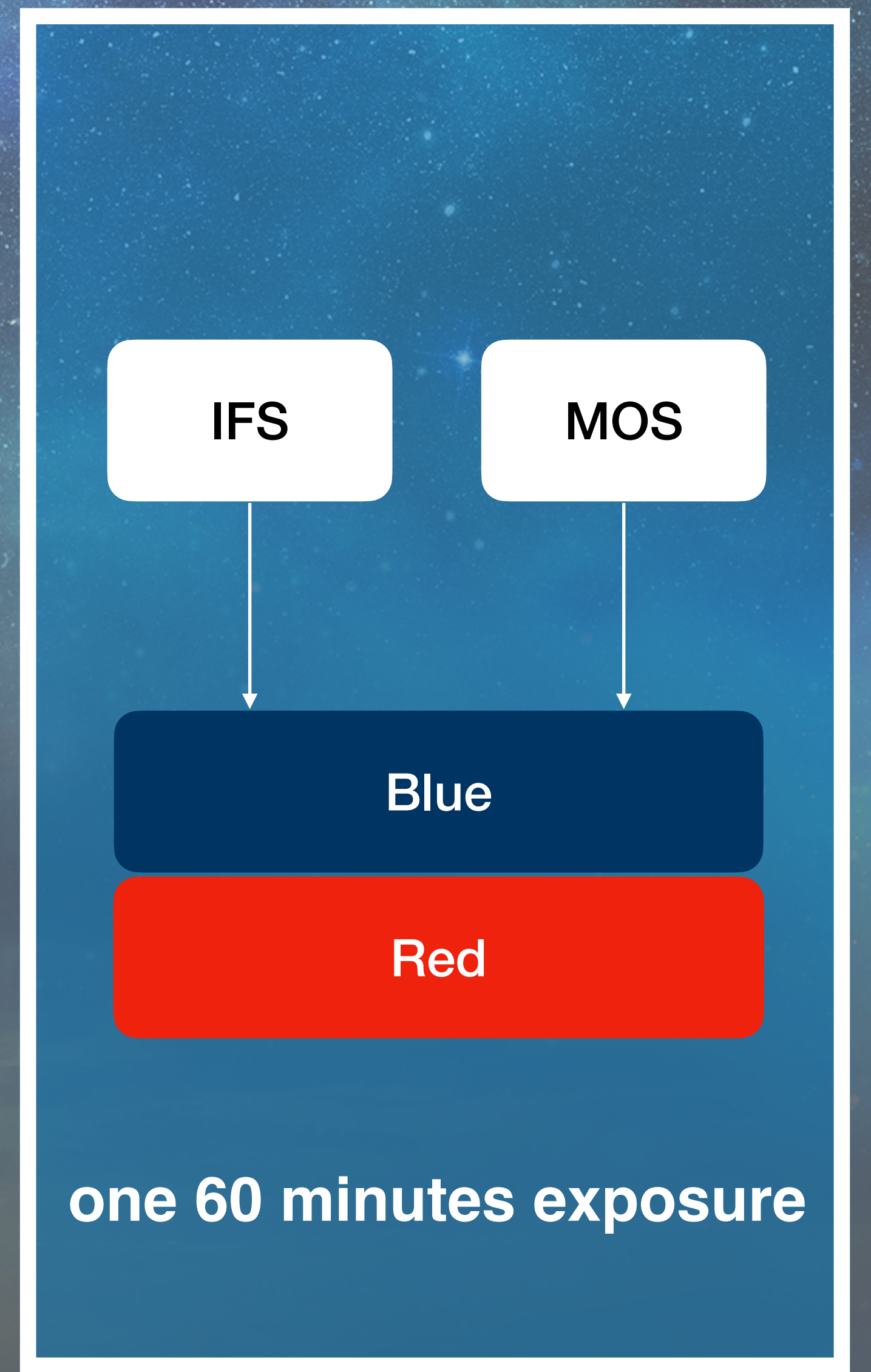sky localisation < 100deg²

EM counterparts

- AT2017gfo-like KN

- theoretical KN

- GRB afterglows

WST ETC

IFS

MOS

Blue

Red

one 60 minutes exposure

ET-WST synergy

BNS population

+ 1CE

sky localisation < 40deg²

EM counterparts

- AT2017gfo-like KN

- theoretical KN

- GRB afterglows

WST ETC

IFS   MOS

Blue

Red

one 60 minutes exposure

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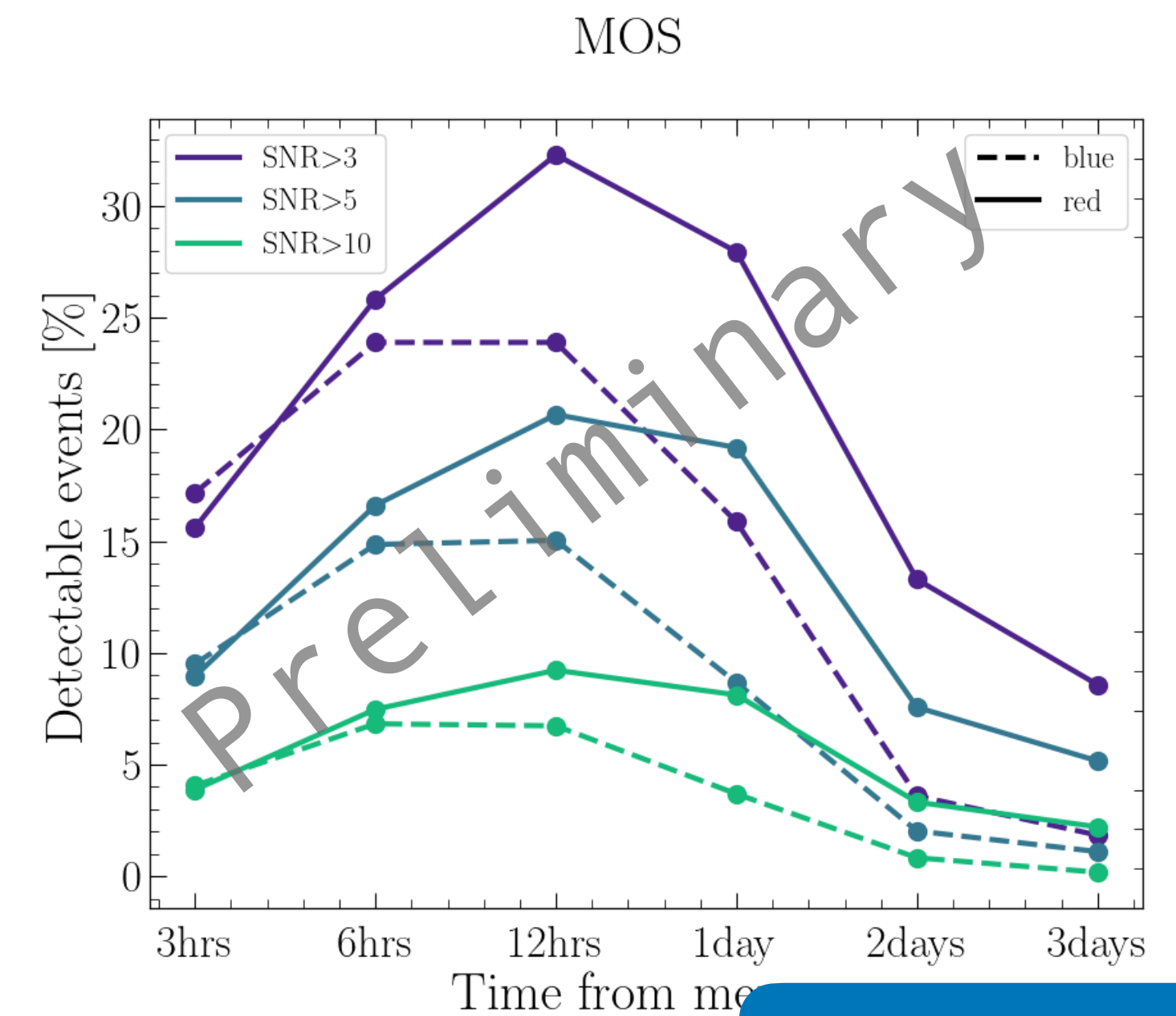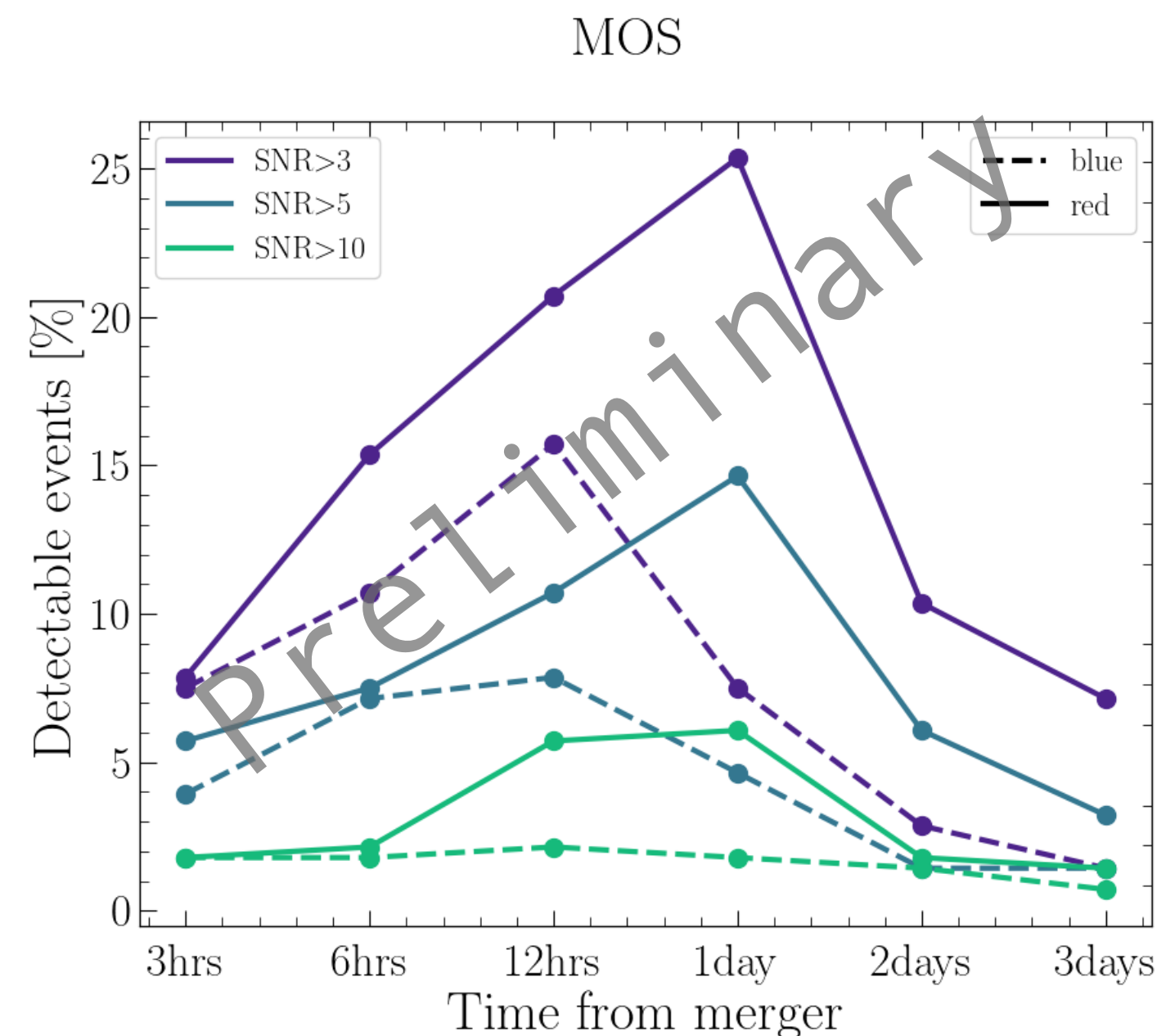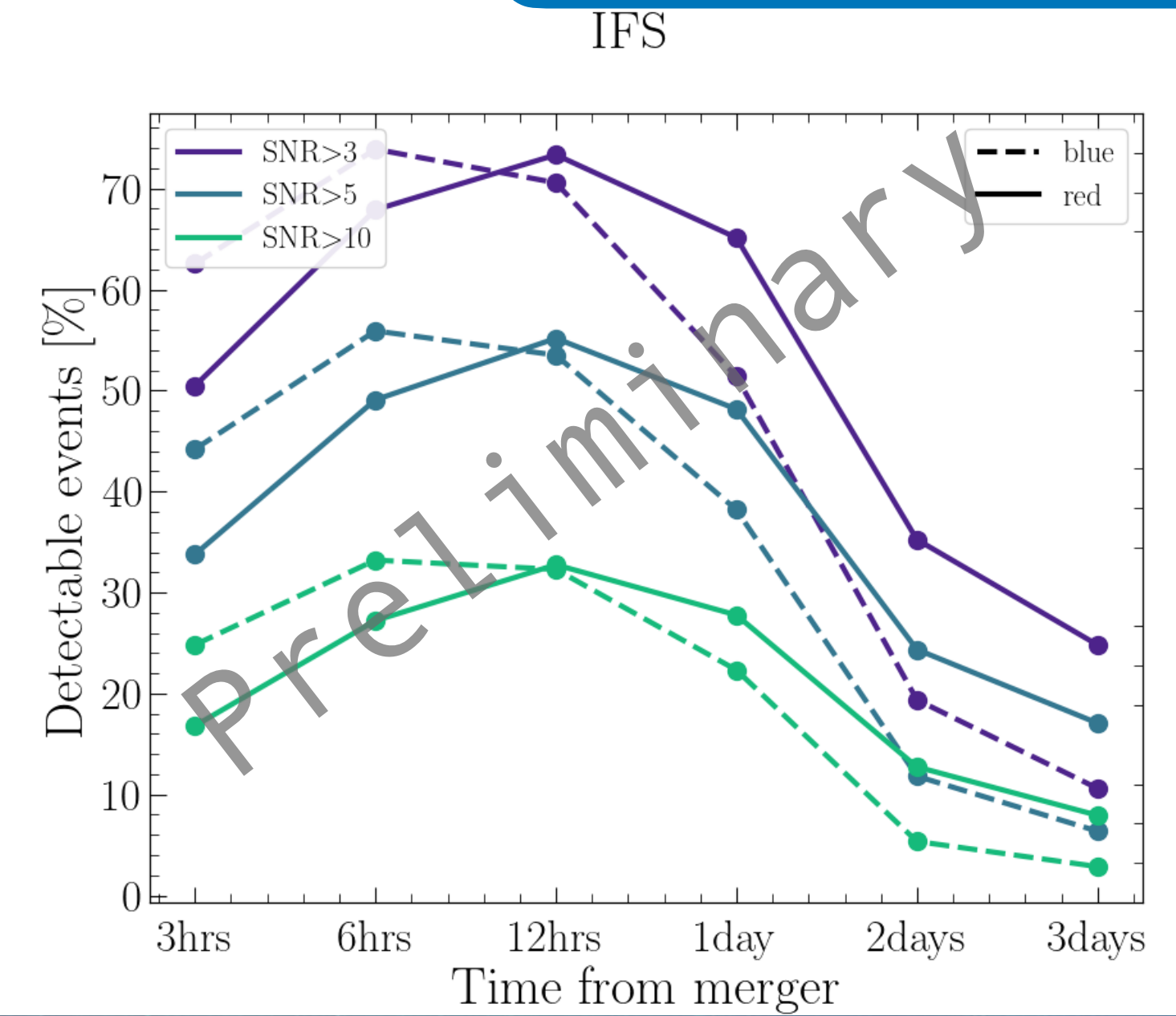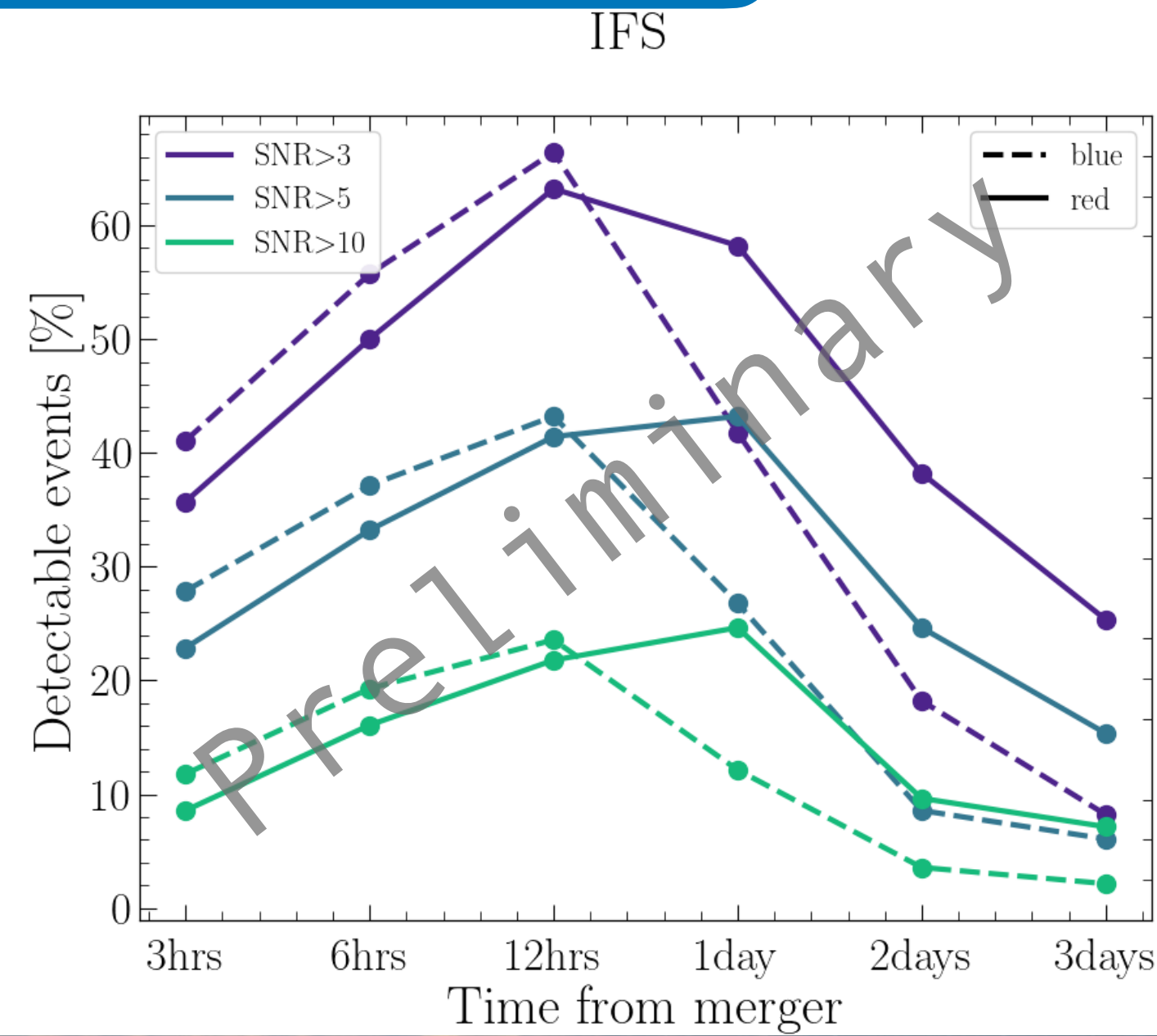
ET-WST synergy

Preliminary results

We sample the counterpart population properties at **different times** after the merger

AT2017gfo KN model

KN theoretical models

BLh gaussian

ET-WST synergy

Preliminary results

White: **ET BNS** detections

Colored: **WST detections**

AT2017gfo KN model

KN theoretical models

BLh gaussian

ET-WST synergy
Preliminary results

WST IFS red - t =12.29hrs

- parent population
- LSST sample
- 3<SNR<5, detectable:18.74%
- 5<SNR<10, detectable:29.26%
- SNR > 10, detectable:45.47%

AB magnitude in LSST i filter

WST MOS red - t =12.29hrs

- parent population
- LSST sample
- 3<SNR<5, detectable:15.79%
- 5<SNR<10, detectable:15.79%
- SNR > 10, detectable:13.47%

AB magnitude in LSST i filter
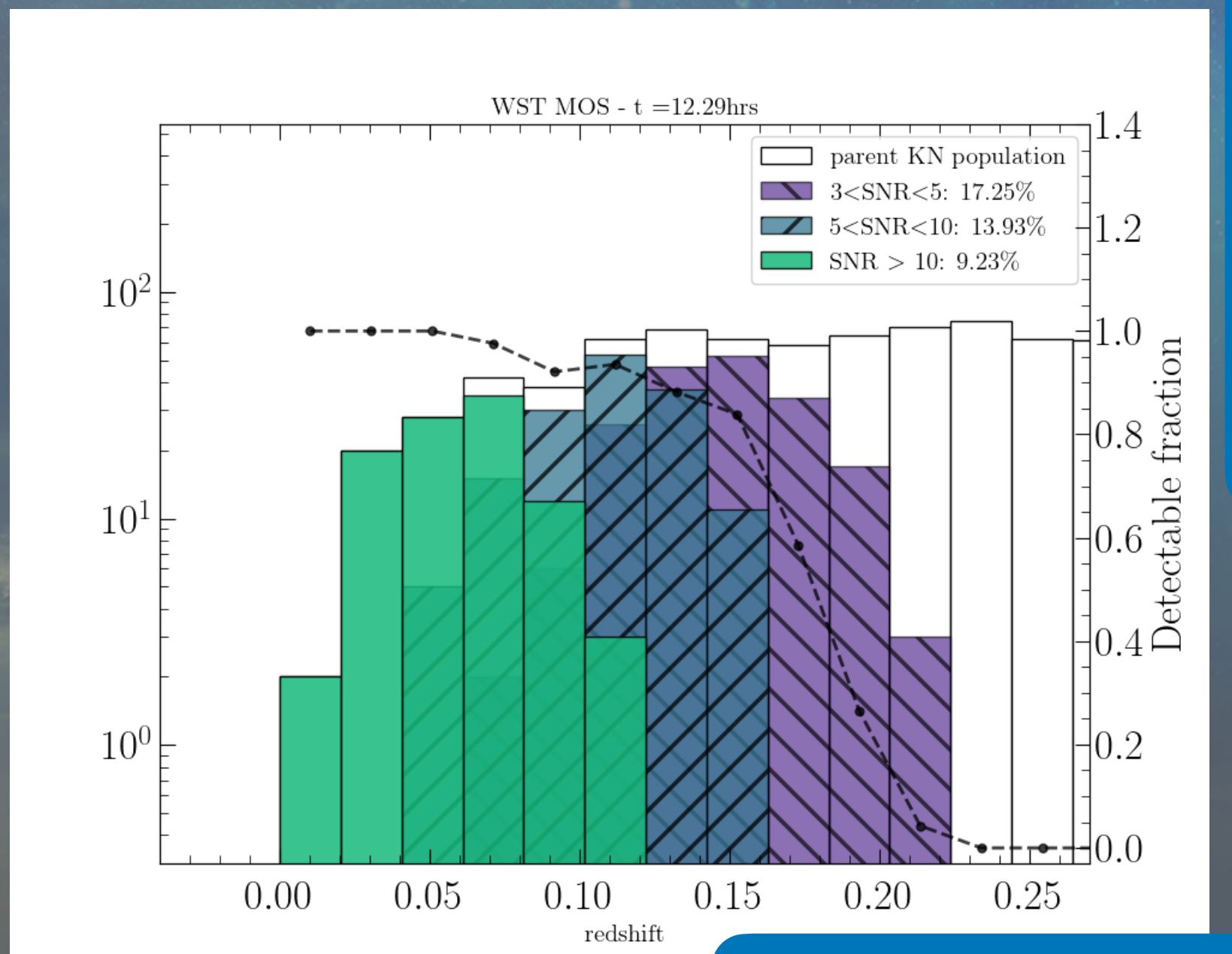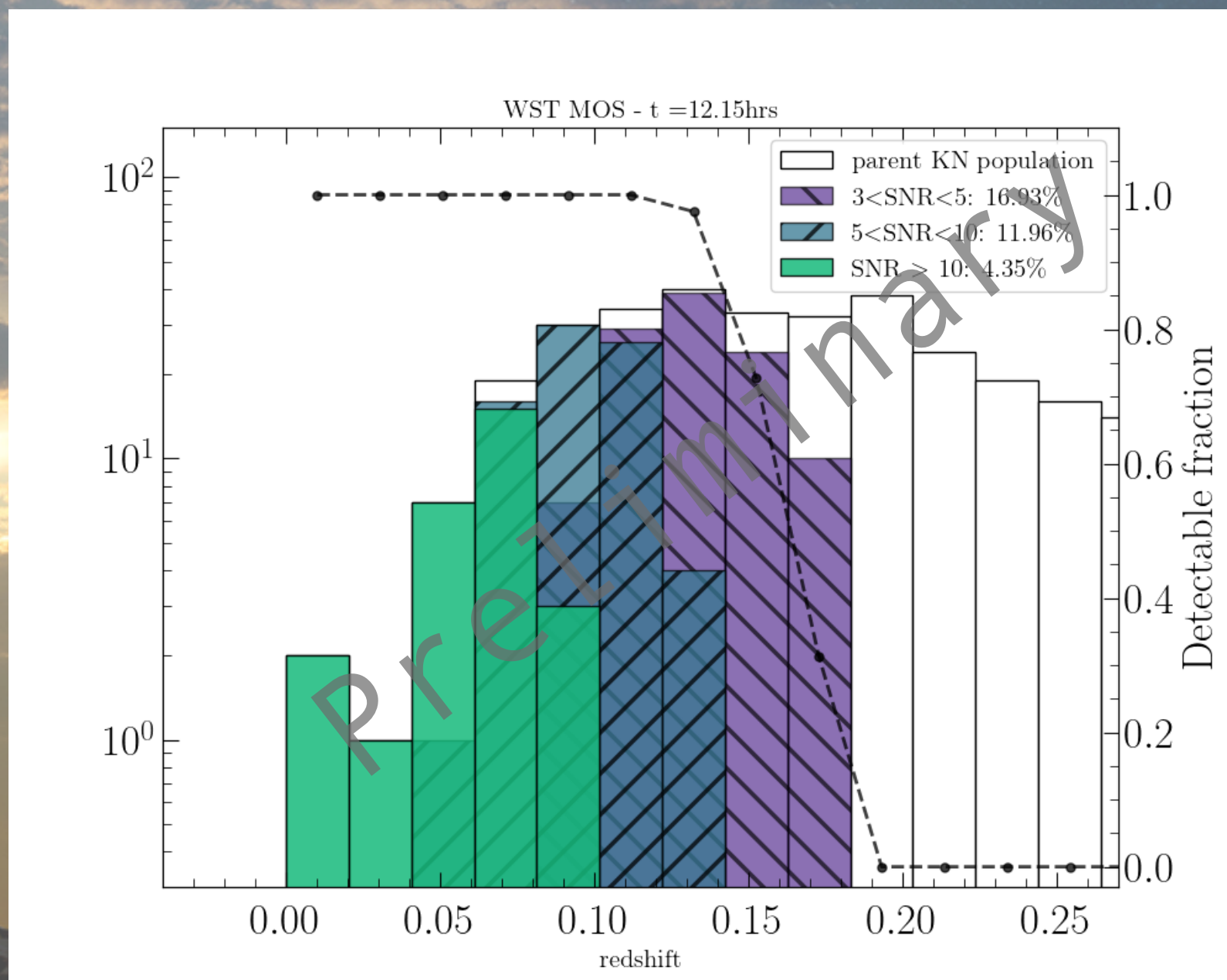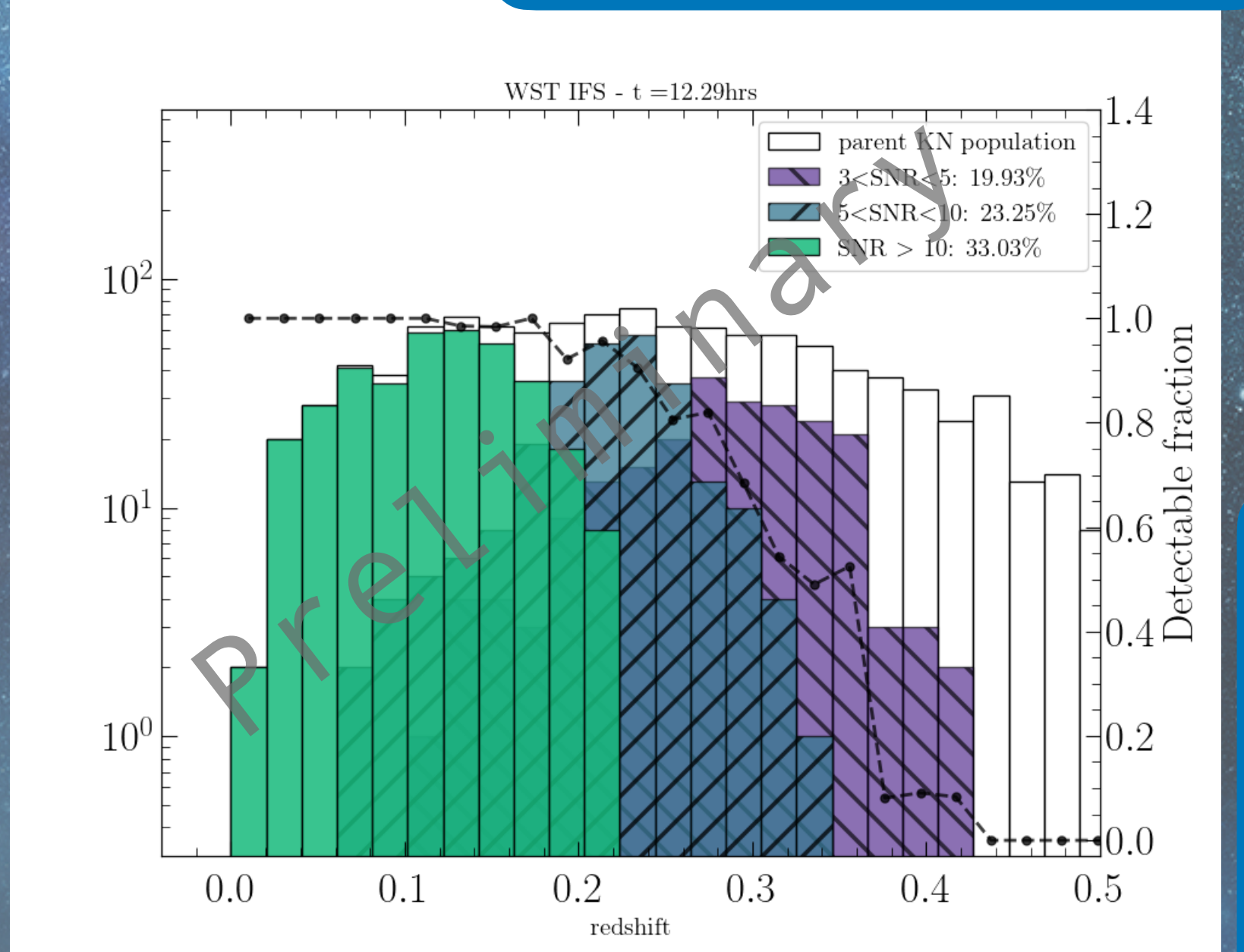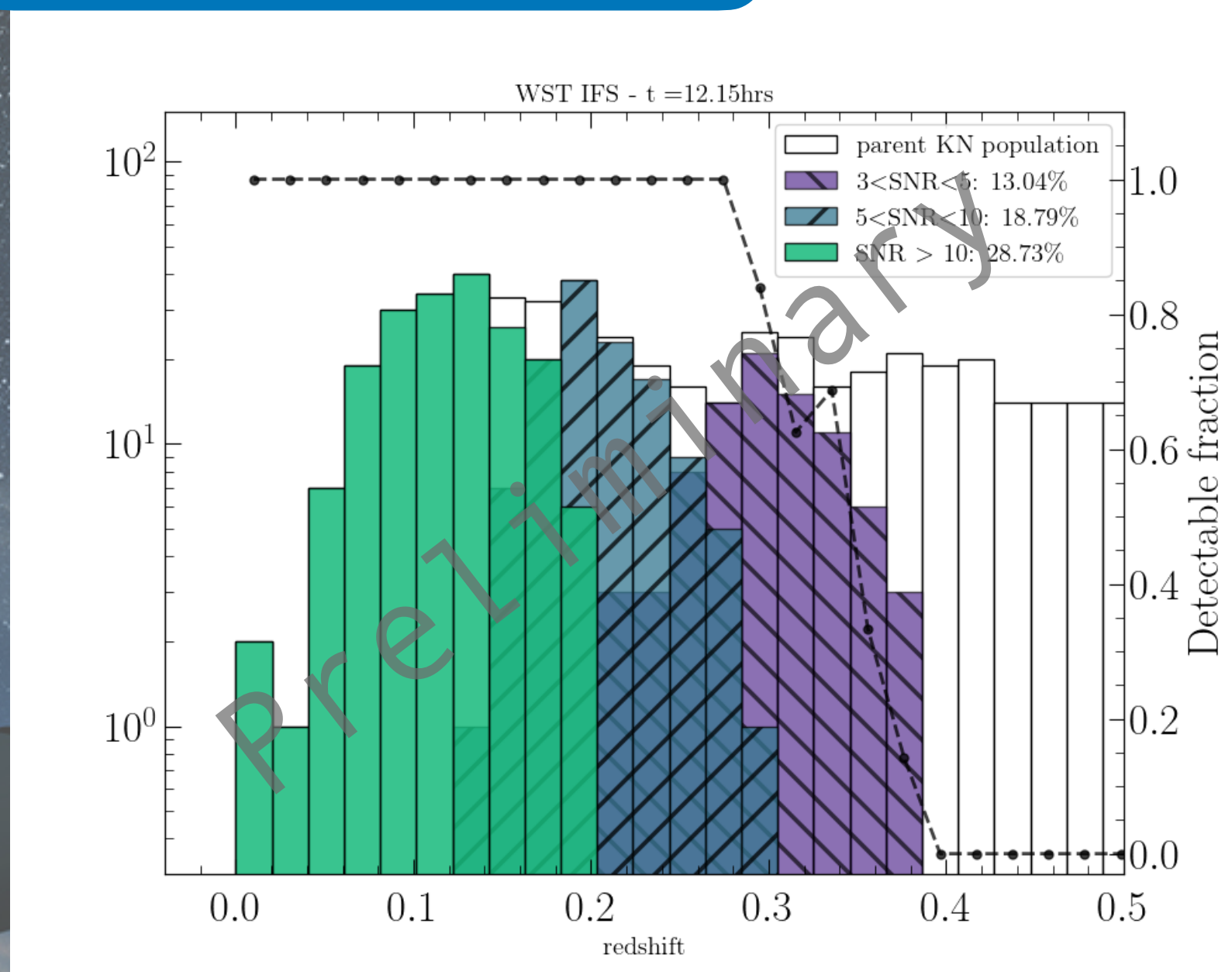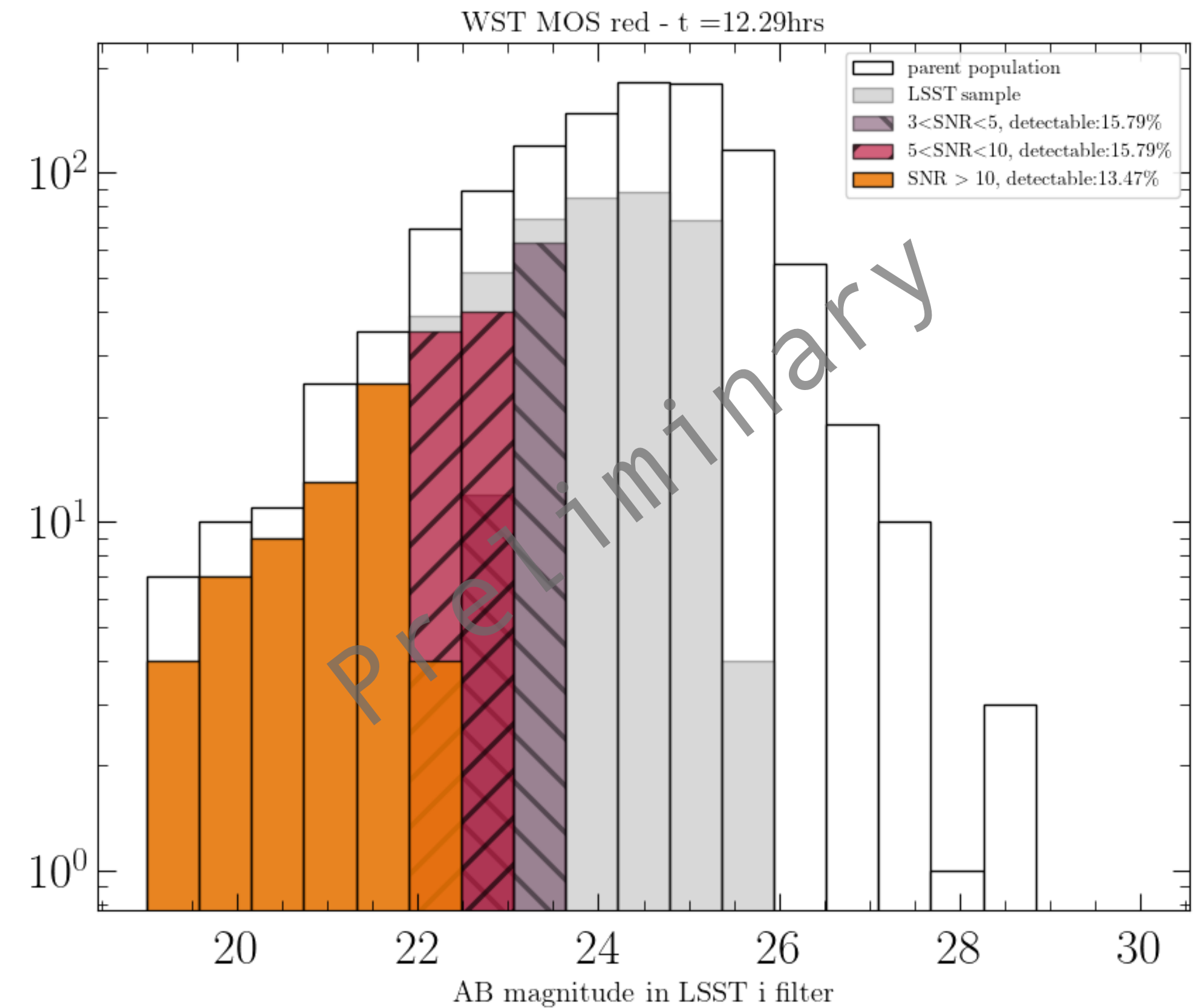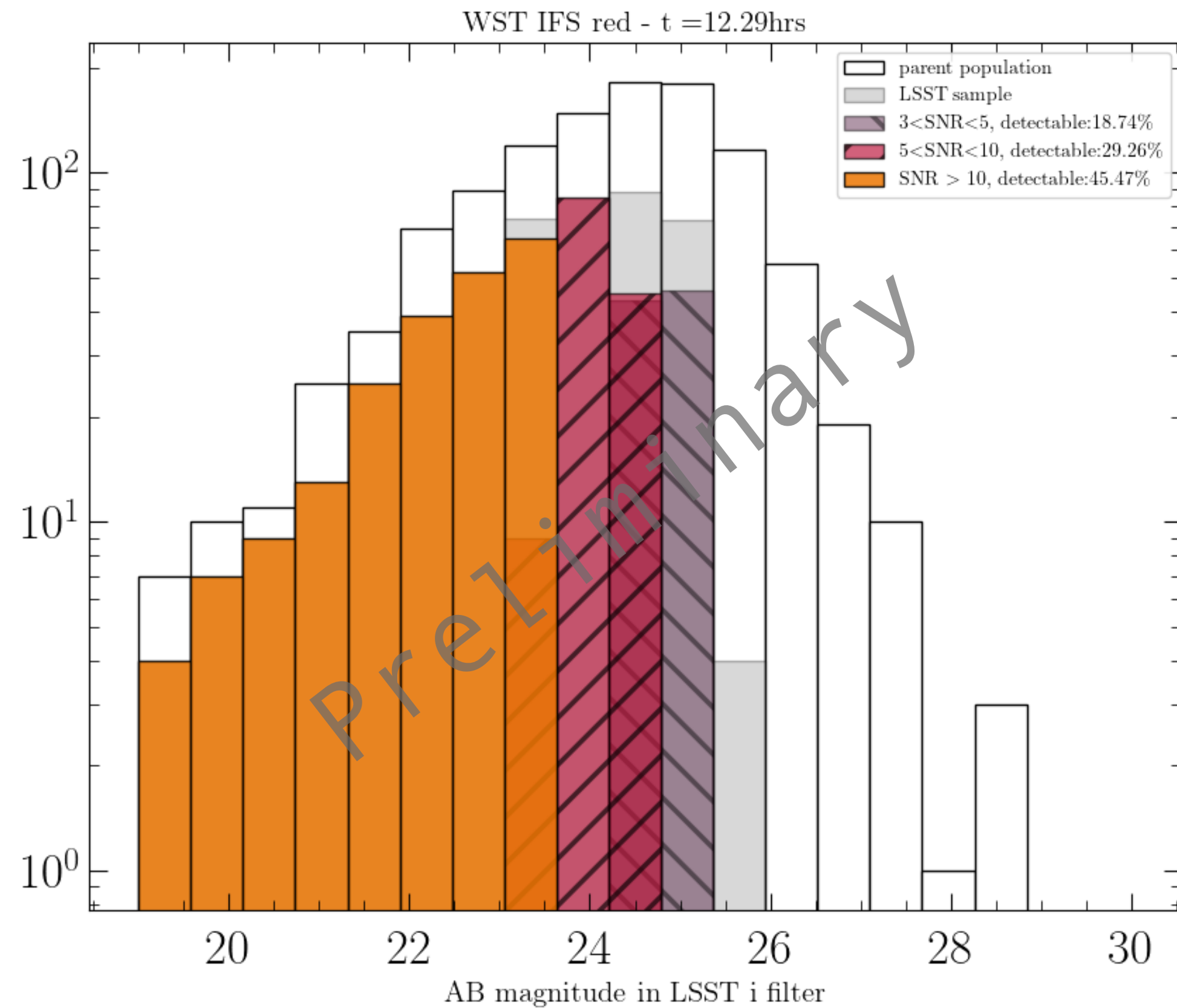
BLh gaussian

White: **ET BNS detections** in 10 years of operations
Grey: **Rubin detections**
Colored: **WST detections**

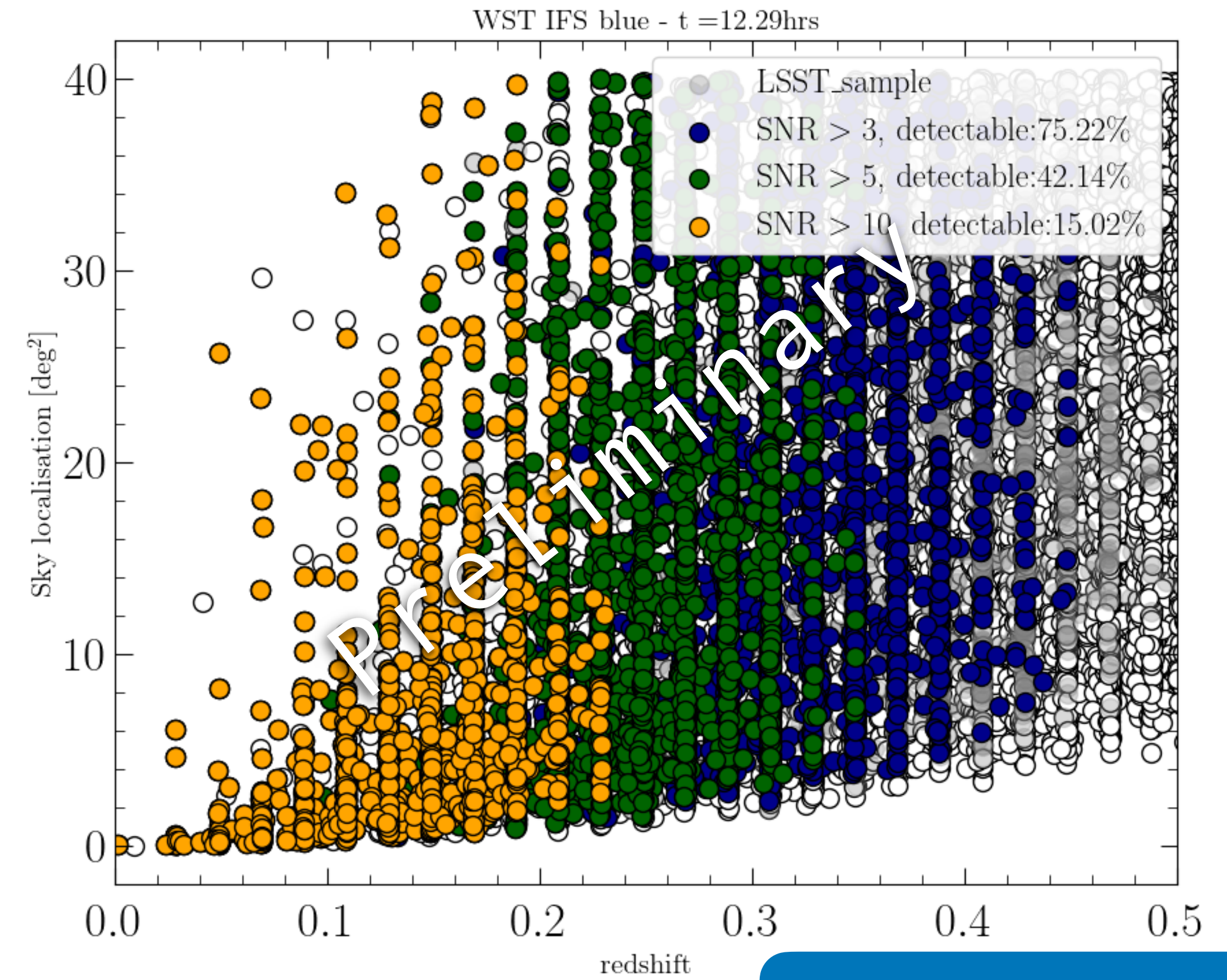Sofia Bisero - Atelier API - November 17th, 2023

ET-WST synergy

Preliminary results

ET alone
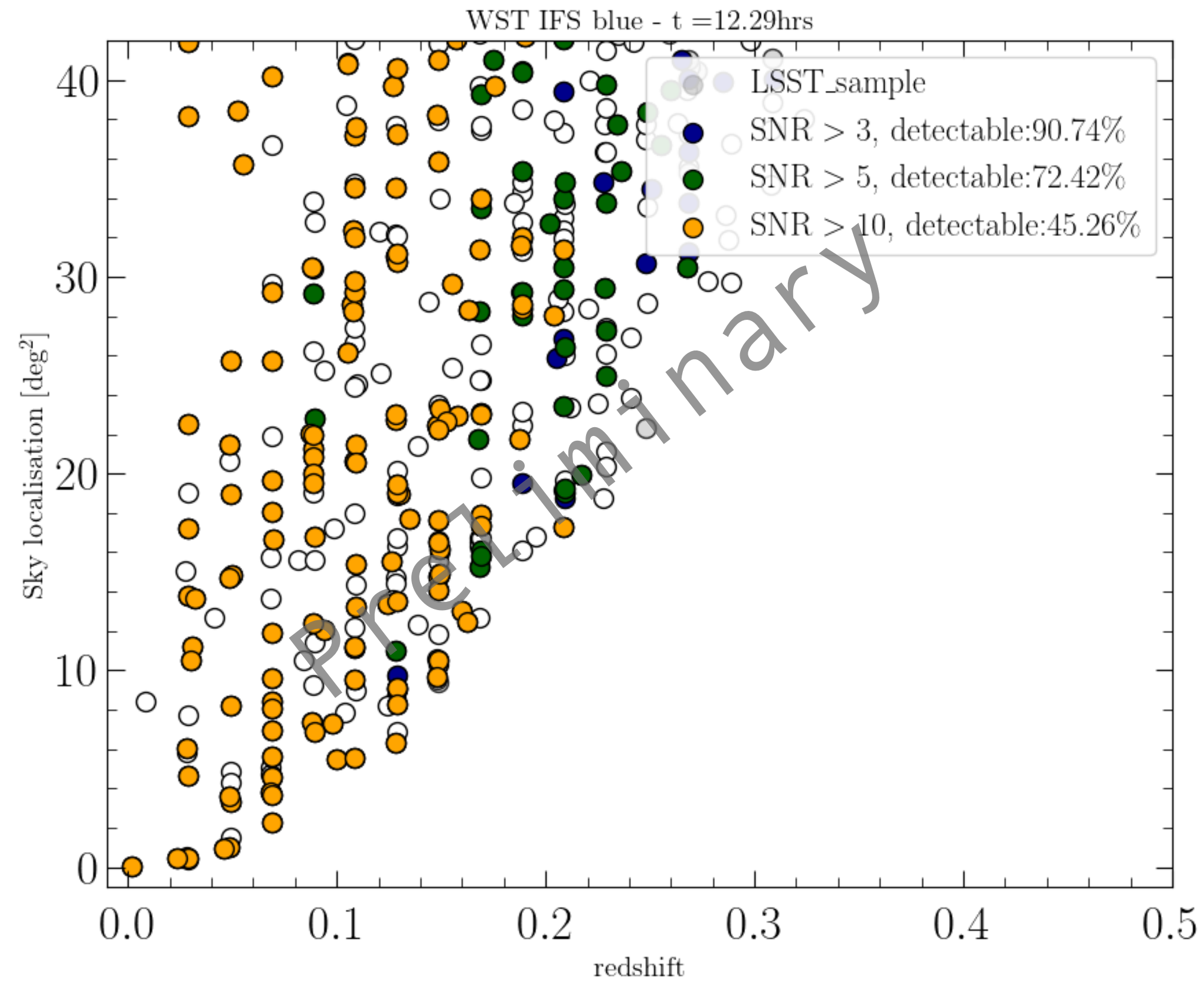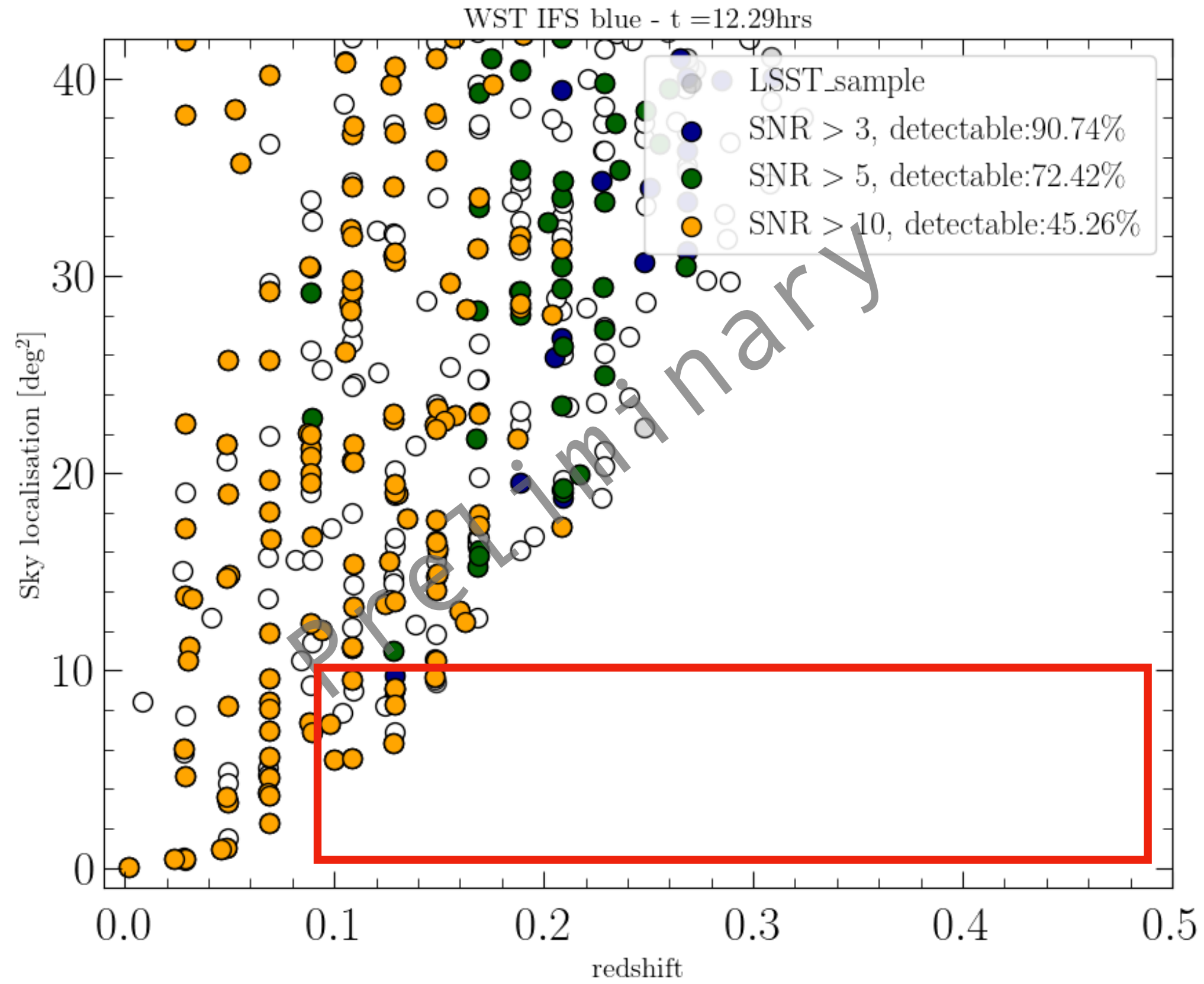
ET+Cosmic Explorer

BLh gaussian

ET-WST synergy

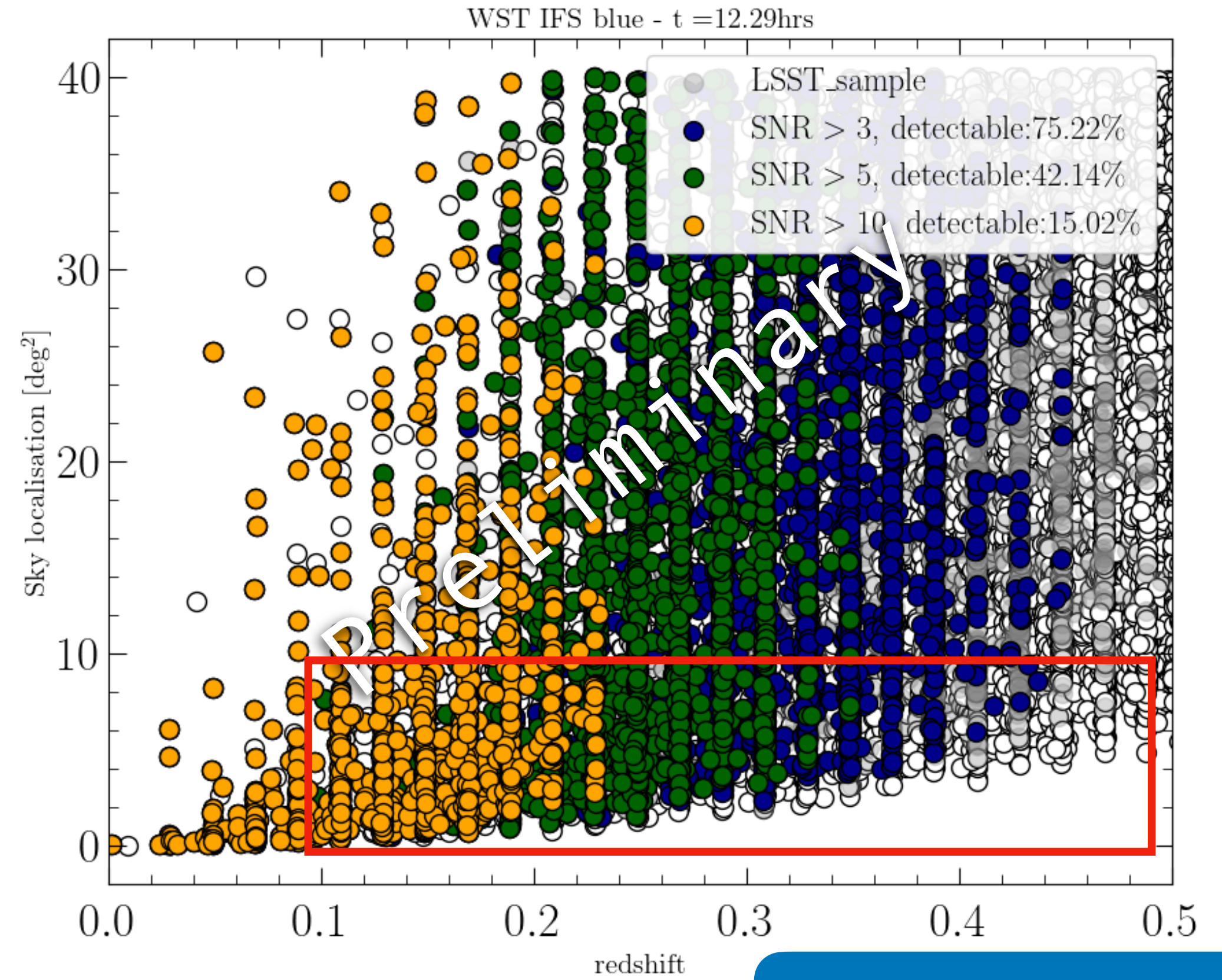**Preliminary results**

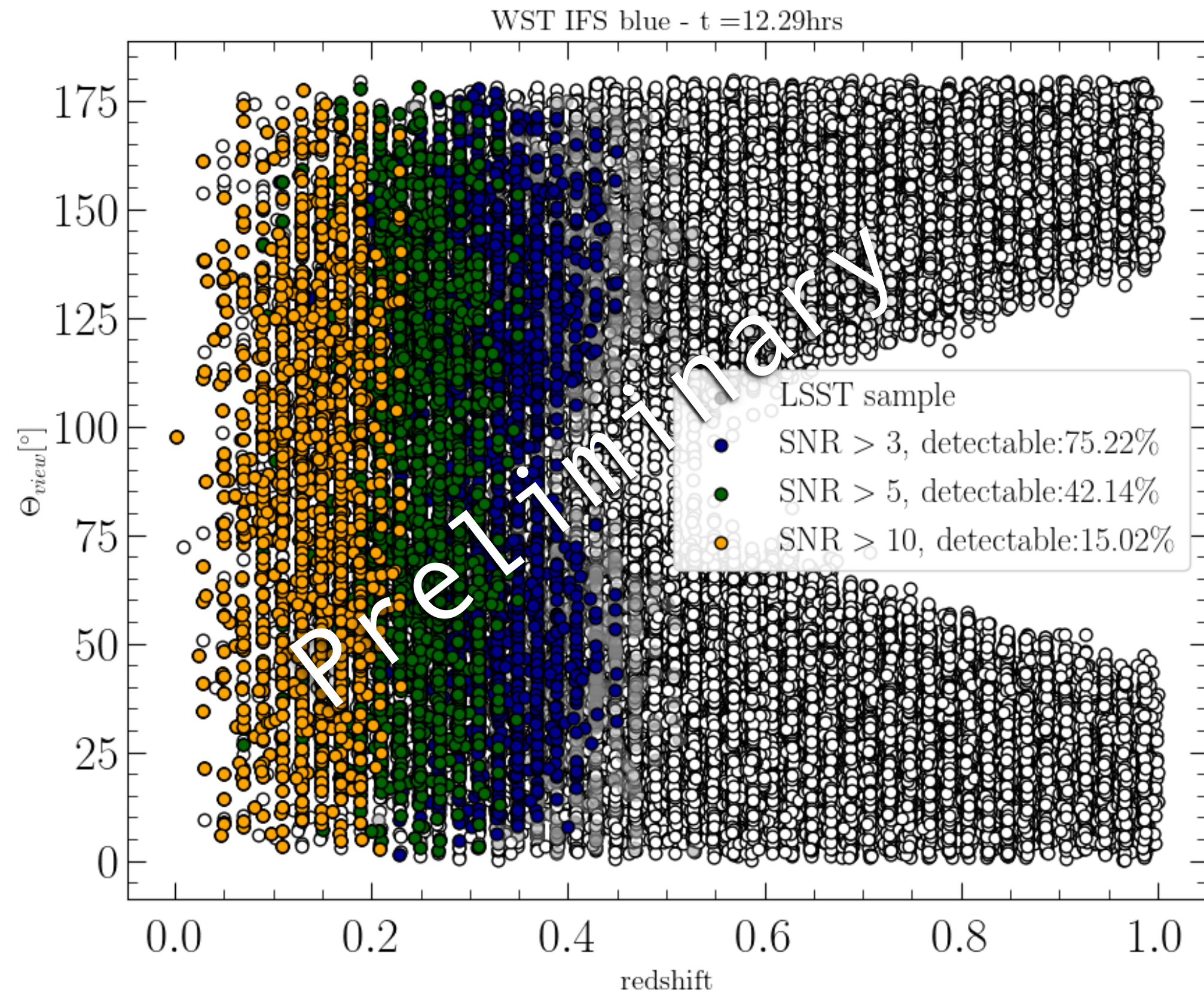**Improved sky localisation**

ET alone

ET+Cosmic Explorer
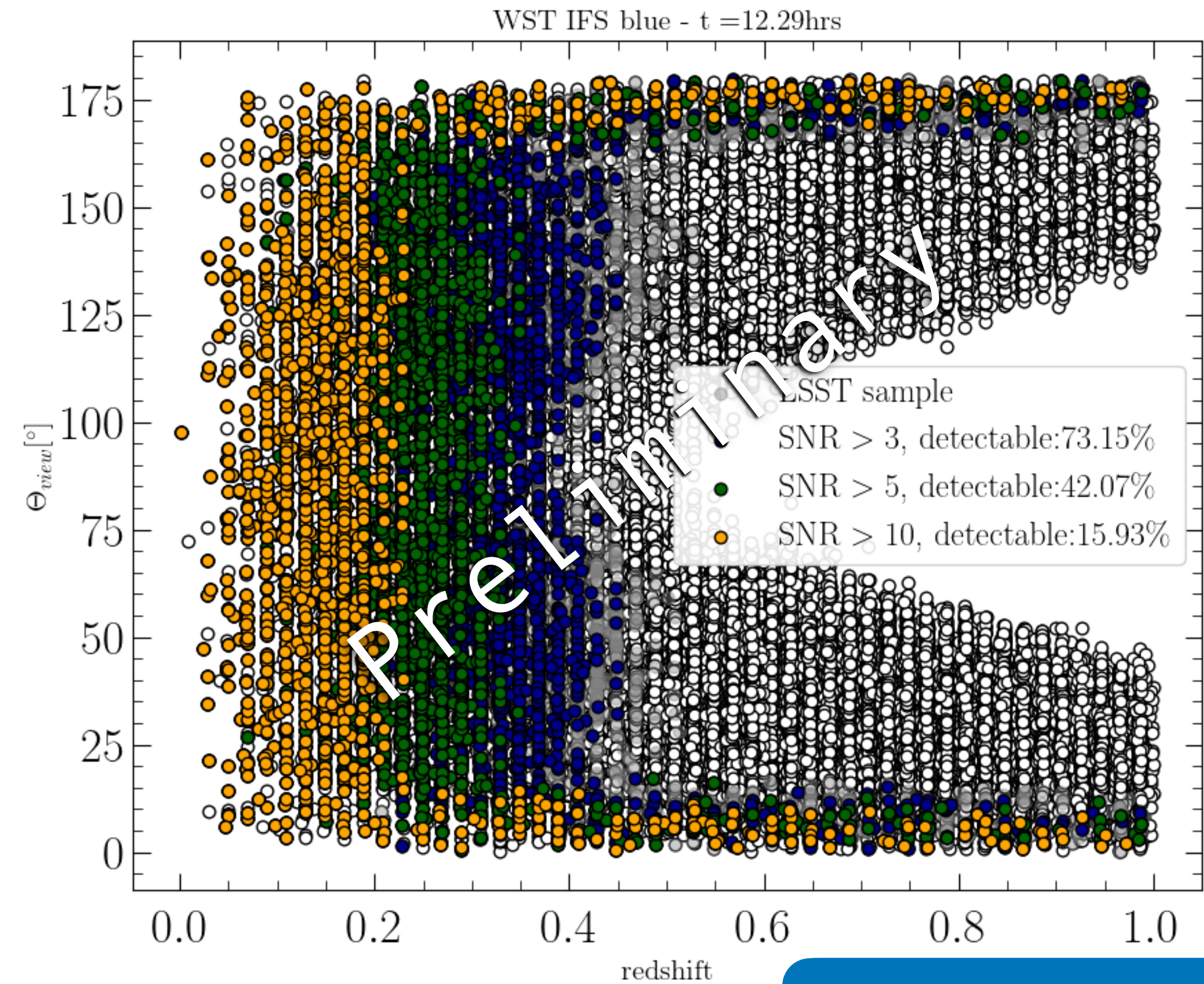

BLh gaussian

ET-WST synergy

Preliminary results

KN only

KN+GRB afterglow

ET+CE

BLh gaussian

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 **on-axis** systems

- 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

Thank you!