

Napoli, June 27, 2024



WG12: GW & NEUTRINOS



SERGIO CAMPANA
OSSERVATORIO ASTRONOMICO DI BRERA

NEUTRINO SOURCES

About 10 gold alters per year from ICEcube.

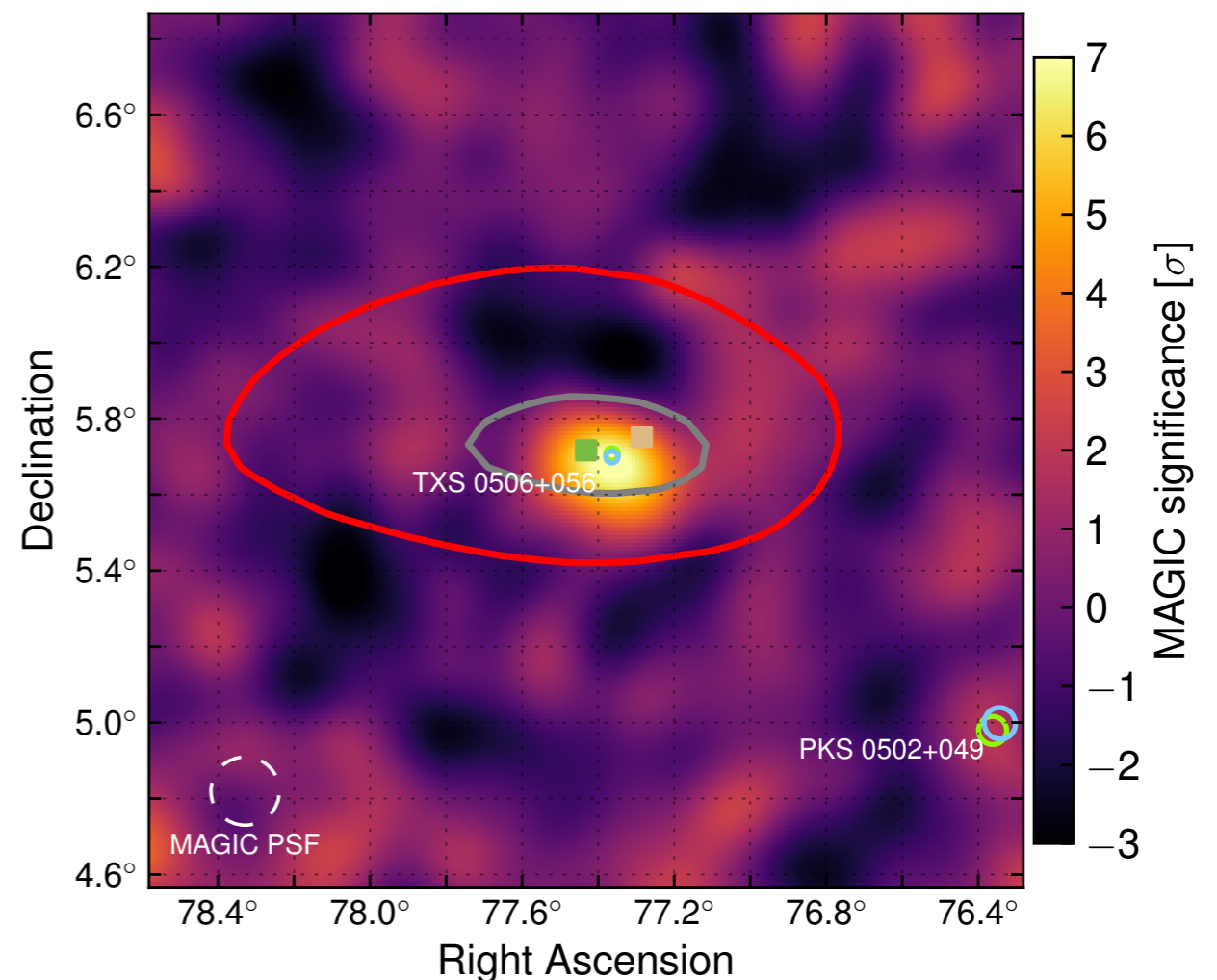
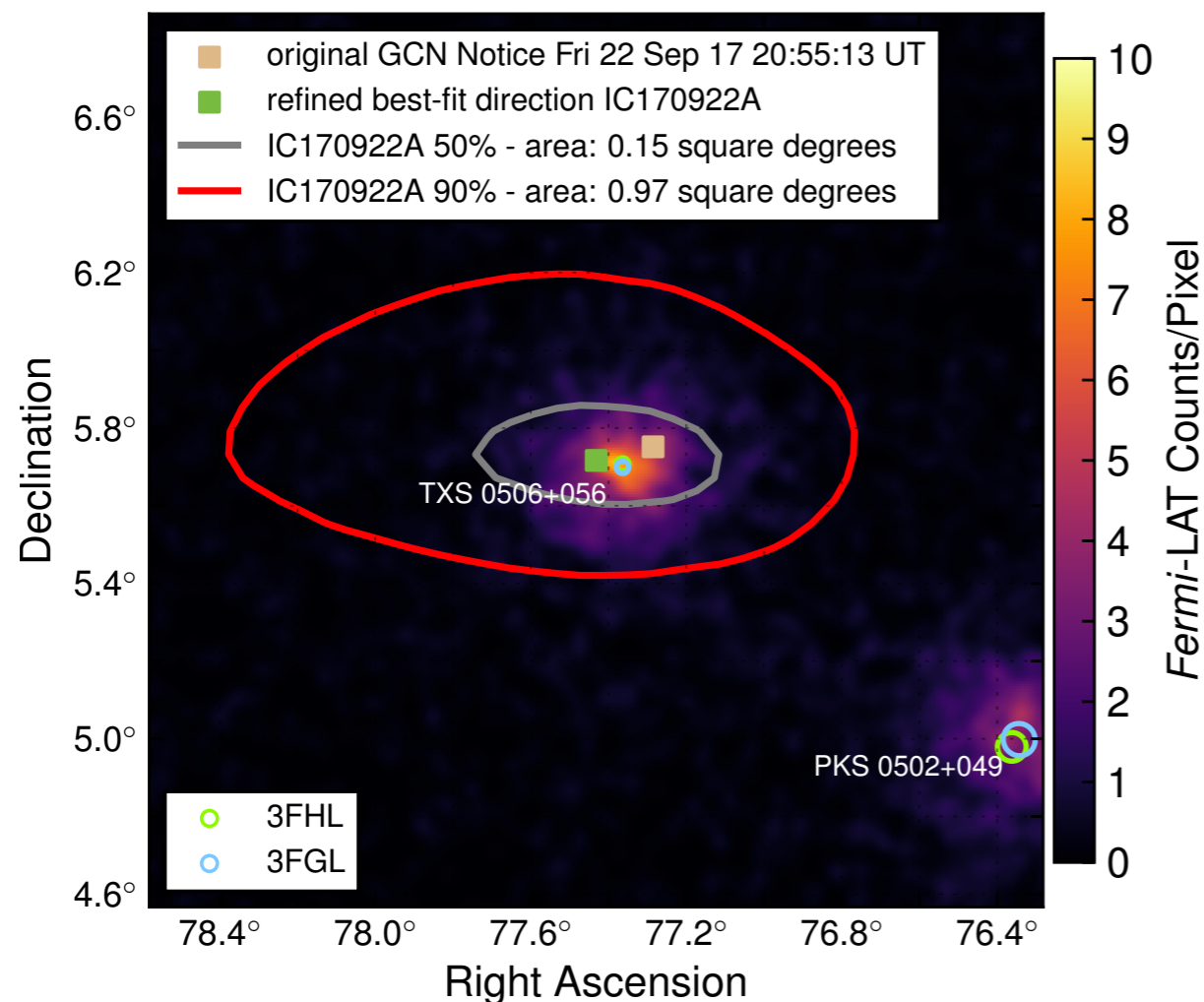
Several different class of sources are potentially neutrino emitters

Only one (possible) association in all these years

ICEcube-170922A = TXS0506+058 (blazar)

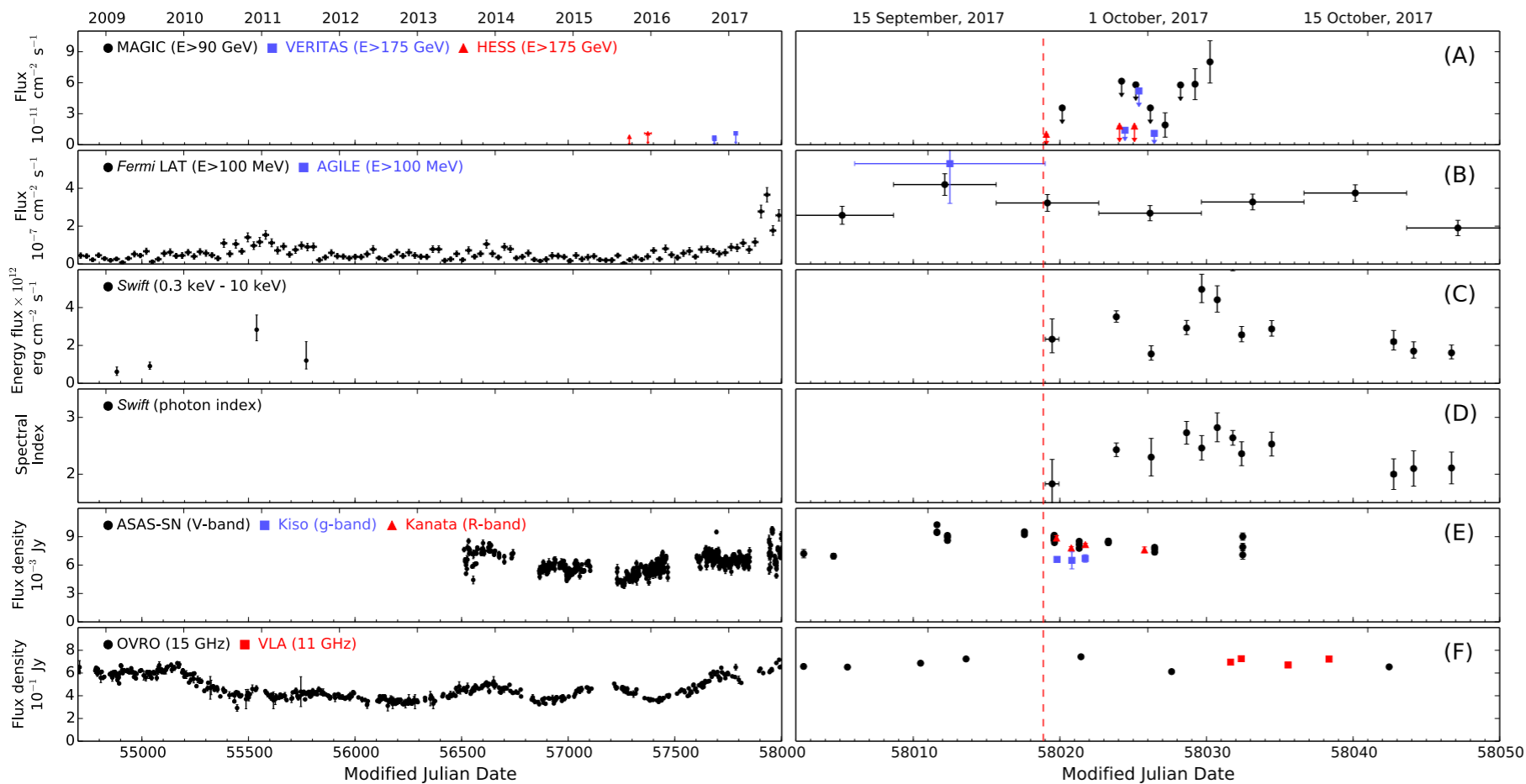
(A)

(B)



Another possible association with a TDE

MULTI-WAVELENGTH MONITORING



TXS0506+058

$z=0.34$

$V \sim 14.5$

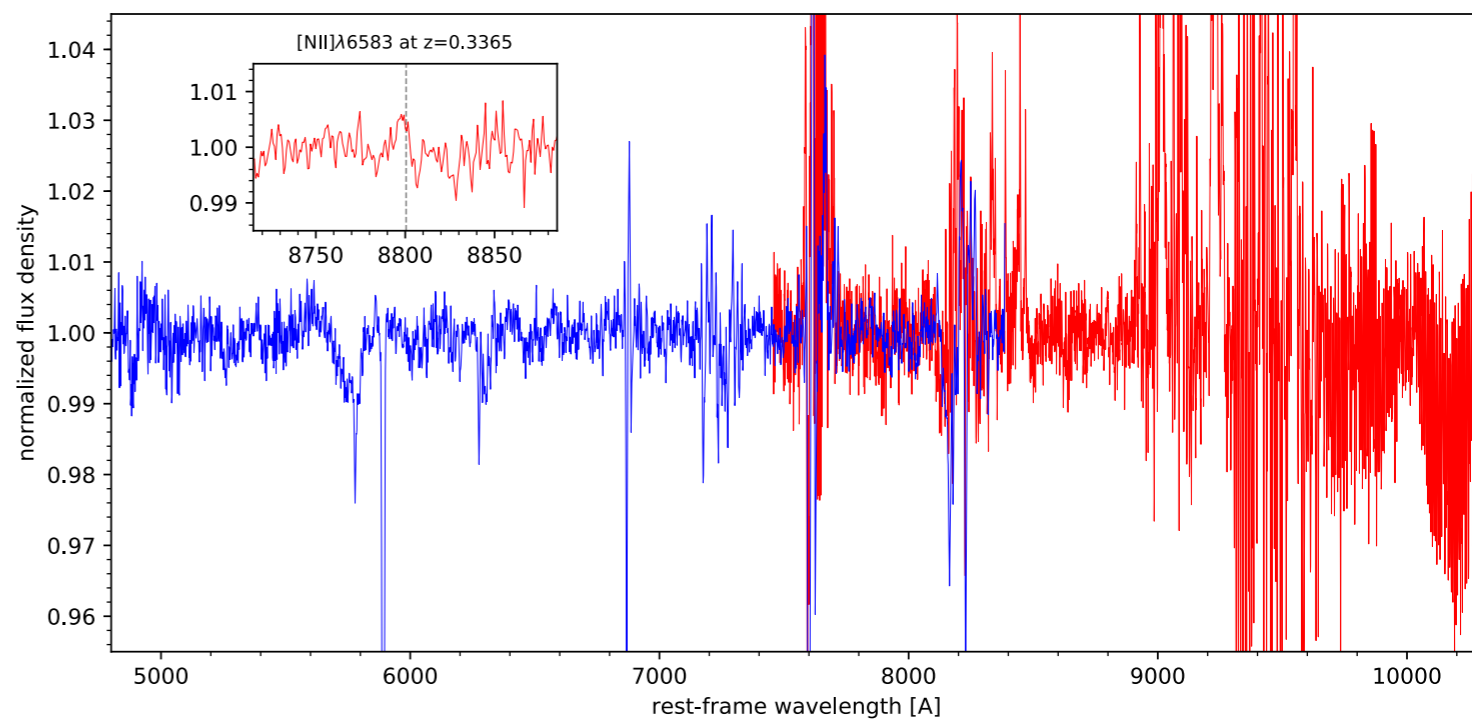


Figure S5: Subaru/FOCAS spectra of TXS 0506+056. Normalized spectra taken with

WHAT SHOULD WE DO?

Follow up spectroscopically, neutrino-emitting counterparts.

Very rare events. The only one discovered so far did not show any spectral variation.

5hr per semester should be far more than enough.

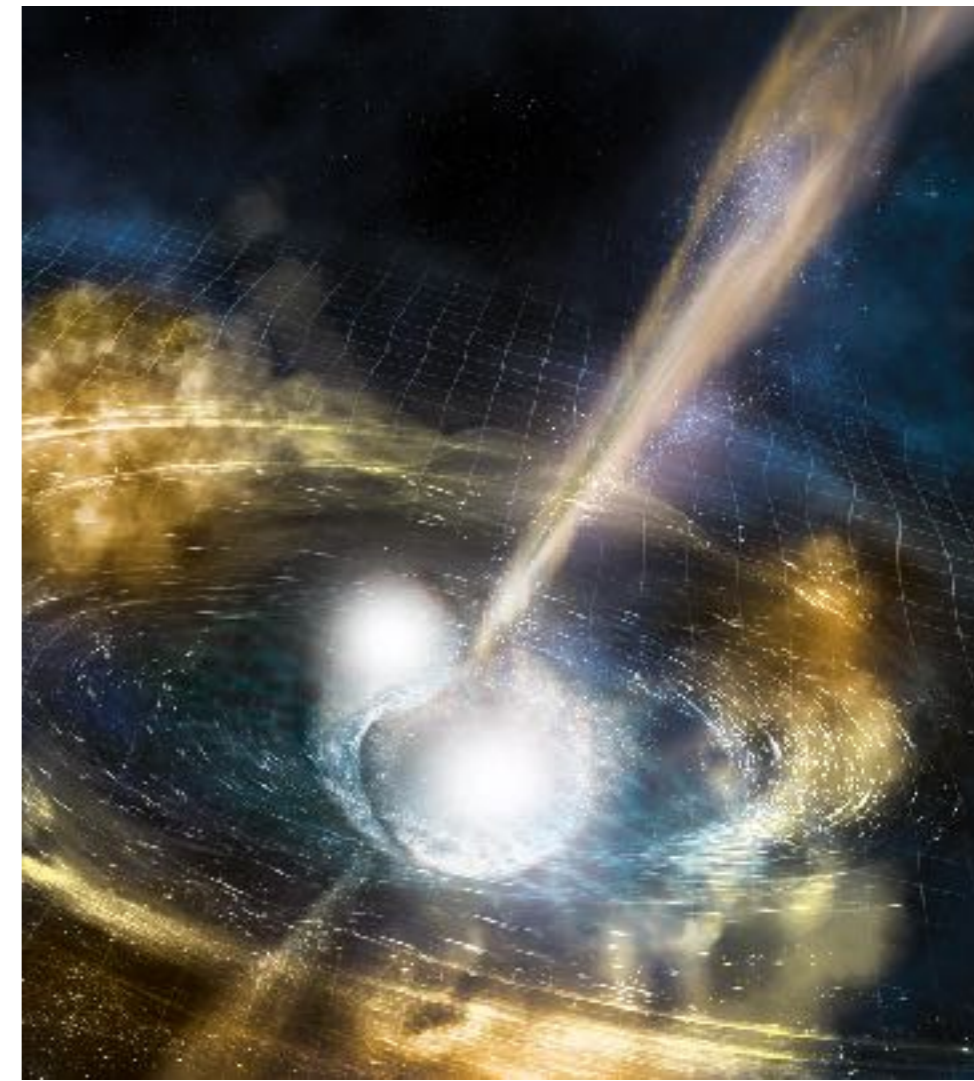
At the same time, if we discover a good counterpart showing spectral variations in response to a high emitting state, we should follow it up extensively, with a valuable pay-off.

GW170817

NS-NS mergers do exist!

Observational features

- short GRBs
- kilonovae
- early blue emission



SOXS UNIQUE CHARACTERISTICS

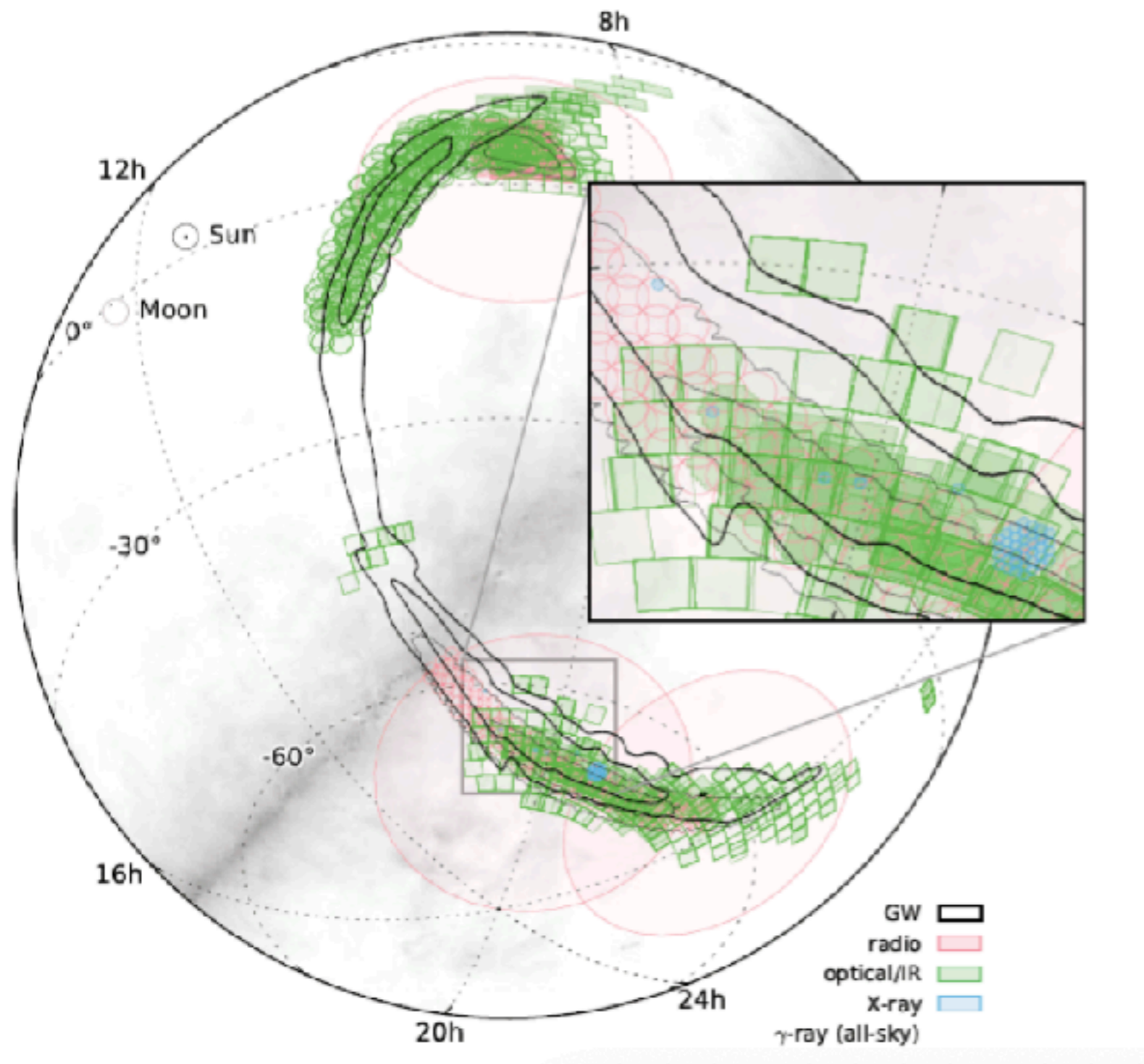
Can trigger at any time (unless bad weather)

Can trigger in (near) real time

Can devote to observations as much time as it is needed

SOXS will have override procedures and, at the moment, GW will have priority over any other program

CANDIDATE SEARCH

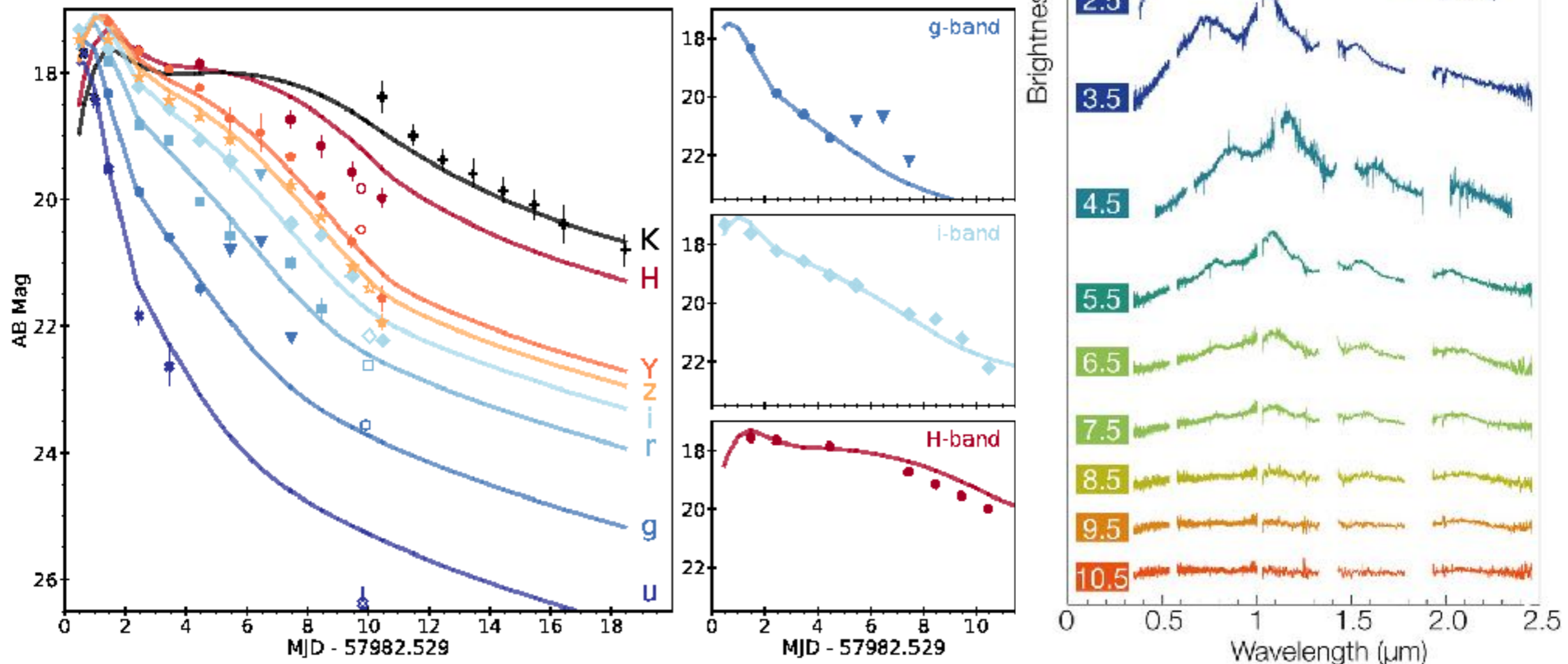


*SOXS will **not** actively search photometric candidates*

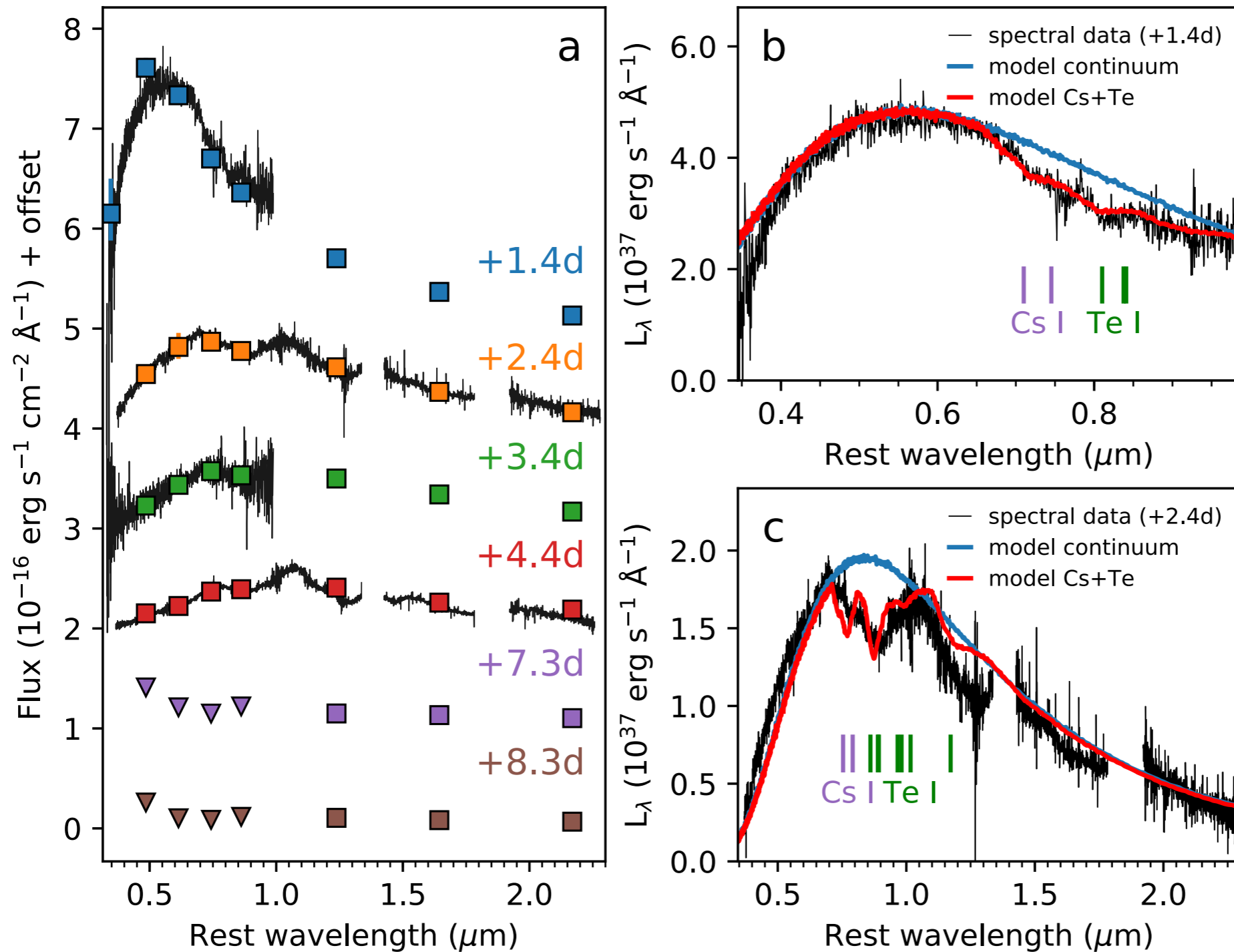
SOXS will point at any meaningful candidate to help identify the true GW counterpart

COUNTERPART FOLLOW UP

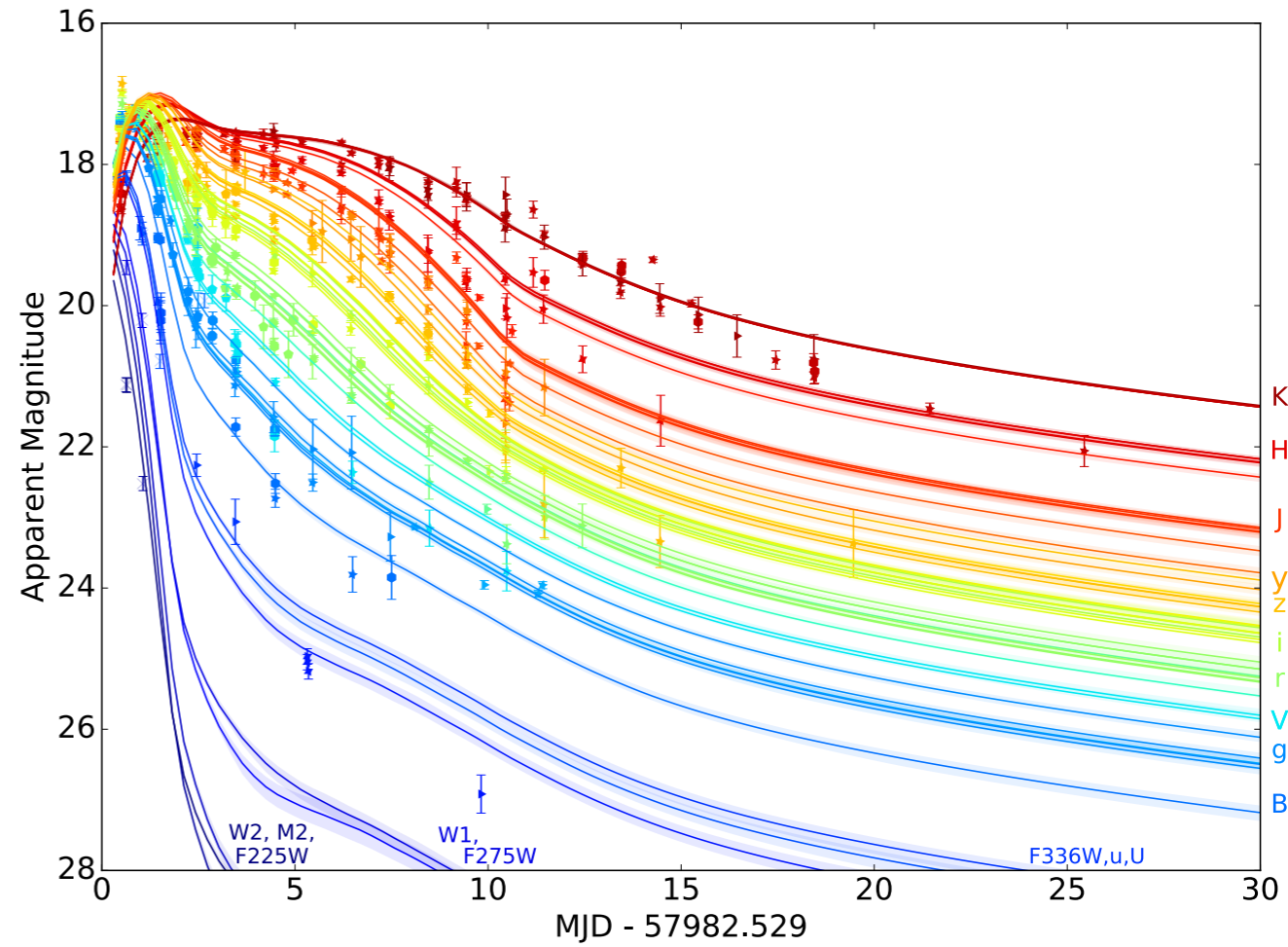
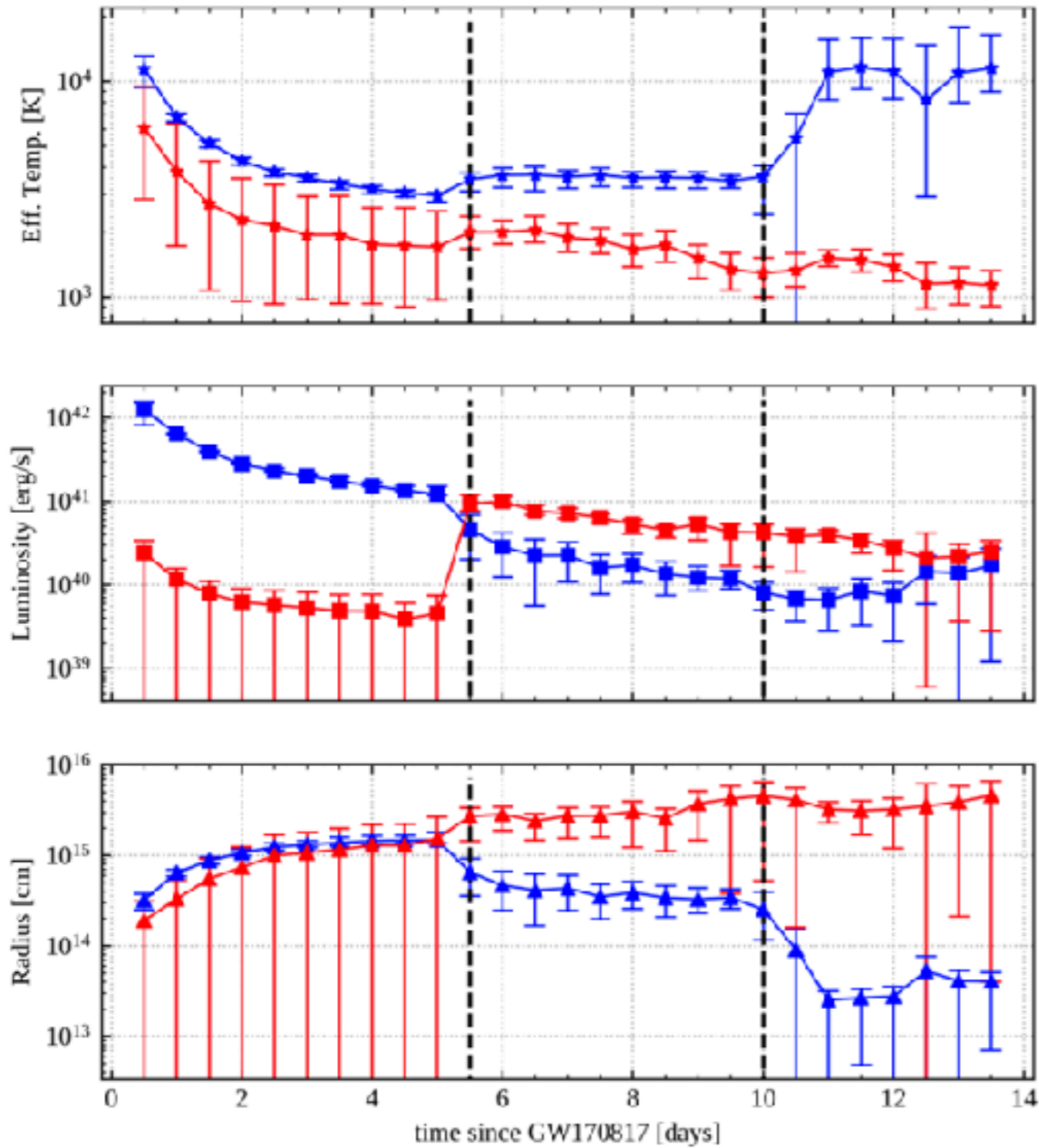
Once the counterpart is identified, SOXS will follow it up intensively as much as it can



NTT ALREADY DID IT!

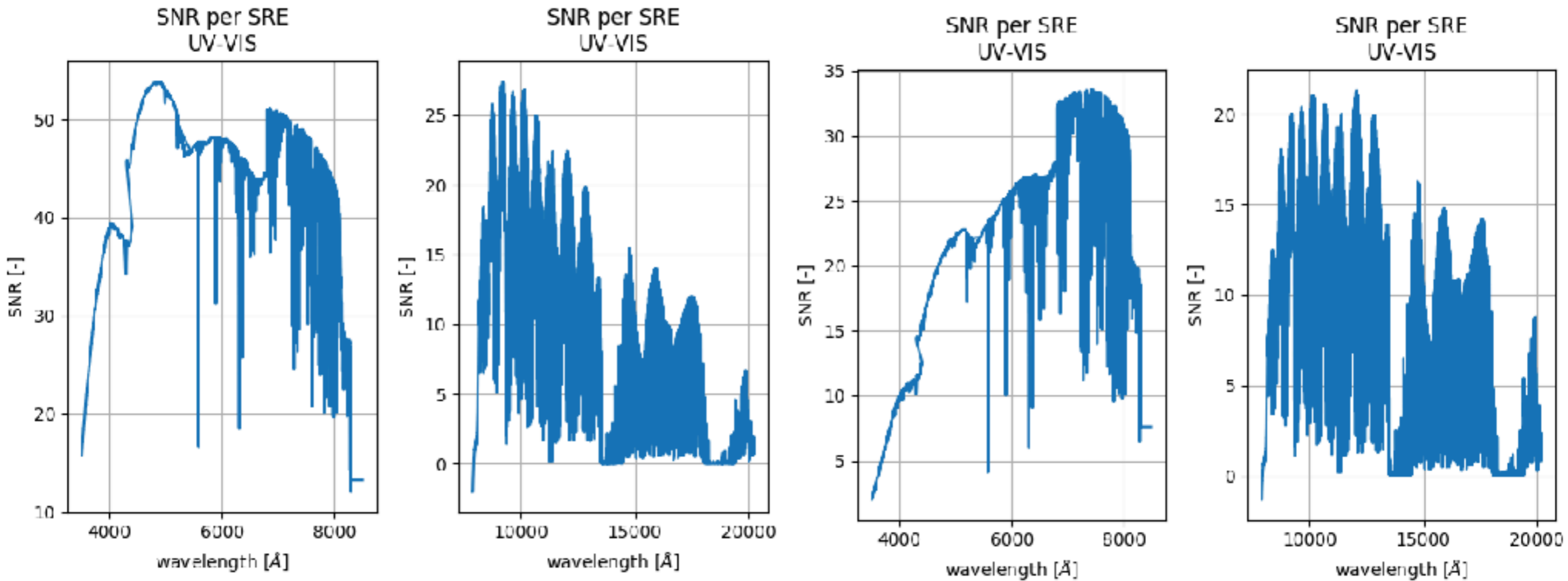


FEASIBILITY



EARLY EVOLUTION

ETC: <http://192.167.38.34/>



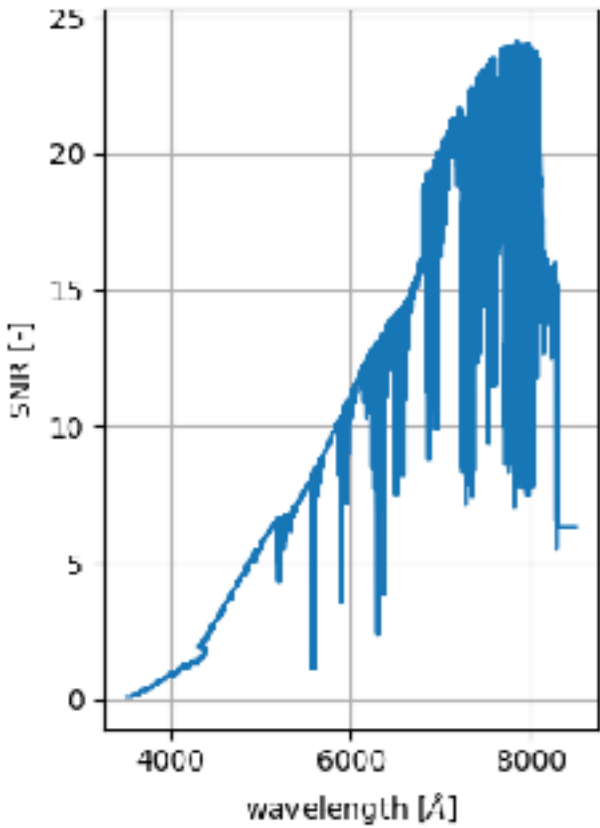
DAY1 - 30 min $T=10,000\text{K}$ $V=18$

DAY1 - 60 min $T=5,000\text{K}$ $V=20$

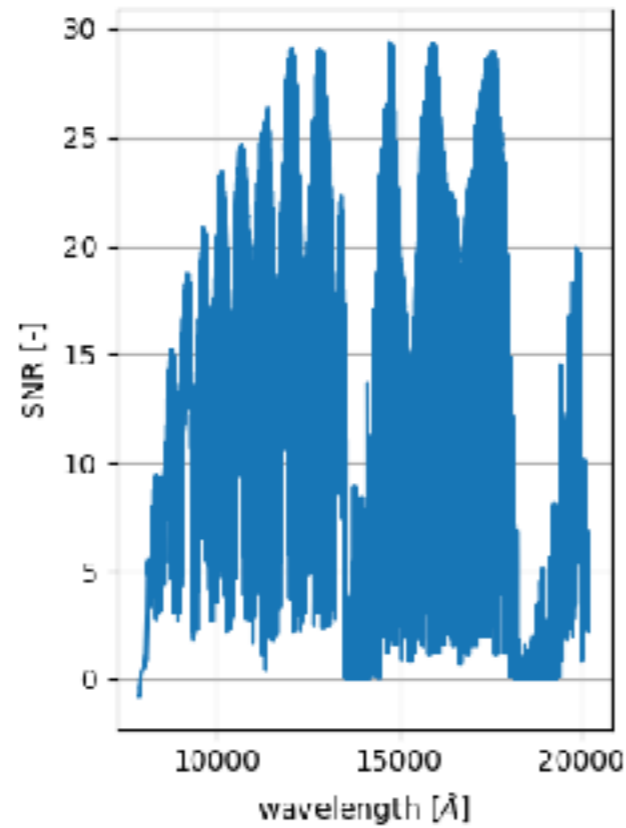
Moon=3, airmass=1.5, AB, binning 4

LATE EVOLUTION

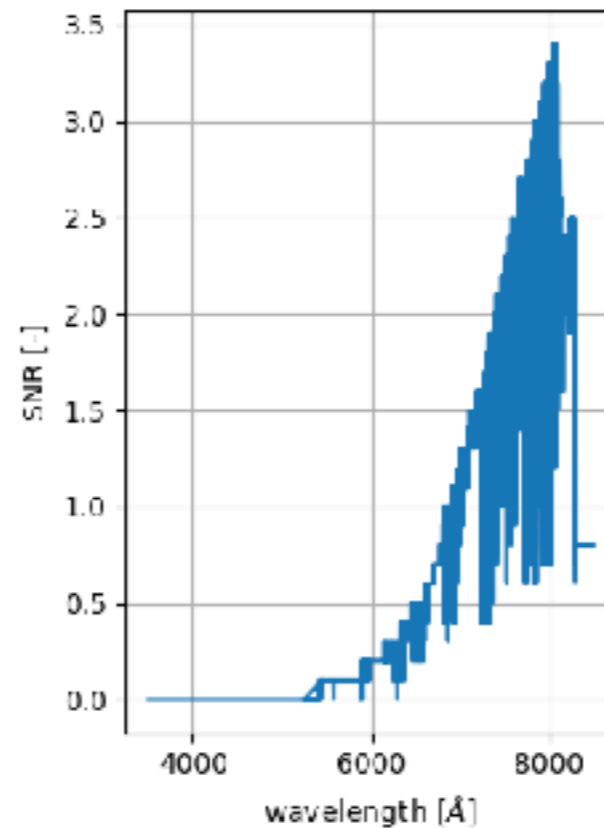
SNR per SRE
UV-VIS



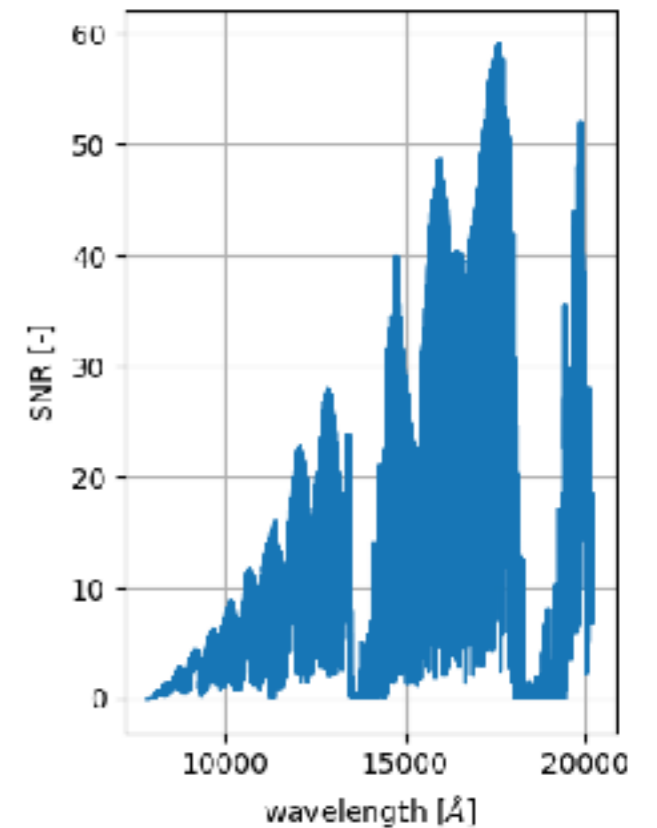
SNR per SRE
UV-VIS



SNR per SRE
UV-VIS



SNR per SRE
UV-VIS



DAY5 - 60 min $T=3,000\text{K}$ $I=19.5$

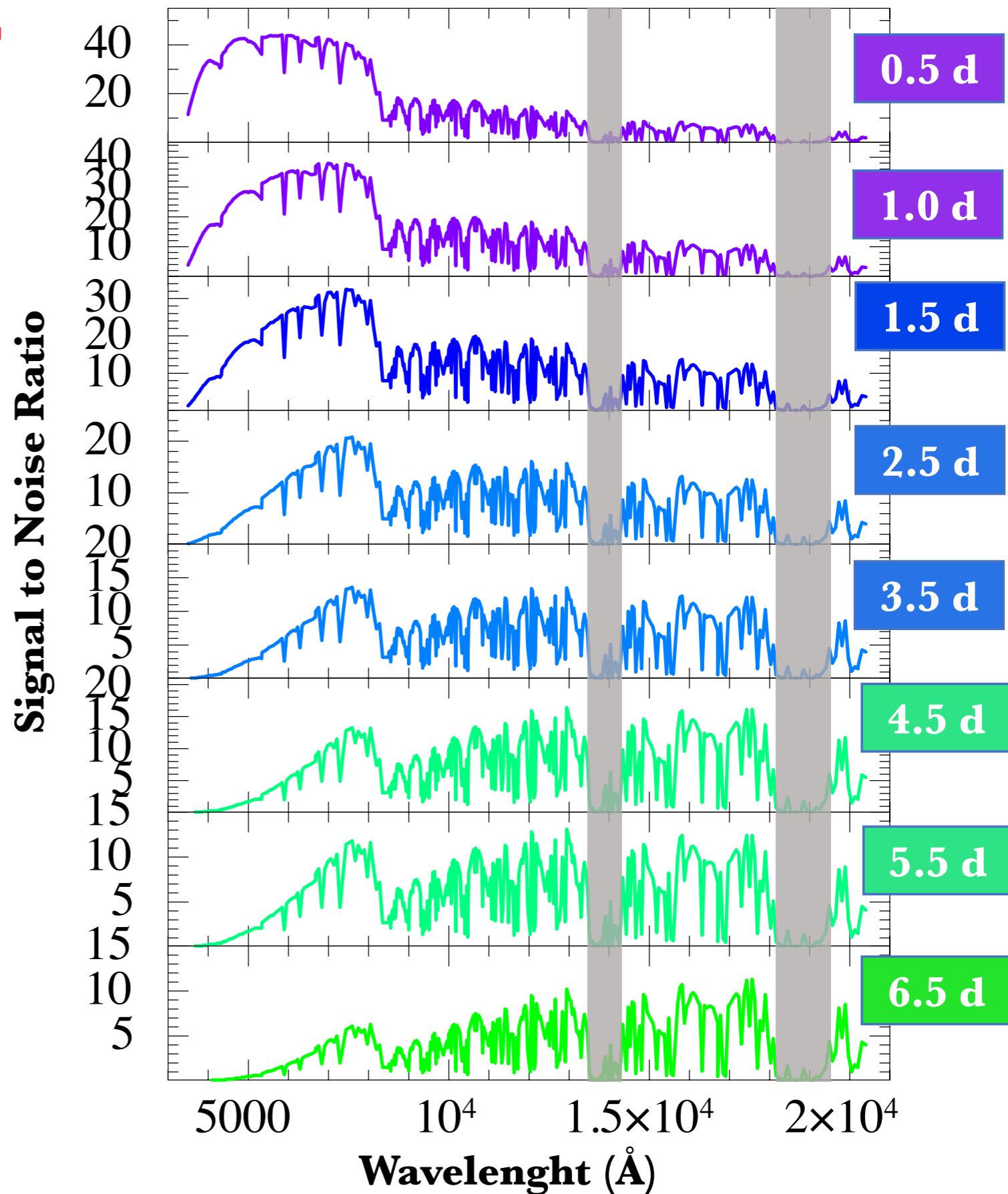
DAY10 - 60 min $T=1,500\text{K}$ $I=22$

Moon=3, airmass=1.5, AB, binning 4

TRACKING THE EVOLUTION

If GW170817 could be taken as a testbed:

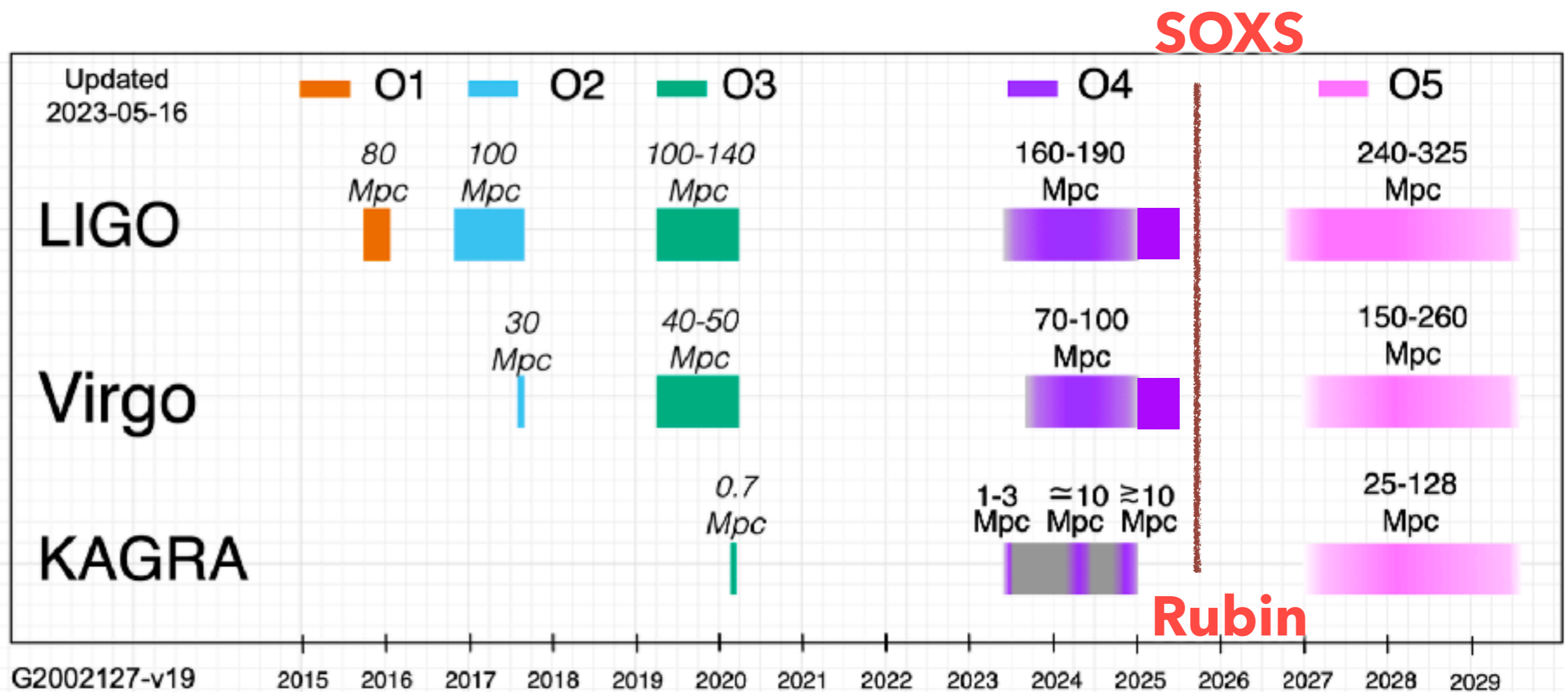
- Follow the fast evolution at the beginning of the explosion, with more than one spectrum per night*
- Track the entire evolution for the first ~10 d at a resolution $R \sim 1000$*



TIMELINE

SOXS will be ready in late 2025

We will talk again about GW triggers in 2027, during the O5 run and then three instruments at design sensitivity



BUT O3b has been extended and we might collect some data during the SOXS commissioning phase

PREDICTIONS FOR O5

Rates of BNS and NSBH detections still very uncertain

$R_{\text{BNS}} = 98^{+260}_{-85} \text{ Gpc}^{-3} \text{ yr}^{-1}$ (LVK, binned GP model ; N. Sarin)

Naive estimate: $R_{\text{BNS}} = 19^{+33}_{-18} \text{ yr}^{-1}$ (rate of production of BNS by the Universe)

Shah et al. 2024: $R_{\text{BNS}} = 17^{+22}_{-10} \text{ yr}^{-1}$

Assuming bright Kilonova models, we have a maximum horizon of ~ 300 Mpc, resulting in $2.7^{+7.0}_{-2.3}$ events per yr.

Assuming faint Kilonova models, we have a maximum horizon of ~ 120 Mpc, resulting in $0.2^{+0.5}_{-0.2}$ events per yr.

BH-NS mergers do exist, too. Stronger gravitational signal, so they can be detected further away, but will have dimmer counterparts. Up to now, none has been detected, despite a few events.

WHAT SHOULD WE DO?

Rubin will start operating next year and other wide-field optical facilities are still surveying the sky.

There is the possibility to detect a serendipitous kilonova (kilonova connected to short GRBs are already covered by GRBs).

Keep a small amount of time for these events (~5 hr).

As for the neutrino counterparts, it is very difficult that a bright serendipitous kilonova ($R < 21$) will be detected, but if this will happen we will observe it.

POLITICS

SOXS ≠ GRAWITA

SOXS ≠ ENGRAVE

We will observe any candidate, if within our horizon

If everyone is interested in O5 we will try to observe candidates on rotation, starting with a number of coins proportional to the timeshare and using a betting strategy (likely):

- INAF
- Weizmann
- INAF
- Weizmann
- INAF
- QUB
- Weizmann
- Finland
- Chile

CONCLUSIONS

SOXS will play a major role in studying GW and neutron counterparts, if any.

All the needed time will be allocated to study in deep detail GW spectra, starting from O5 (2027).

If GW170817 can be used as a template, GW study is well within reach of SOXS capabilities, to cover the early, fast-evolving blue phase, as well as the late, very red kilonova phase.