SOXS (Son Of X-Shooter): the transient hunter

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on behalf of the SOXS team

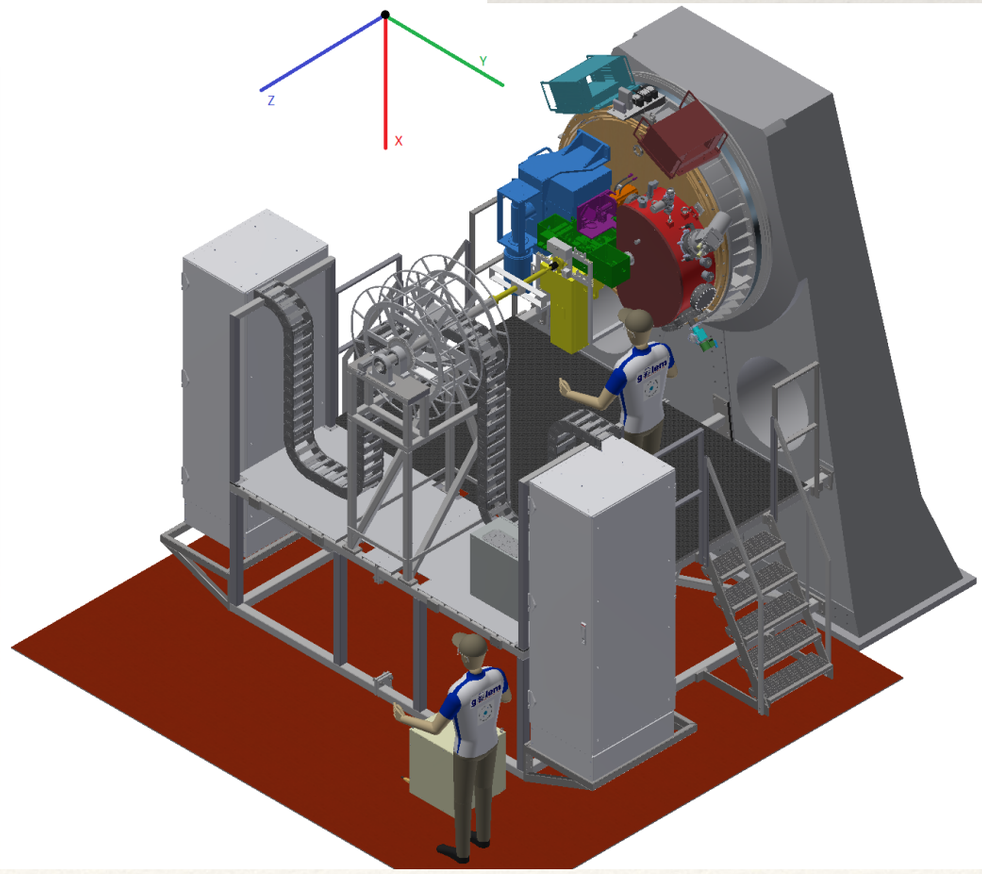
CNOC XII - Cefalù September 27, 2022

SOXS@NTT in a nutshell

Main characteristics

- Single-object
- Broad band spectrograph 350-2000 nm
- R~4,500 (4,000-6,000)
- Two arms (UV-VIS + NIR) 350-850 nm + 800-2000 nm
- Acquisition camera to perform photometry ugrizY (3.5'x3.5', 0.2" pixel)

NTT is a 3.6m ESO telescope in La Silla



History (more recent)

ESO call for new instruments at NTT (06/2014)

Proposal submission (02/2015)

SOXS selected by ESO (05/2015) out of 19

Signed MoU INAF-ESO

Signed MoU INAF-Partners

Project Phase	Start	End	Duration
Preliminary Design	08/2016	07/2017	12 months
Final Design	08/2017	10/2018	14 months
MAIT	11/2018	11/2022	48 months+COVID
PAE	04/2023	07/2023	3 months
Commissioning & SV & PAC	09/2023	03/2024	6 months
Operations & GTO	2024	2029	

Responsibilities

INAF ~ 49% (CP, NIR-arm, integration, management, etc.)

Wiezmann ~24% (UV-VIS arm optics and mechanics)

QUB ~8% (reduction pipeline, bought UV-VIS-CCD)

FINCA ~7% (Calibration Unit)

MAS ~6% (Acquisition camera)

Tel Aviv University ~4%

DAWN & Aarhus Univ. ~2%

SOXS UV-VIS arm

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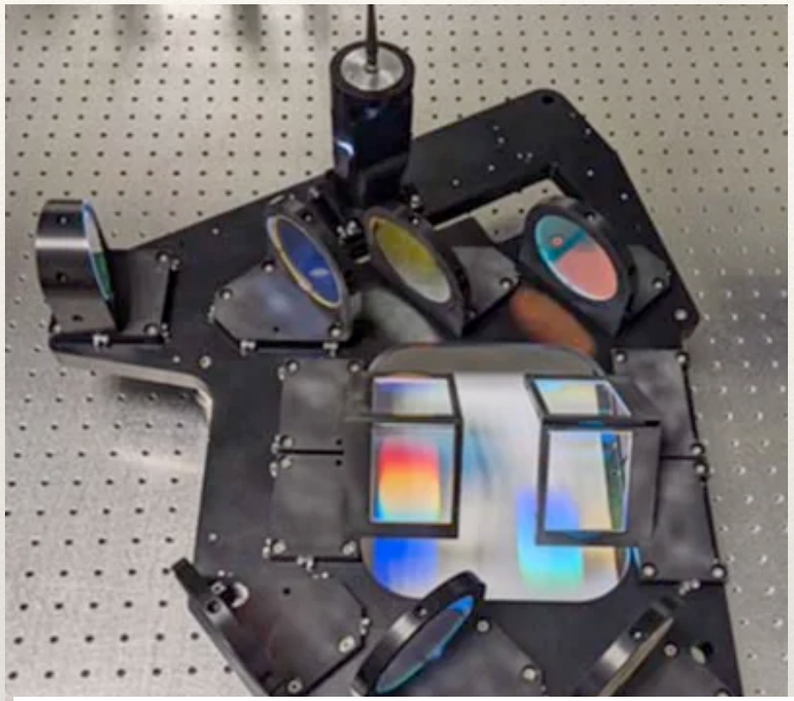
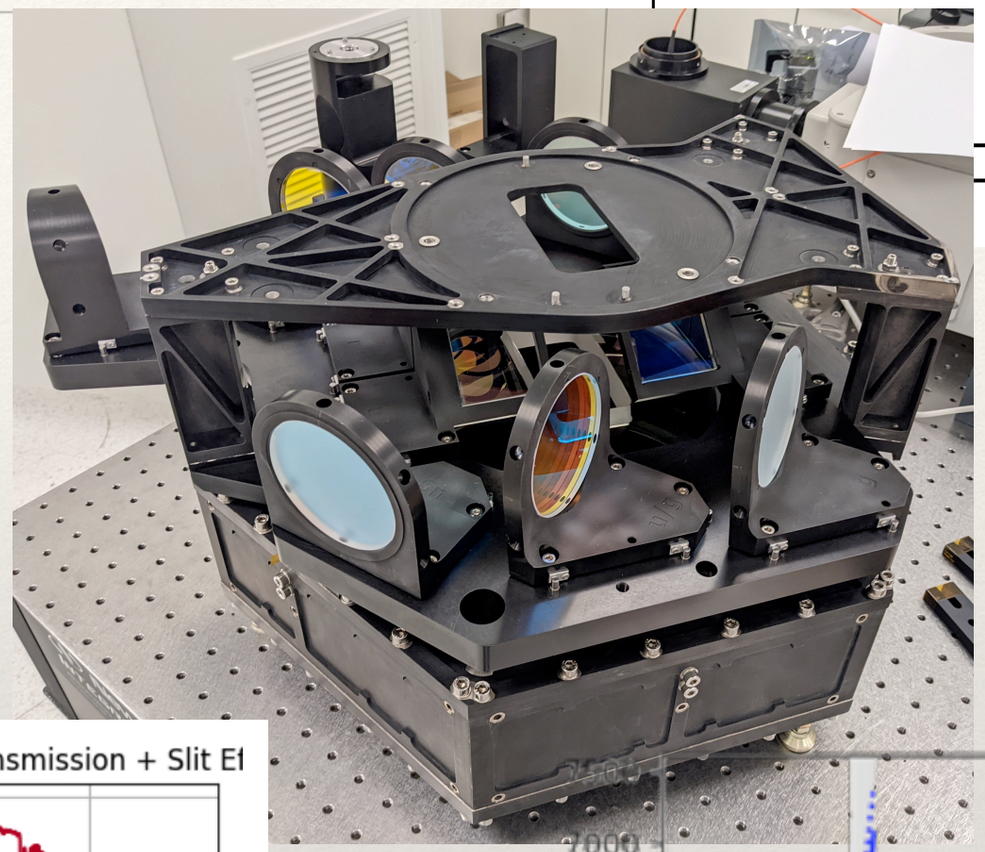
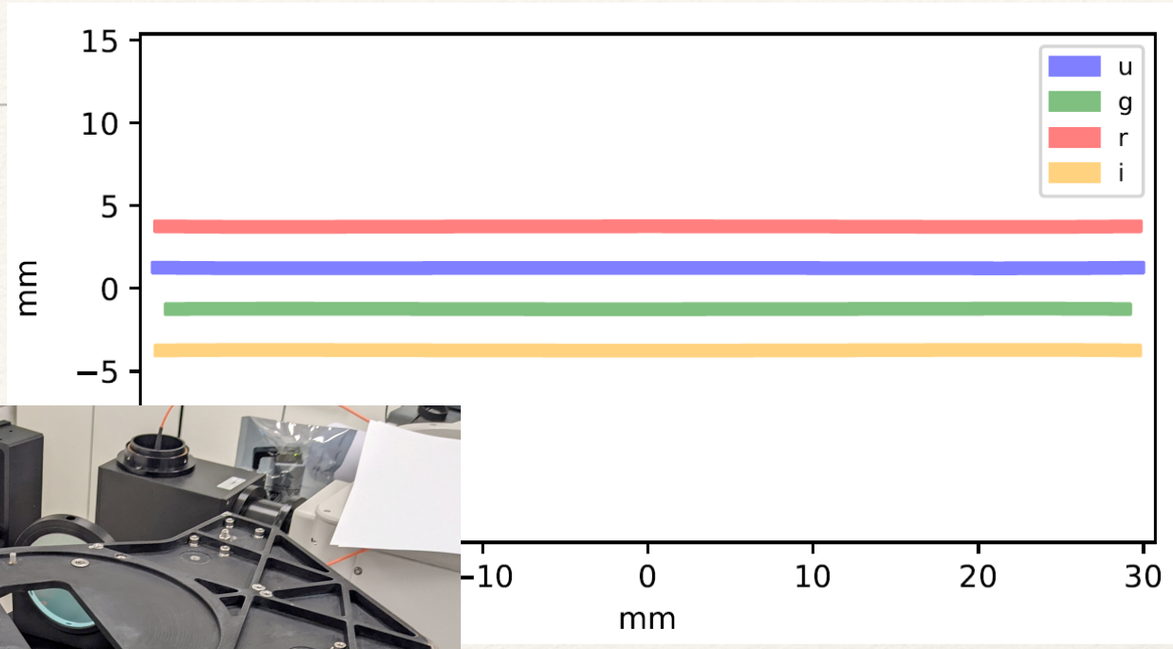
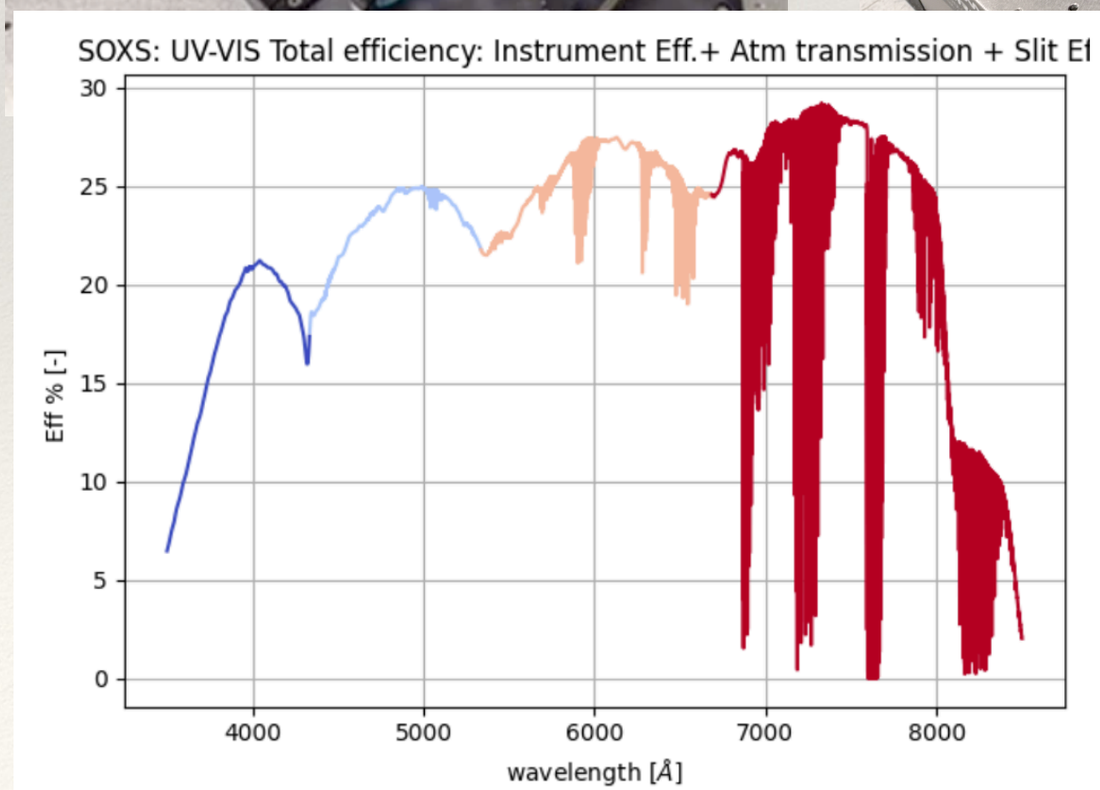
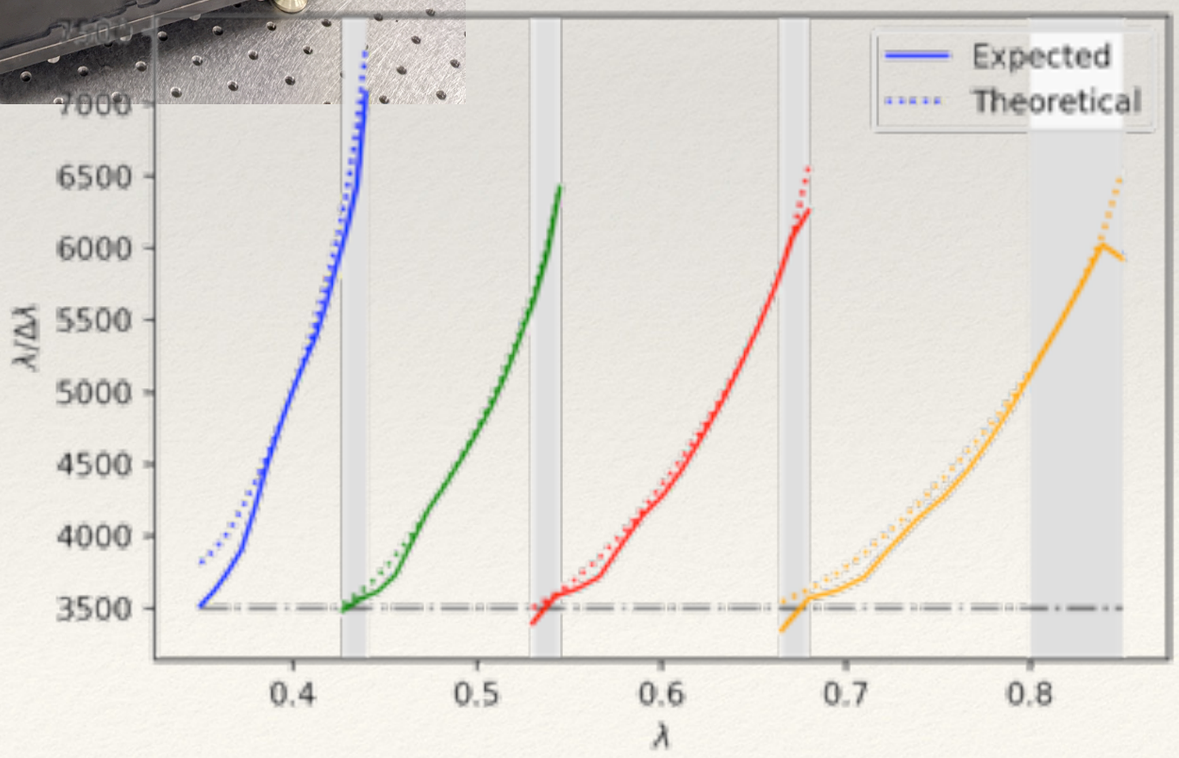
WEIZMANN INSTITUTE OF SCIENCE



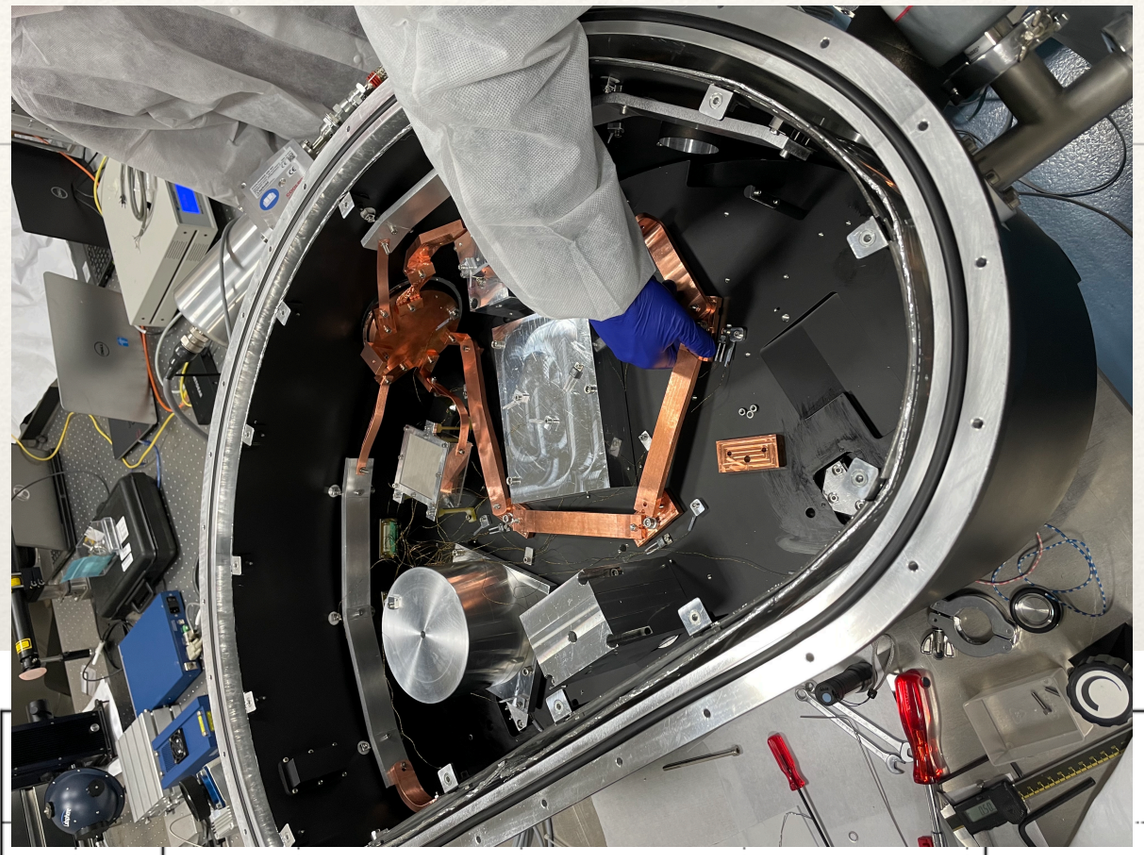


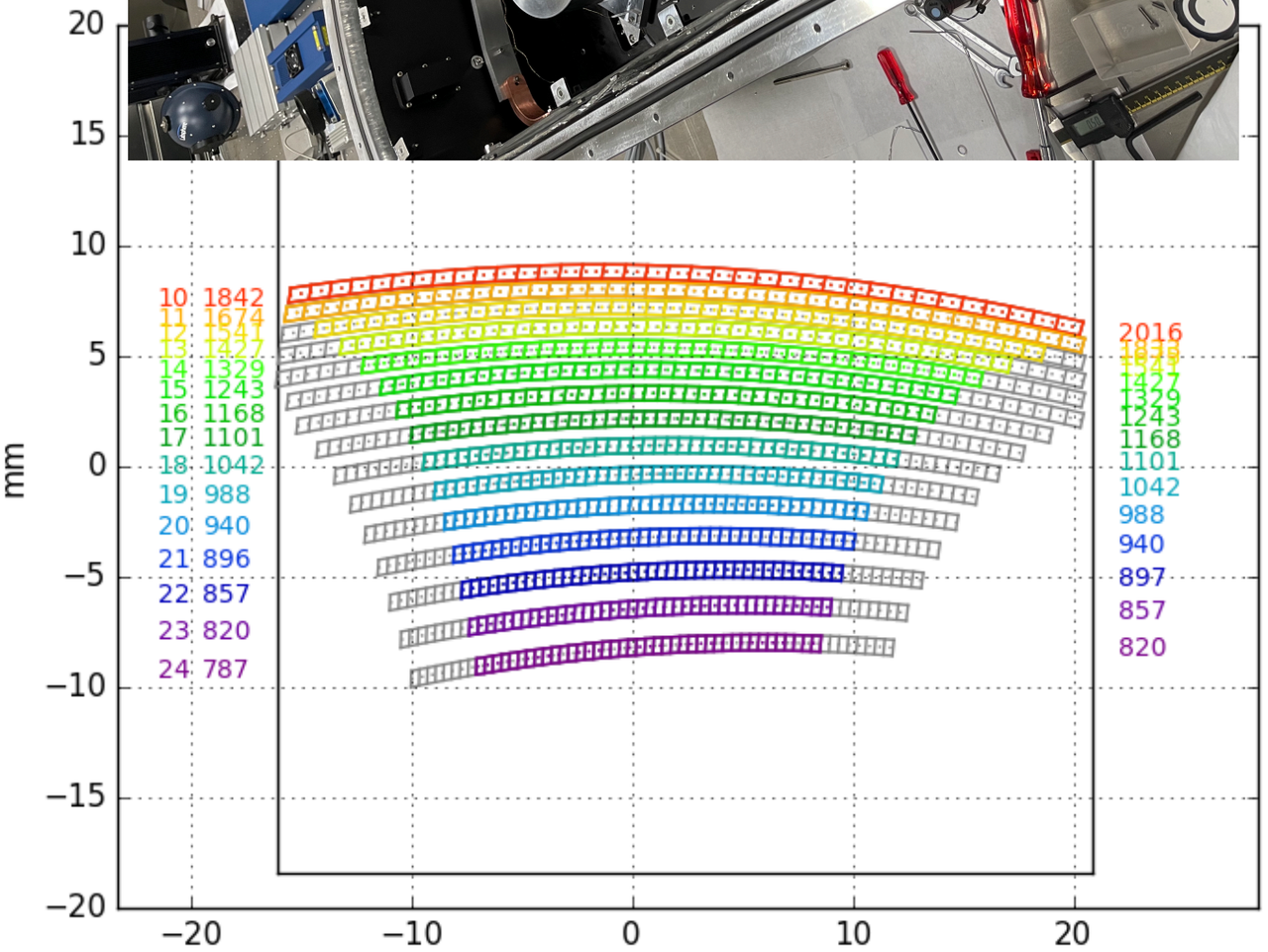






SOXS NIR arm




mm
10 1842
11 1674
12 1541
13 1427
14 1329
15 1243
16 1168
17 1101
18 1042
19 988
20 940
21 896
22 857
23 820
24 787
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1243
1168
1101
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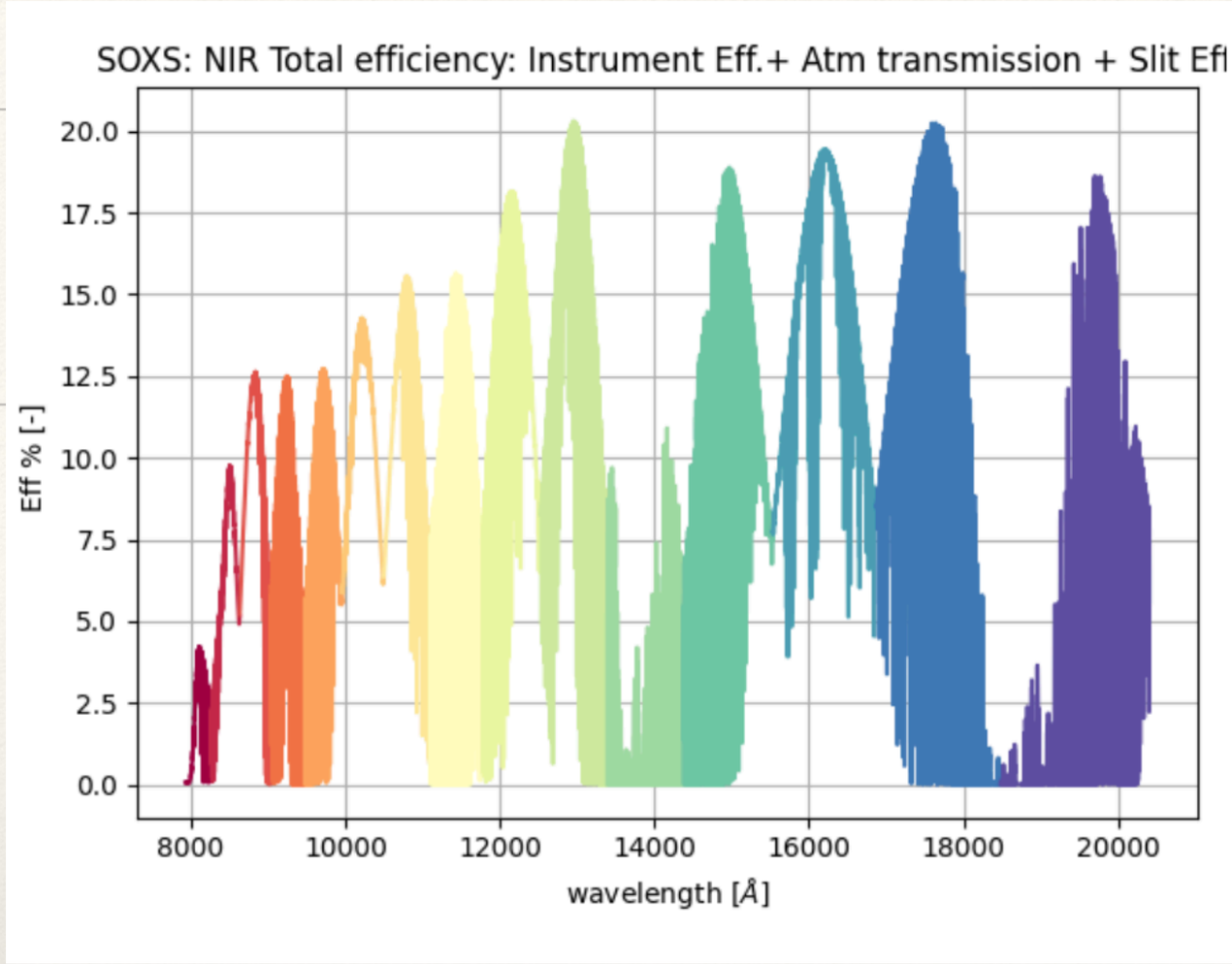
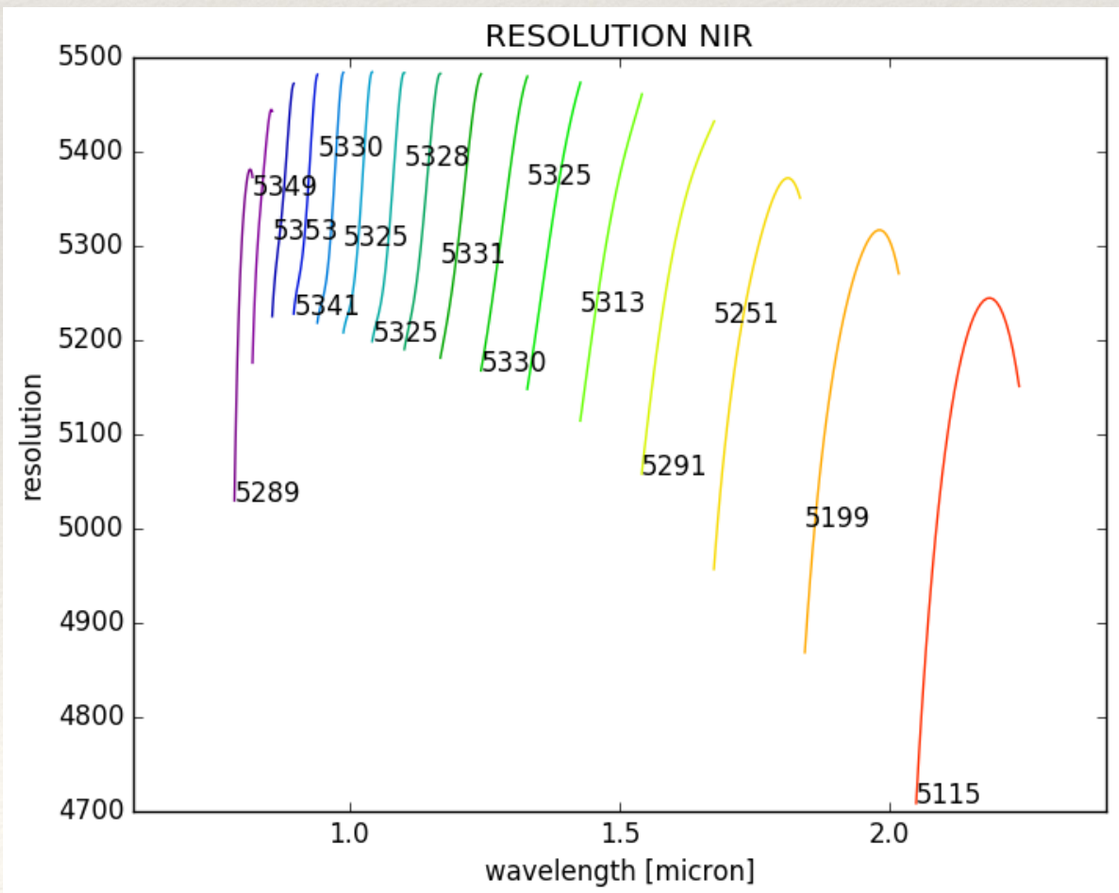
988
940
897
857
820


SOXS: NIR Total efficiency: Instrument Eff.+ Atm transmission + Slit Effi
Eff % [-]
wavelength [Å]


RESOLUTION NIR
resolution
wavelength [micron]
5289
5349
5353
5341
5330
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5313
5291
5251
5199
5115

Kulkarni's comparison

Instrument efficiencies

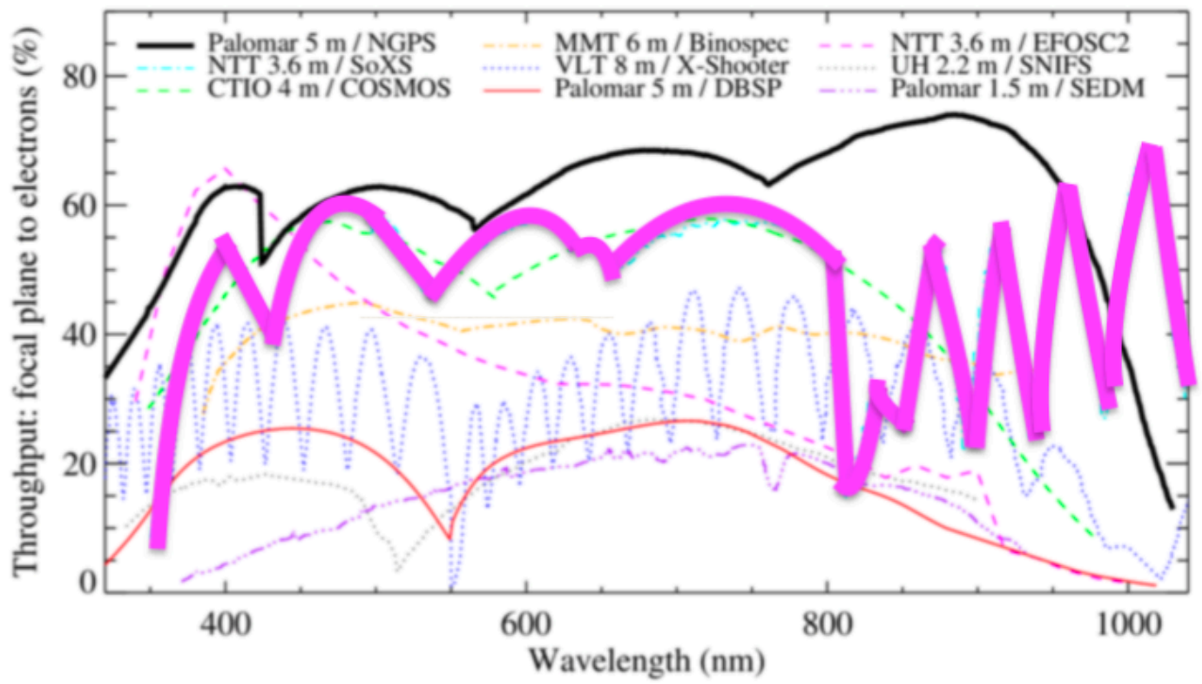
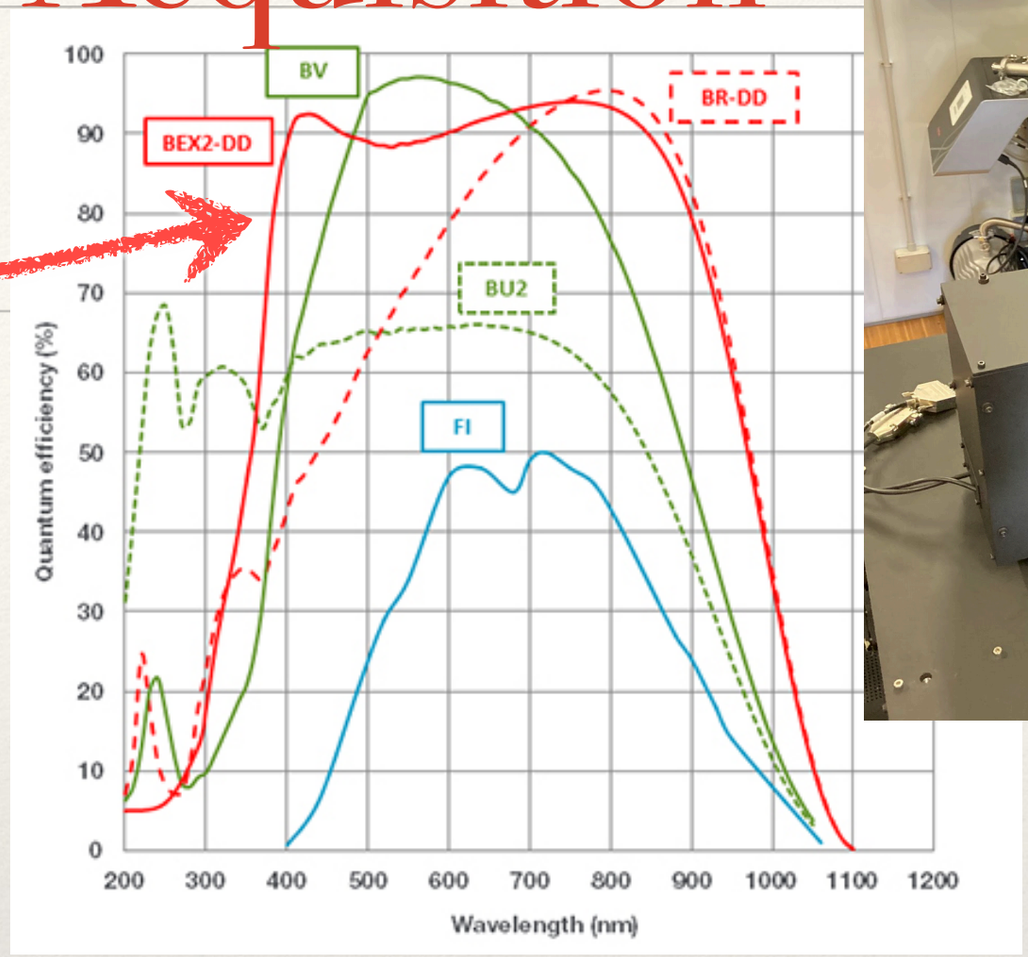


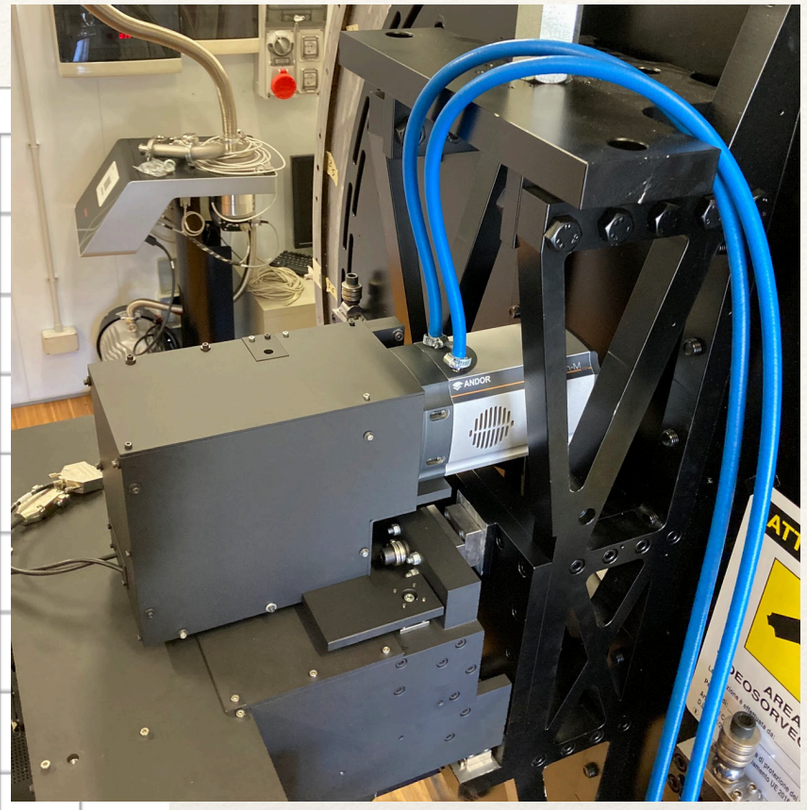
Figure 5. The throughput from the focal plan to photoelectrons of the Next Generation Palomar Spectrograph (NGPS; solid line). The throughput for other spectrographs varies between this measure to "from sky to photoelectrons". References: Son of X-Shooter (SoXS, Claudi et al. 2018, M. Genoni, pers. comm.), COSMOS (Martini et al. 2014), Binospec (Fabricant et al. 2019), X-Shooter (Vernet et al. 2011), DBSP (Oke & Gunn 1982), EFOSC2, which is part of PESSTO (Smartt et al. 2015), SNIFS (Lantz et al. 2004; Lombardo et al. 2017), and SEDM (Blagorodnova et al. 2018). Figure supplied by E. Kirby.

https://arxiv.org/abs/2004.03511

(Imaging!) & Acquisition Camera

- Andor iKon M-934
- CCD sensor BEX2-DD

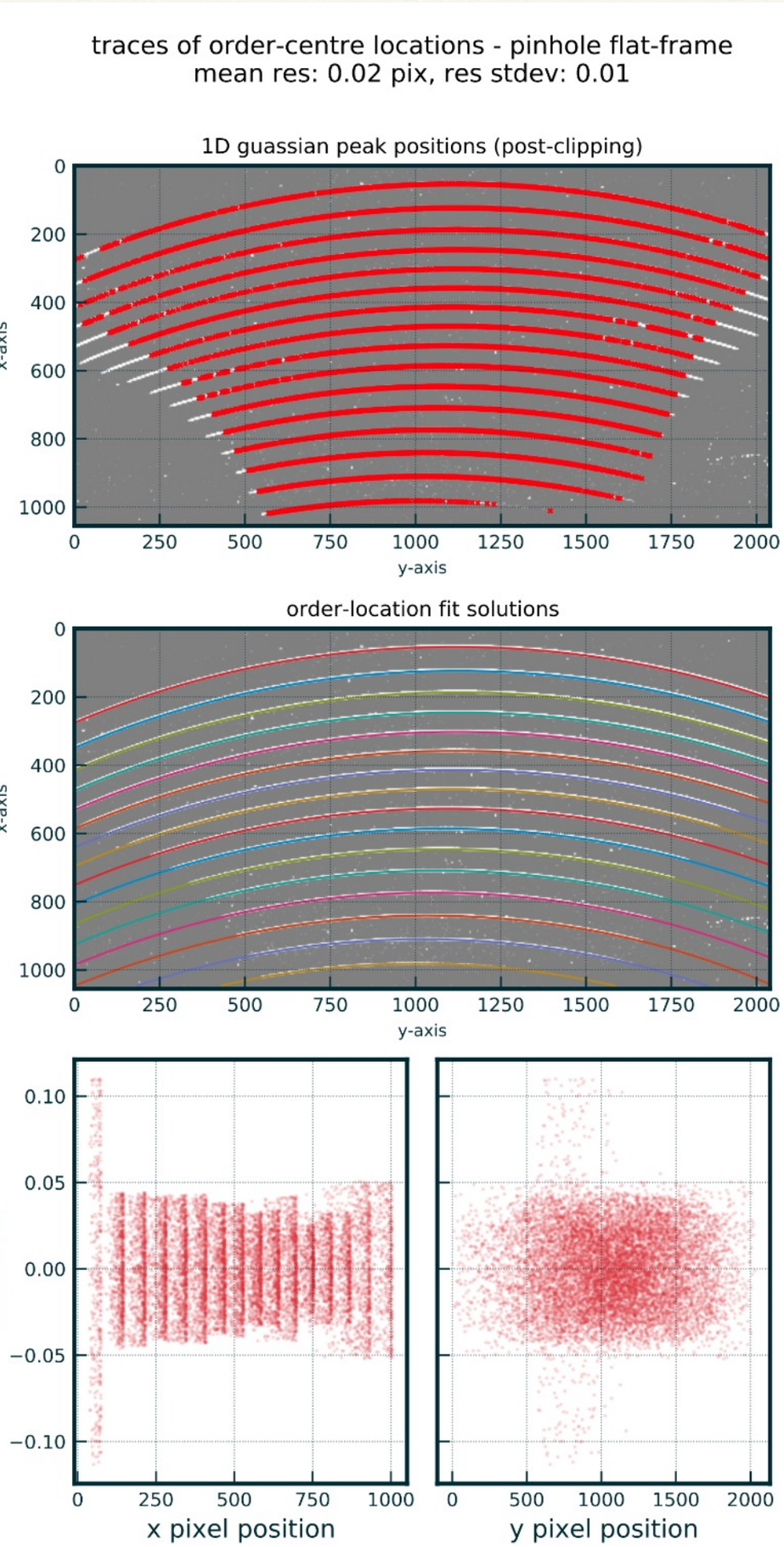




3.5’x3.5’ Field of view

LSST Band (Wav)	1 sec	2 sec	3 sec	5 sec	10 sec	15 sec	20 sec
u’ (355.7nm)	15.9	16.7	17.5	17.7	18.4	18.7	19.1
g’ (482.5nm)	18.2	18.9	19.4	19.8	20.5	20.8	21.0
r’ (626.1nm)	18.0	18.6	19.0	19.5	20.0	20.3	20.4
I’ (767.2nm)	16.4	17.1	17.5	17.9	18.4	18.6	18.8
z’ (909.7nm)	15.3	15.9	16.2	16.5	16.9	17.2	17.4

VIMOS Band (Wav)	1 sec	2 sec	3 sec	5 sec	10 sec	15 sec	20 sec
V (550nm)	19.5	20.1	20.5	21.0	21.5	21.8	21.9



Pipeline

- Pixel detrending – bias, flat, dark, linearity corrections (dark only for NIR)
- Produce 2D distortion corrected, orders merged pre-extraction spectrum for each arm (rectification)

Very quick. Data reduction in near-real time. No need for a quicklook. Written in python and integrated within ESO-Reflex

soxspipe works also on the photometric data; astrometric and photometric corrections with Pan-STARSS

The SOXS pipeline will be public

SOXS GTO

- 180 n/yr for 5 yr

- Bad weather shared with ESO

- Time: 8.5 hr * 0.75 eff * 0.9 good *180 n/yr ~ 1000 hr/yr

- SOXS GTO fully dedicated to Target of Opportunity observations for transient and variable sources, very limited time for long term monitoring of variable sources

Data policy

SOXS-GTO sources selected with clear triggering criteria, criteria will be made public before the start of the operations (and updated every 6 months).

Consortium GTO data will remain private for 12 months (or when data are published).

SOXS will also take classification spectra of sources from optical surveys (up to 25% of SoXS GTO observing time).
These data can be claimed by the SOXS Consortium within 3 days, if they fall under a GTO proposal (and will then remain private for 12 months). Otherwise classification data are public.

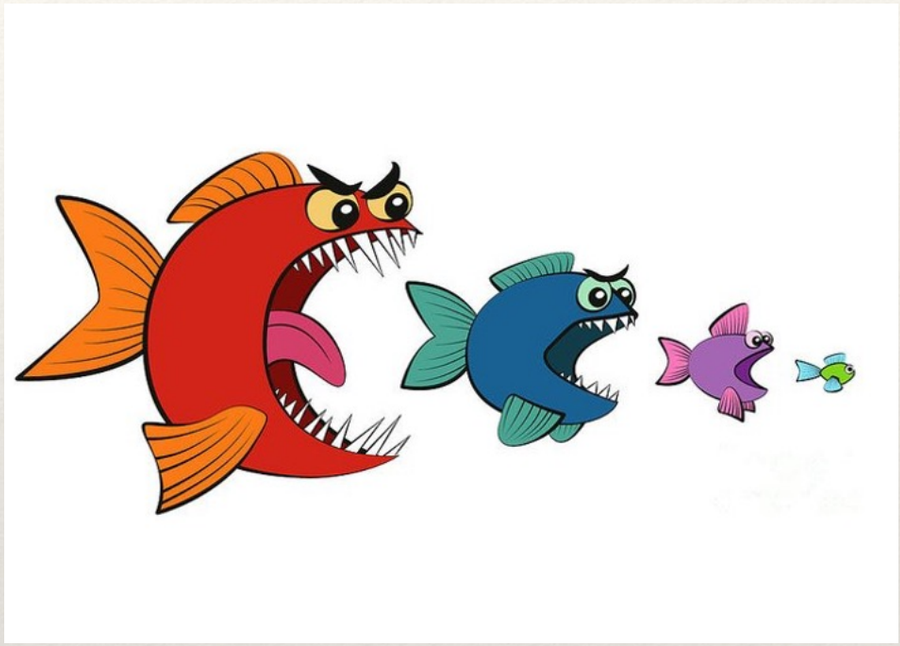
Operations

SOXS DUTIES

- prepare the overall night schedule in advance
- one scientist will remain on-call for problems and for **changing** the schedule in case of unforeseen fast-track events
- remain on call in case of (rare) instrument problems or more general problems
- help ESO users in case of need (helpdesk during working hours)
- classify “classification targets”
- light quality control

What do we do with SOXS?

SOXS is smaller than X-Shooter
SOXS is single object vs. 4MOST/TiDES
SOXS has a medium resolution (no UVES)
SOXS has no strong UV coverage (350 nm, no CUBES)
SOXS has no K-band coverage (2000 nm, no XS)

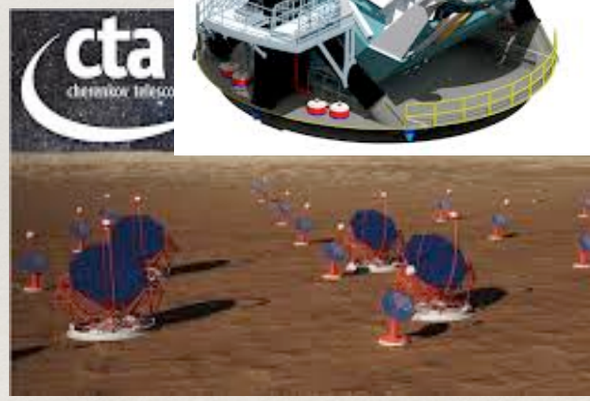


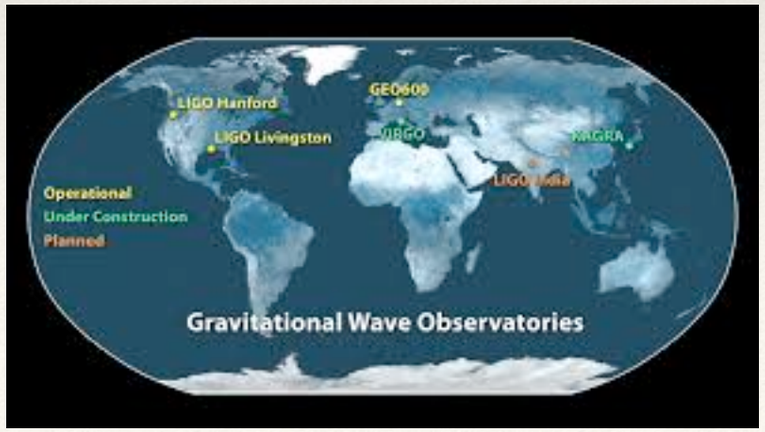
Difficult to identify a single driving science case

Why do we need SOXS

Current & new optical survey: ATLAS, ASAS-SN, ZTF, Rubin/LSST, …
Space optical missions: Gaia, EUCLID?, …
Space high-energy missions: Swift, Fermi, eROSITA?, SVOM, …
Radio new facilities: MeerKAT, SKA, …
VHE: MAGIC, HESS, CTA
Messengers: LIGO-Virgo, KM3Net, ANTARES, …

SOXS@NTT will have 180 n/yr (for 5 yr)
~2,000 - 3,000 spectra/yr





SOXS Science cases

~20% of Nature papers are on transient sources

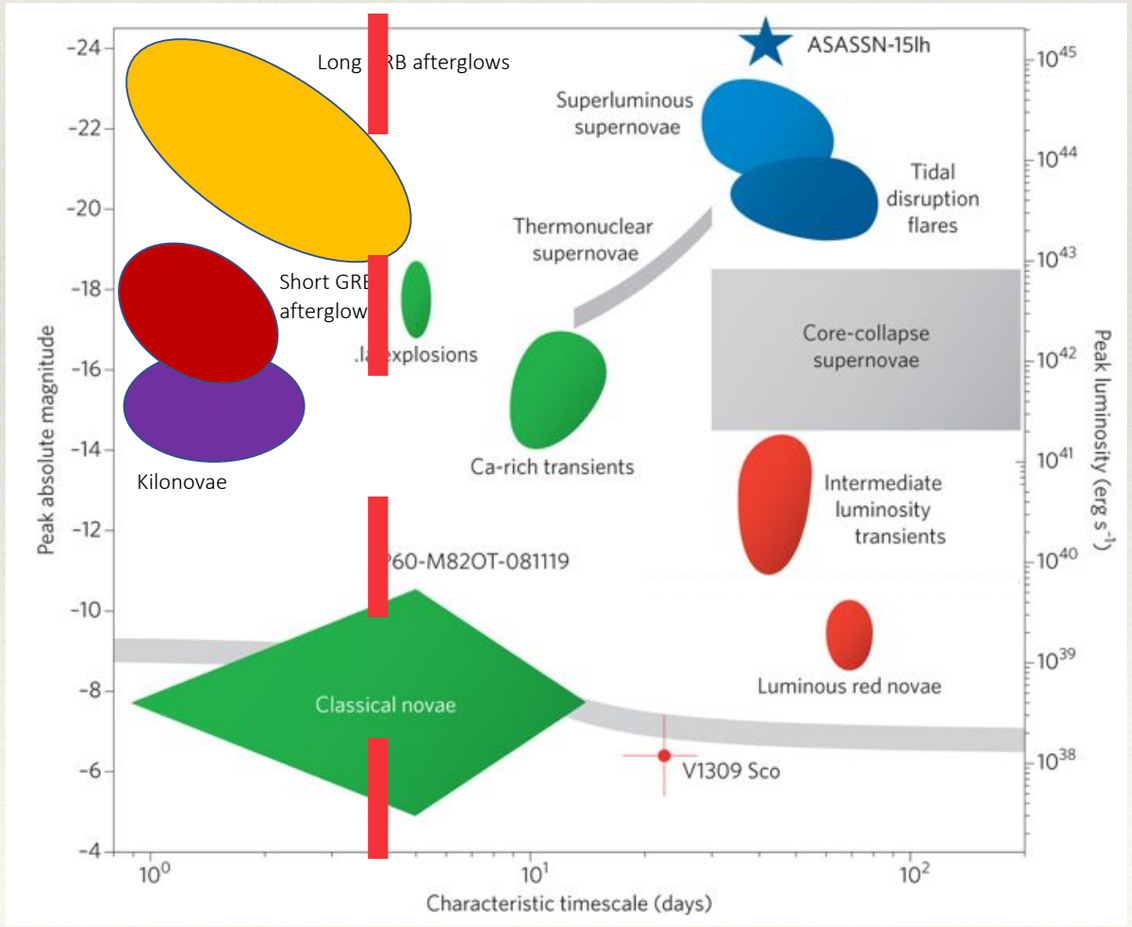
- Classification (service)
- **SN (all flavours)**
- **GW & ν**
- **TDE & Nuclear transients**
- **GRB & FRB**
- Blazars & AGN
- X-ray binaries & magnetars
- Novae & WDs
- Young Stellar Objects & Stars
- Asteroids & Comets
- Unknown

ExtraGalactic

Galactic

Solar System

Use at BEST our STRENGTHS:
- **Rapid follow-up**
- **Always available (complete sample, dense monitoring)**



Imaging & Acquisition camera

Preliminary ETC for the imaging with the SOXS acquisition camera

Performances comparable to EFOSC2, slightly worse in the blue-red filters, better in the reddest filters

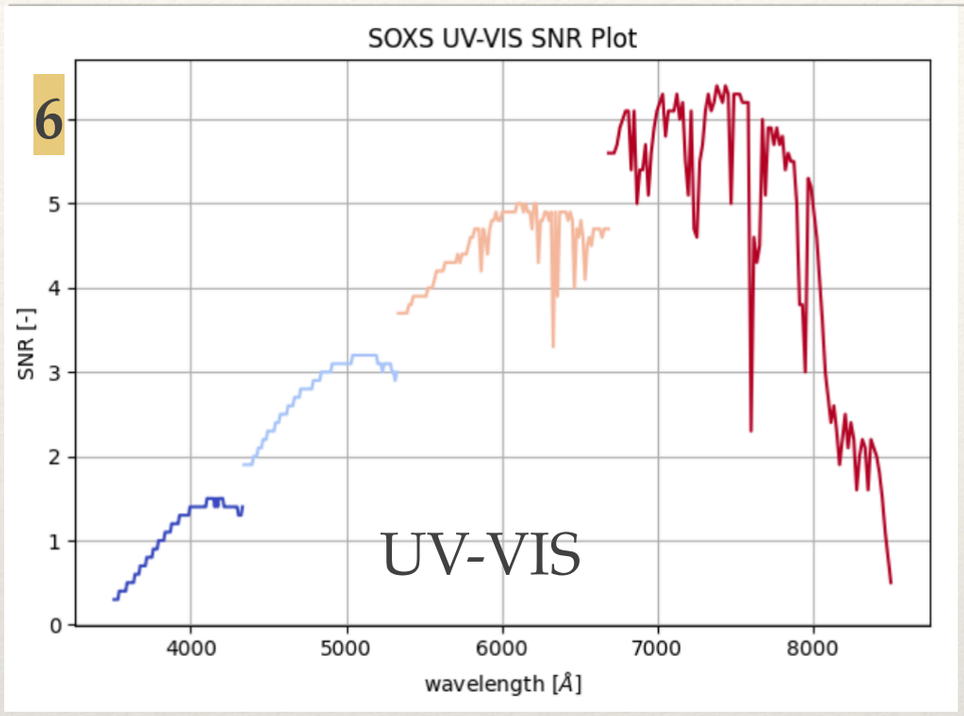
Single exposure 1500s, 0d Moon, 1.2 airmass, 1'' seeing, BB=5600K, mag_AB=24.5

	SOXS	EFOSC2
V	4.2	10.0
g	4.1	9.8
r	6.2	10.0
i	5.7	6.1
z	4.0	3.1

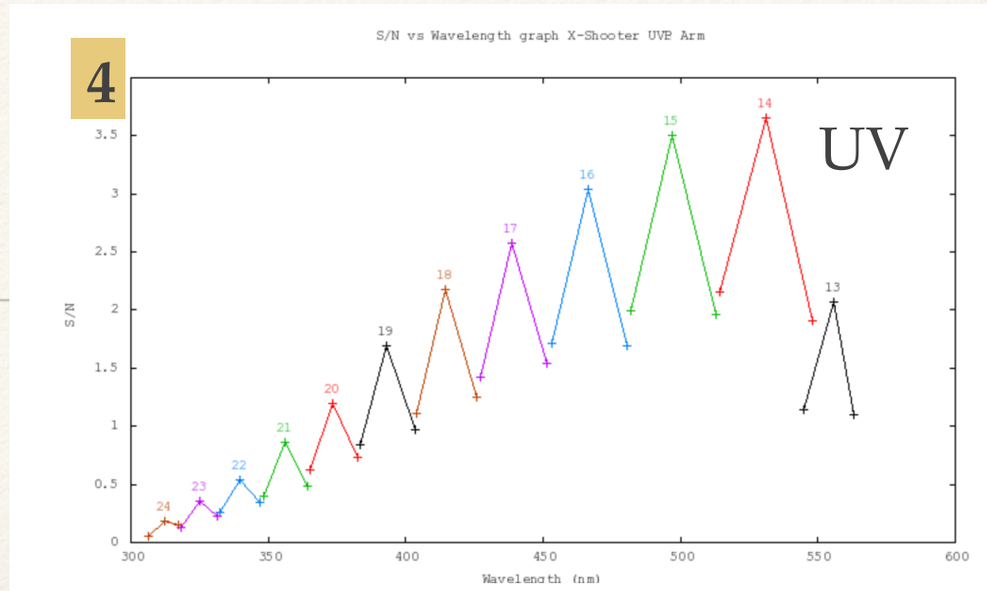
SNR

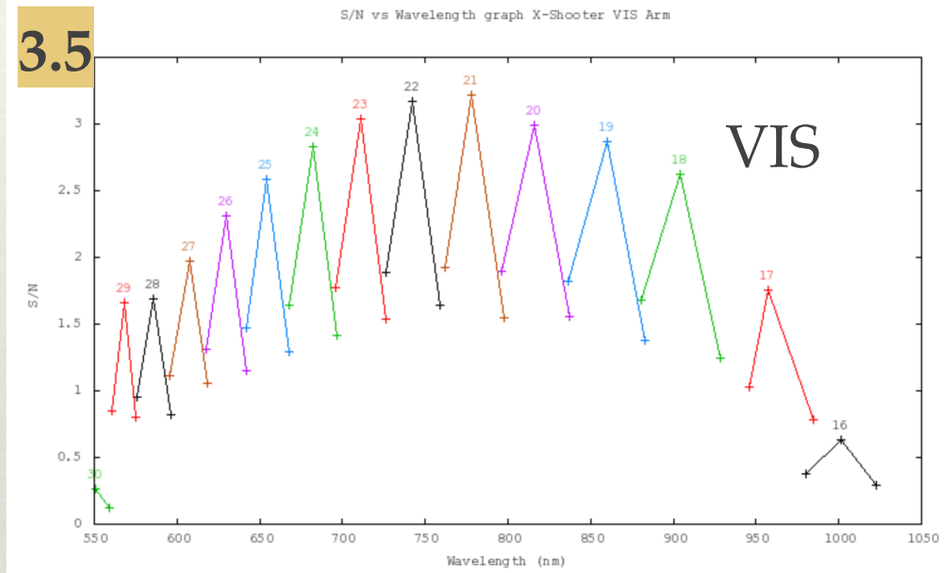
Four 900s exposures, 0d Moon, 1.2 airmass, 1” seeing, PWV=30 BB=5600K, Rmag_AB=21.5

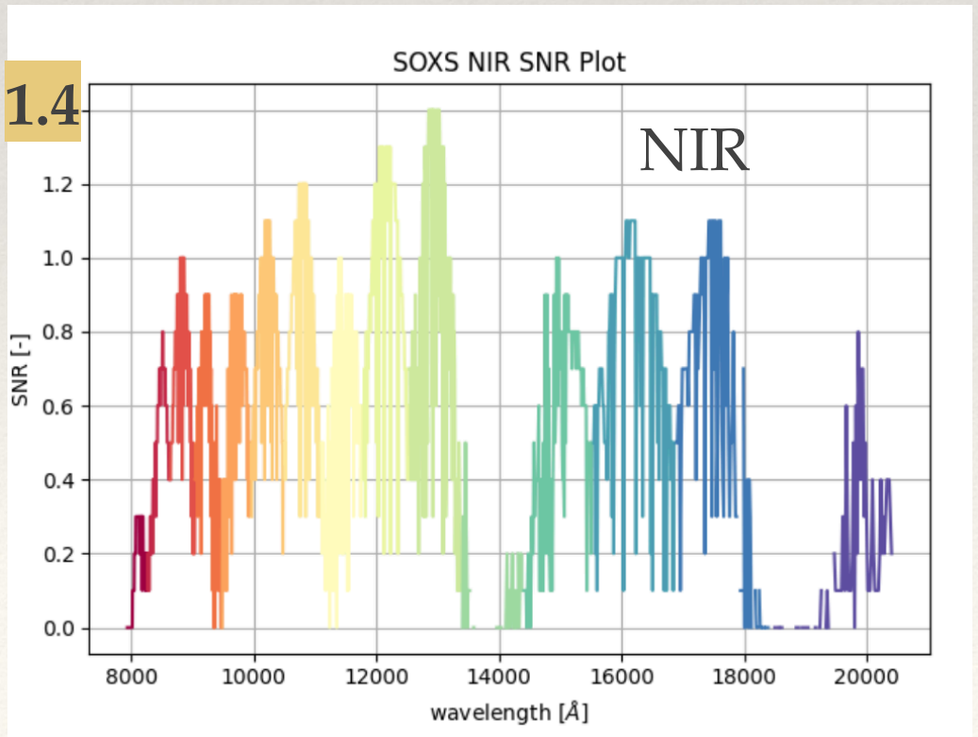
SOXS vs. X-shooter

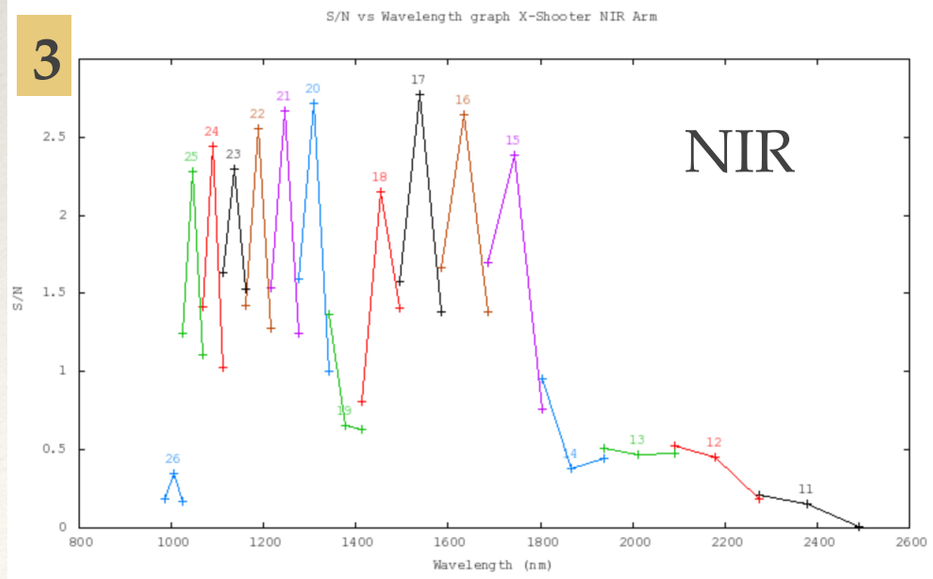


SNR per resolution element

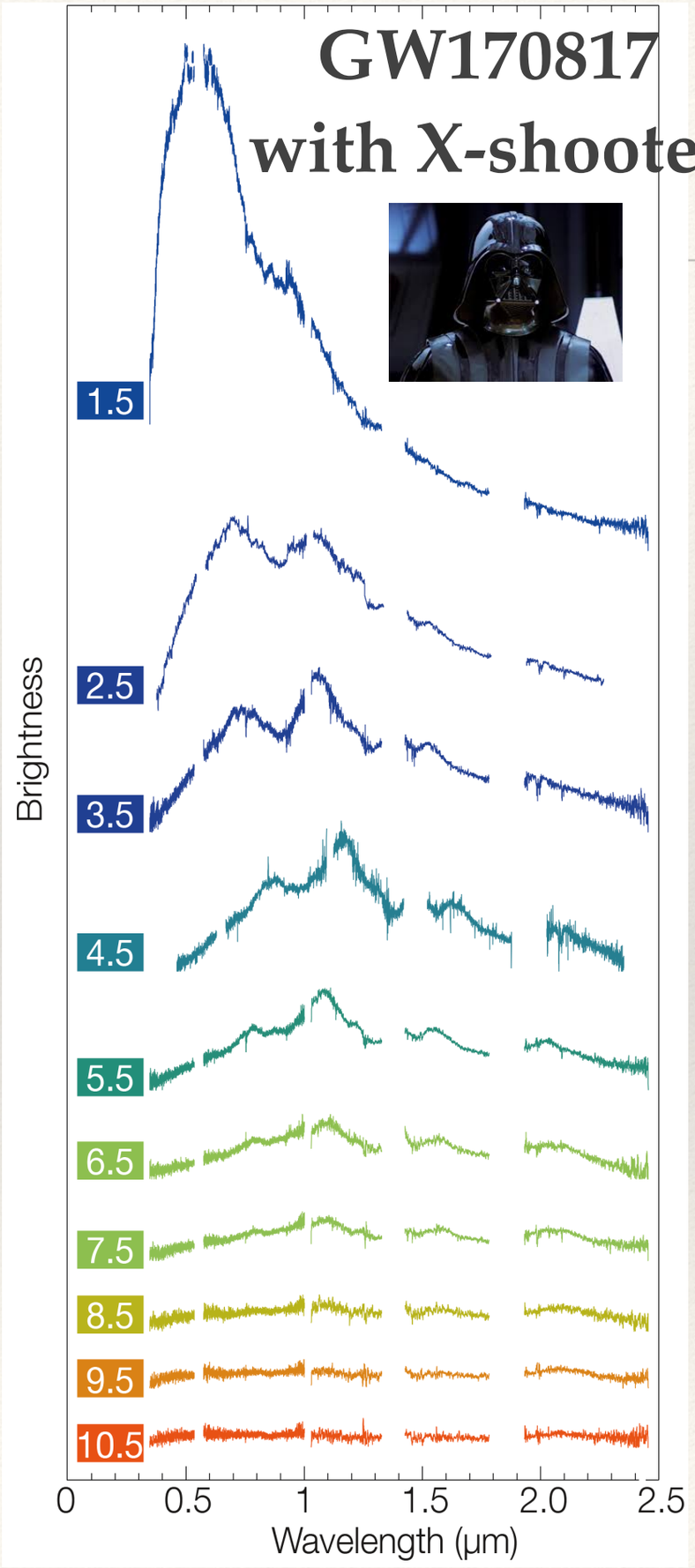


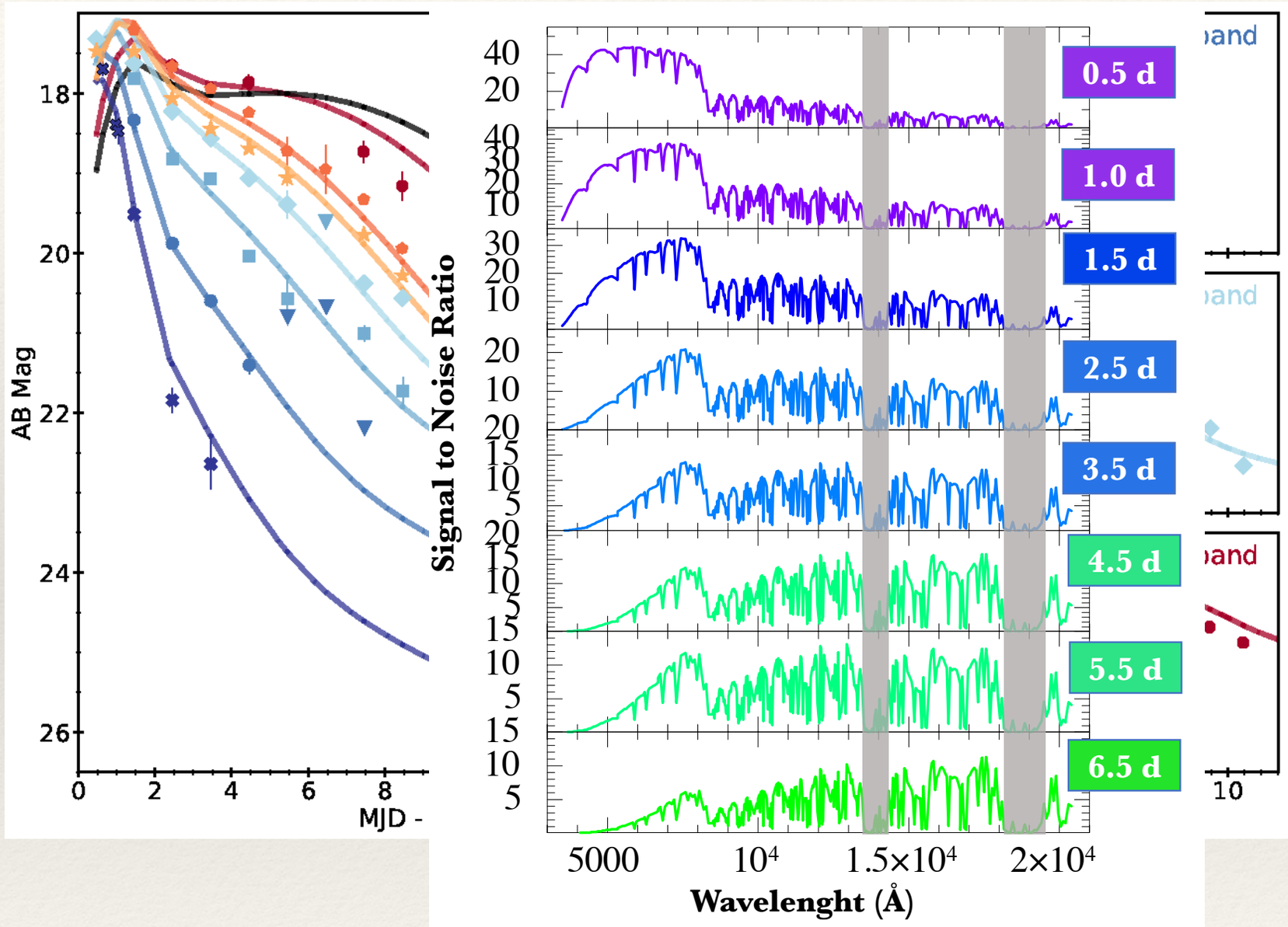






What can SOXS do?



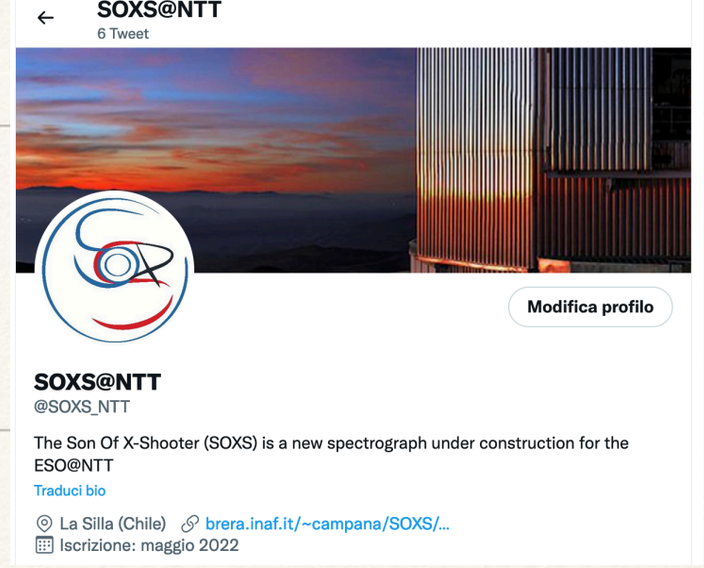


SOXS ETC

http://192.167.38.34/

Take home

News on Twitter



- *SOXS: single-object, broad-band spectrograph (350-2000nm) with imaging capabilities at ESO/NTT*
- *First light in autumn 2023, start of GTO April 2024*
- *SOXS/GTO: 180 n/yr for 5 years, fully dedicated to transient and variable sources. SOXS Consortium is in charge for the NTT operations. Possibility to trigger every night with a fast reaction (~15min on source)*
- *Transients, fast-reaction targets, complete samples, dense monitoring campaigns*