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

Paolo D'Avanzo
INAF - Osservatorio Astronomico di Brera

on behalf of the SOXS team

XVII Marcel Grossmann Meeting, July 2024, Pescara (Italy)

History

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

Proposal submission (02/2015)

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

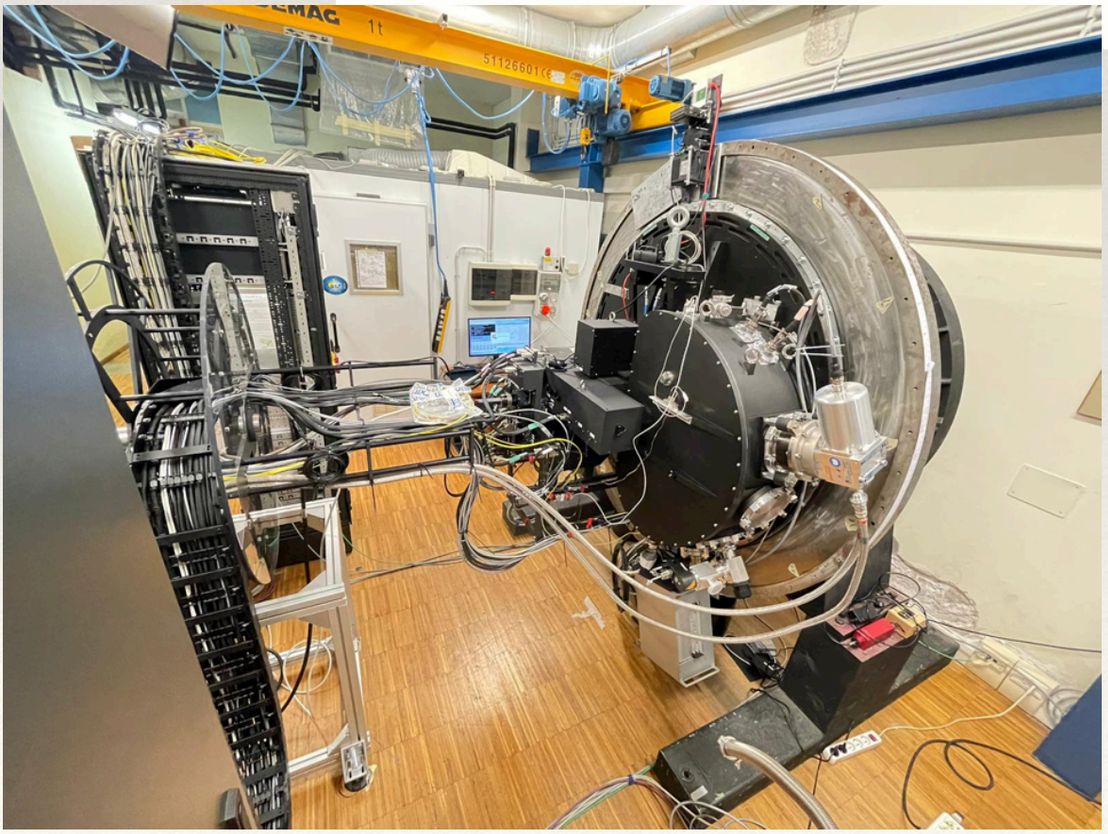
Signed MoU INAF-ESO
Signed MoU INAF-Partners

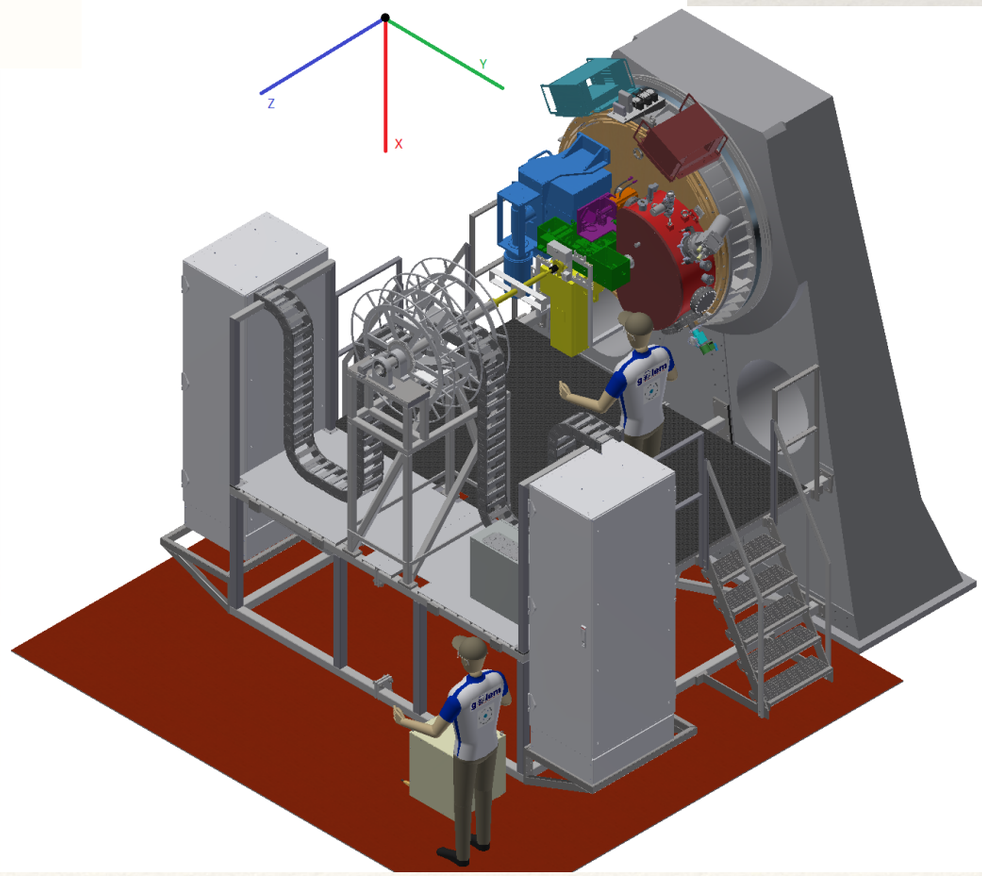
Project Phase	Start	End	Duration
Preliminary Design	08/2016	07/2017	12 months
Final Design	08/2017	10/2018	14 months
MAIT	11/2018	06/2024	67 months+COVID
PAE	07/2024	11/2024	3 months
Commissioning & SV & PAC	01/2025	06/2025	6 months
Operations & GTO	2025	2030	

SOXS 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)





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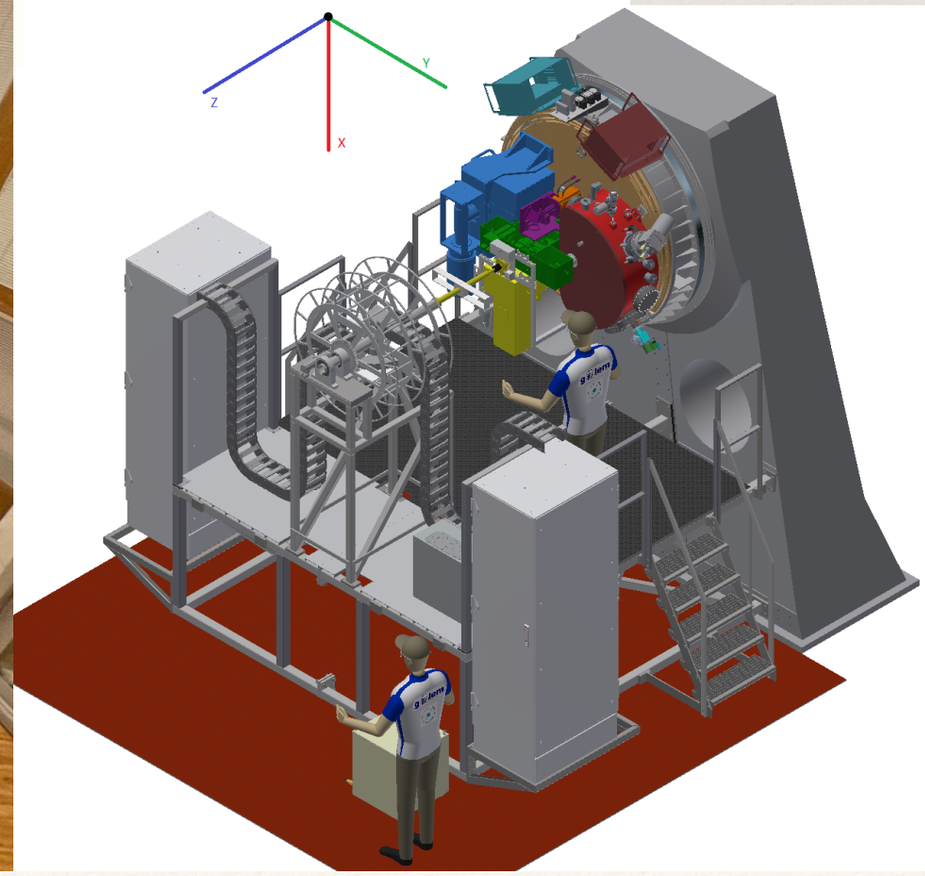


SOXS Consortium

Institutes from 6 Countries

- INAF (OA Brera, Capodimonte, Padova, Roma, Catania, FGG)
- Weizmann Institute (Israel)
- Queen's University Belfast (UK)
- Millenium Institute (Chile)
- Turku Univ. & FINCA (Finland)
- University of Tel Aviv (Israel)
- Neils Bohr Institute & Aarhus

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)

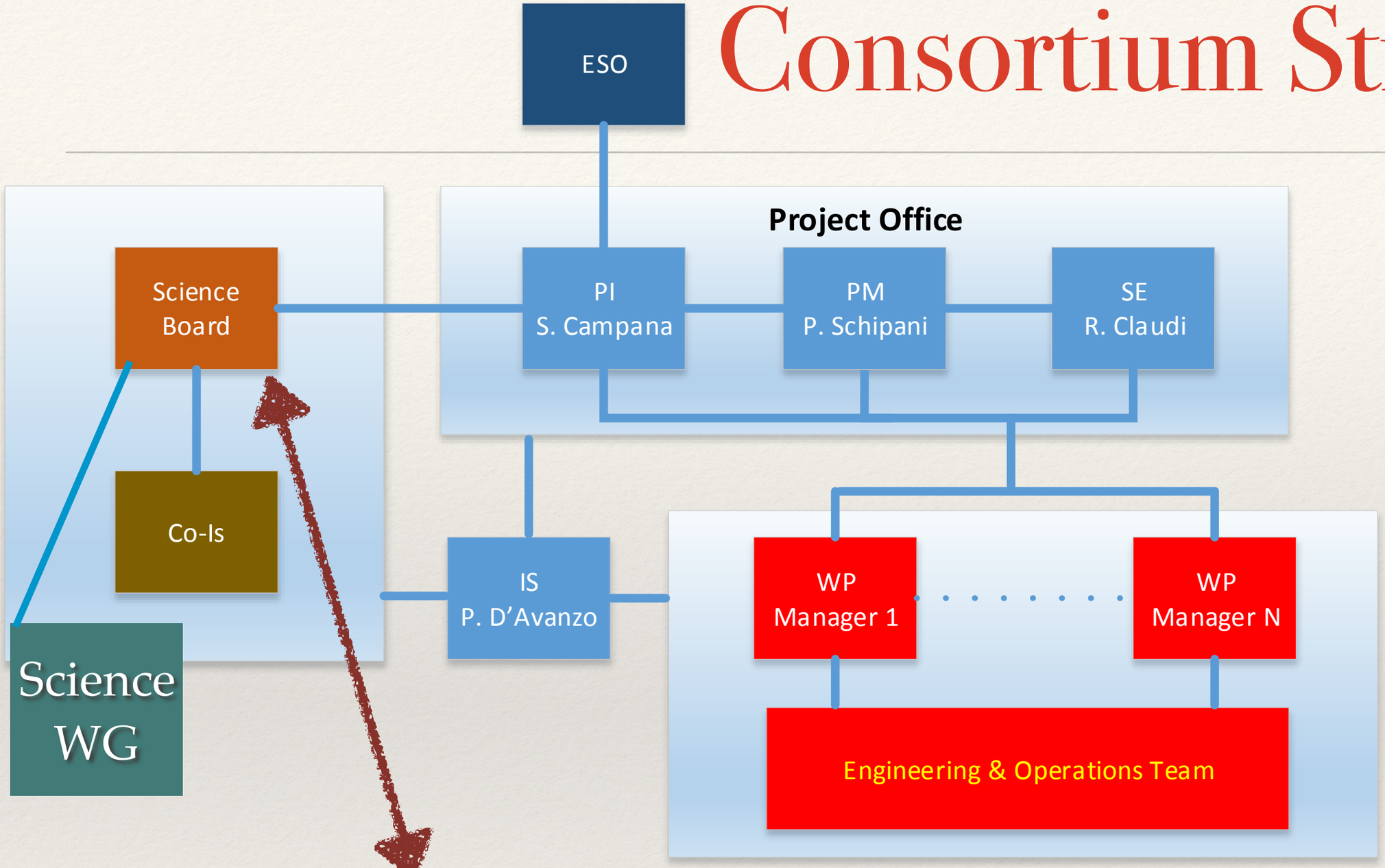
FINCA ~7% (Calibration Unit)

MAS ~6% (Acquisition camera)

Tel Aviv University ~4%

DAWN & Aarhus Univ. ~2%

Consortium Structure



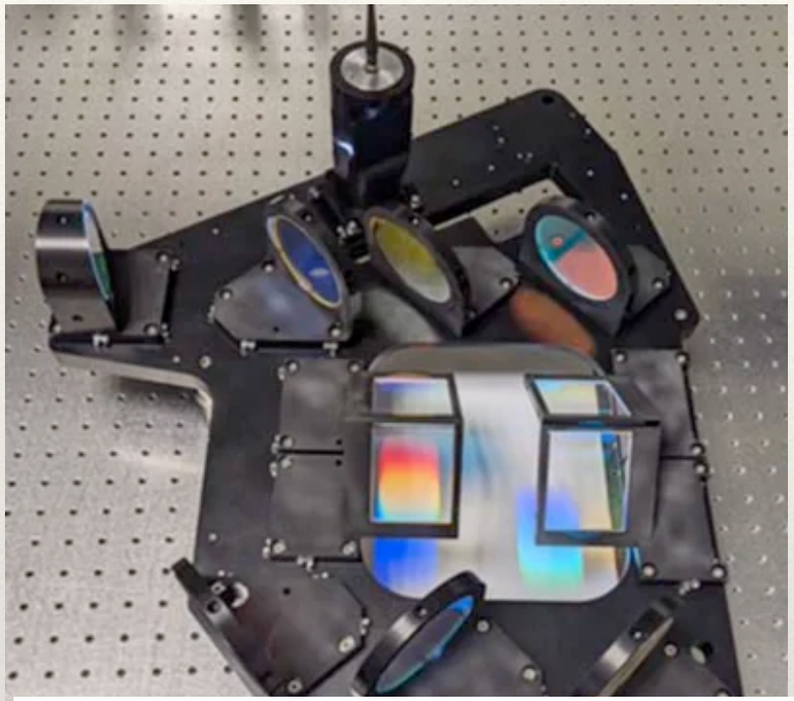
- E. Cappellaro (INAF-OAPadova) - Italy
- M. Della Valle (INAF-OANapoli) - Italy
- A. Gal-Yam (Weizmann) – Israel
- S. Smartt (Univ. Belfast) – UK
- I. Arcavi (Tel Aviv University) – Israel
- S. Mattila (FINCA) – Finland
- M. Stritzinger (Aarhus U.) – Denmark
- S. Campana (INAF-OABrera) - Italy

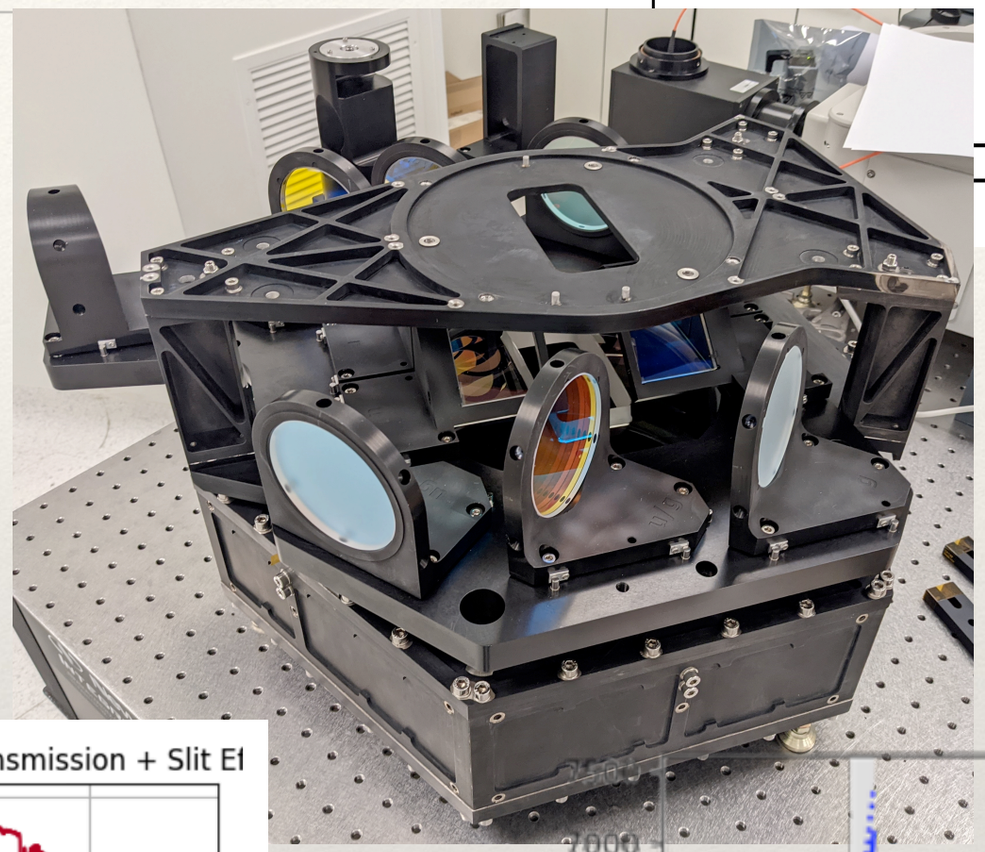
Work-Packages & People

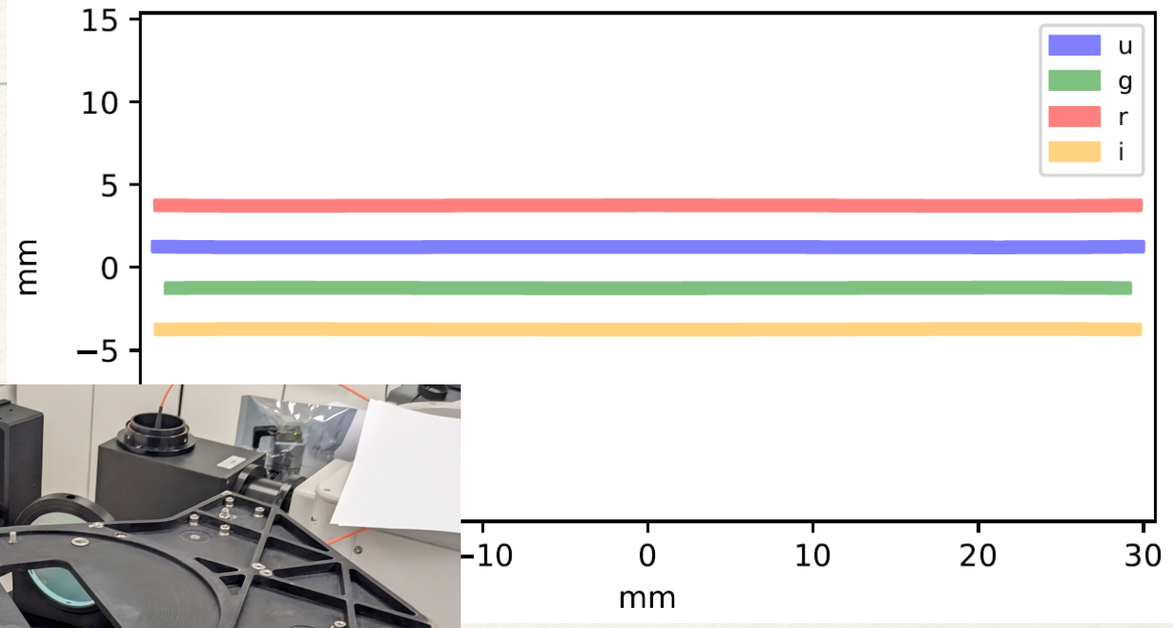
Optics WP Manager - Matteo Munari (INAF - Osservatorio astronomico di Catania)
Mechanics WP Manager - Matteo Aliverti (INAF - Osservatorio astronomico di Brera)
Electronics WP Manager - Giulio Capasso (INAF - Osservatorio astronomico di Capodimonte)
Software WP Manager - Andrea Baruffolo (INAF - Osservatorio astronomico di Padova)
Vacuum & Cryogenics WP Manager - Salvo Scuderi (INAF - Osservatorio astronomico di Catania)
AIT WP Manager - Kalyan Radhakrishnan (INAF - Osservatorio astronomico di Padova)
Instrument Model WP Manager - Matteo Genoni (INAF - Osservatorio astronomico di Brera)
VIS Spectrograph WP Manager - Sagi Ben-Ami (Weizmann Institute)
VIS Spectrograph Optics WP Manager - Adam Rubin (Weizmann Institute)
VIS Spectrograph Mechanics WP Manager - Ofir Hershko (Weizmann Institute)
VIS Detector WP Manager - Rosario Cosentino (INAF - Osservatorio astronomico di Catania)
NIR Spectrograph WP Manager - Fabrizio Vitali (INAF - Osservatorio astronomico di Roma)
NIR WP Manager - Francesco D'Alessio (INAF - Osservatorio astronomico di Roma)
Acquisition Camera WP Manager - Anna Brucalassi (Millenium Institute & INAF)
Calibration Unit Optics WP Manager - Haynino Kuncaraycti (Turku University)
Operations software lead WP Manager - Marco Landoni (INAF - Osservatorio astronomico di Brera)
Pipeline WP Manager - David Young (Queens' University Belfast)

SOXS UV-VIS arm

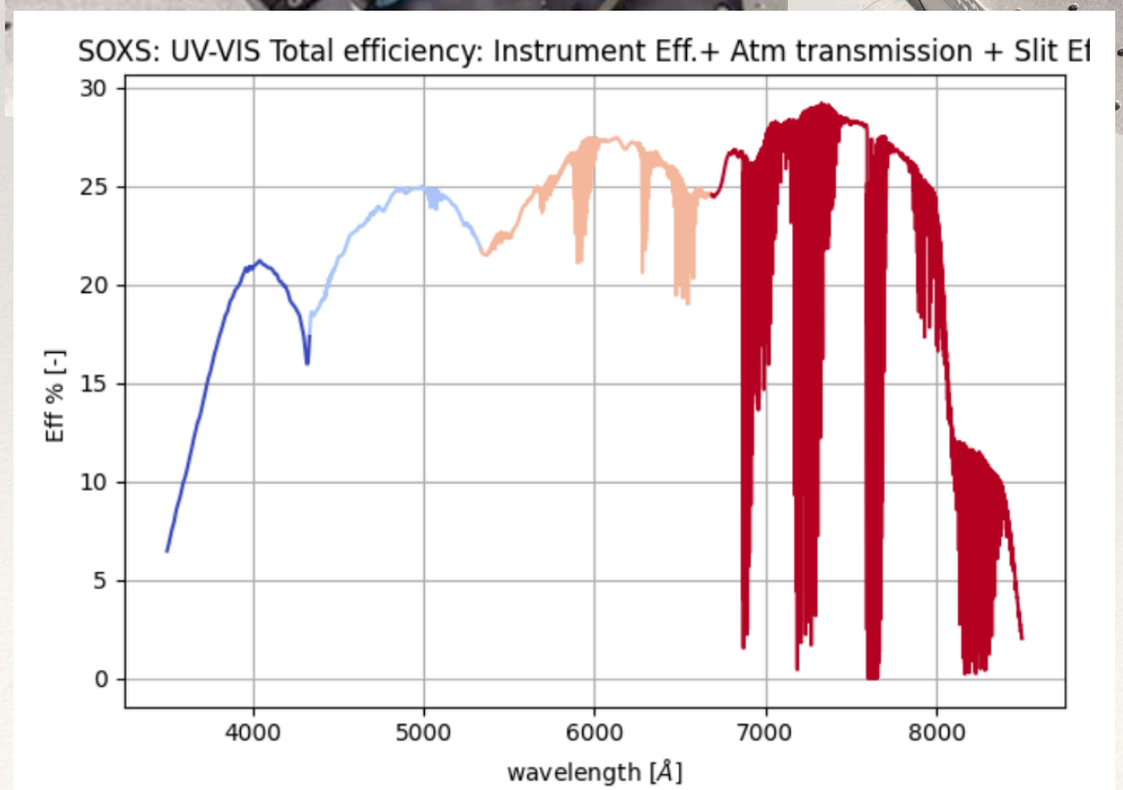
מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

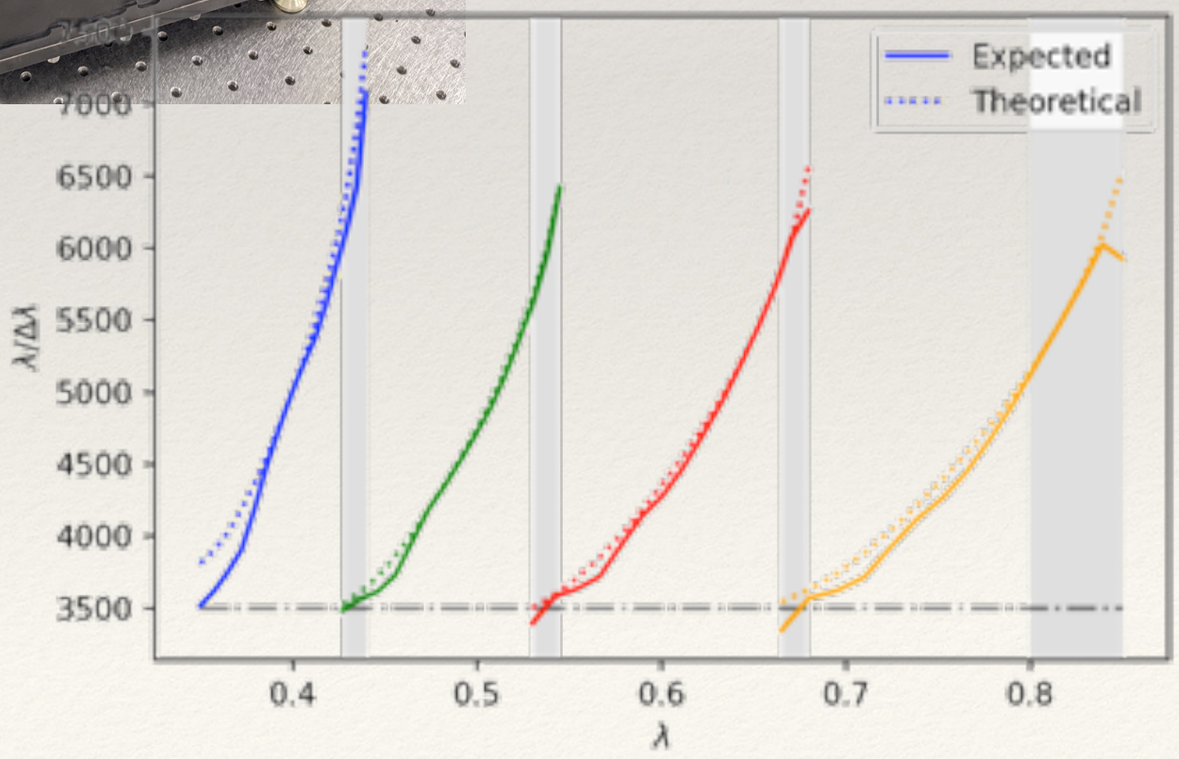






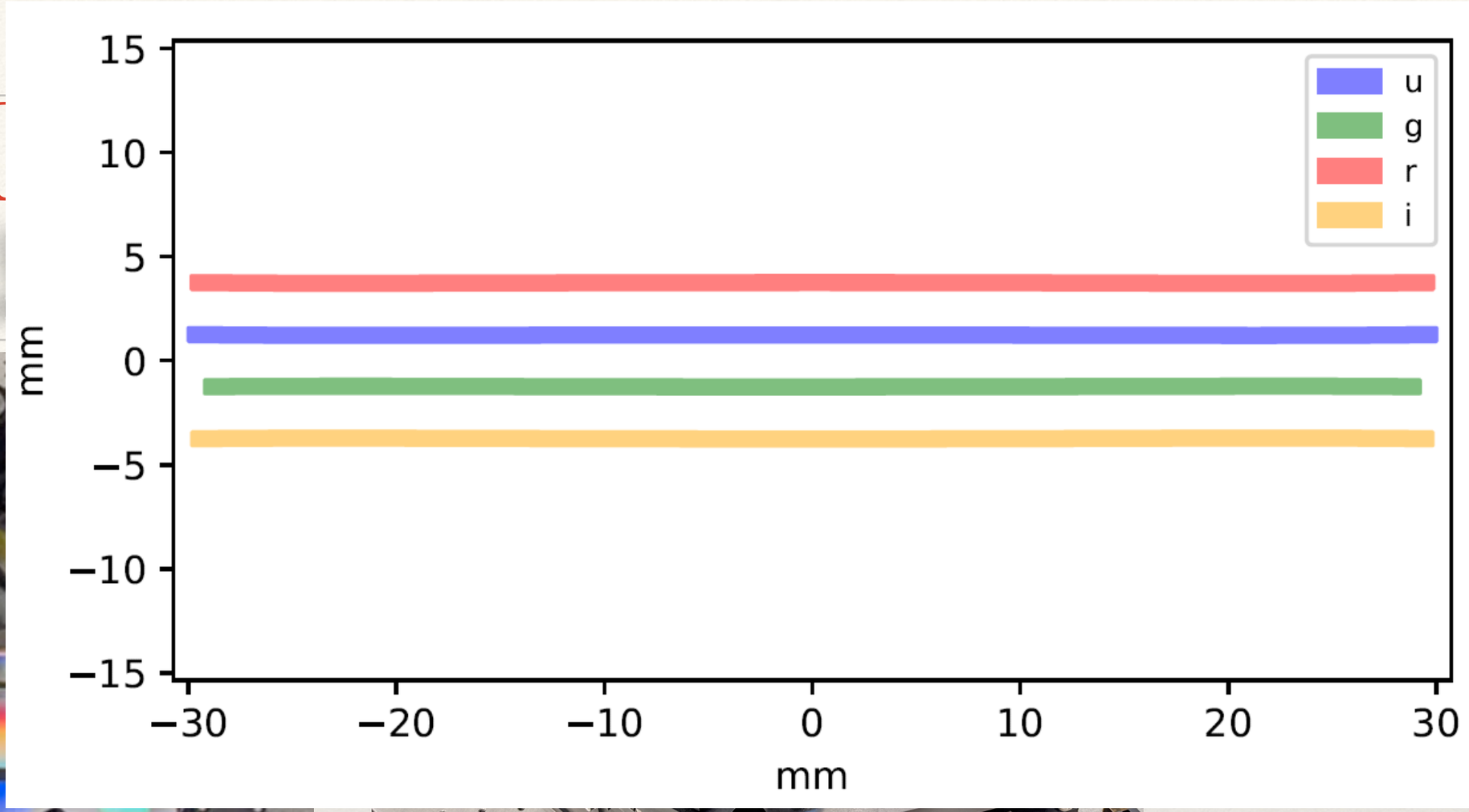
u: 350 - 440 nm
g: 427 - 547 nm
r: 527 - 680 nm
i: 664 - 850 nm





SOX

WEIZMANN



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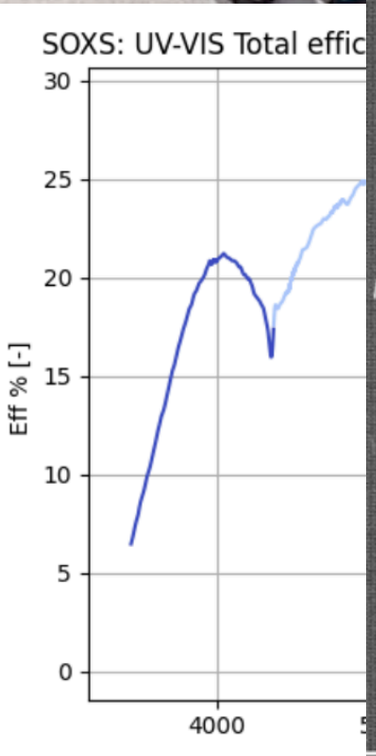
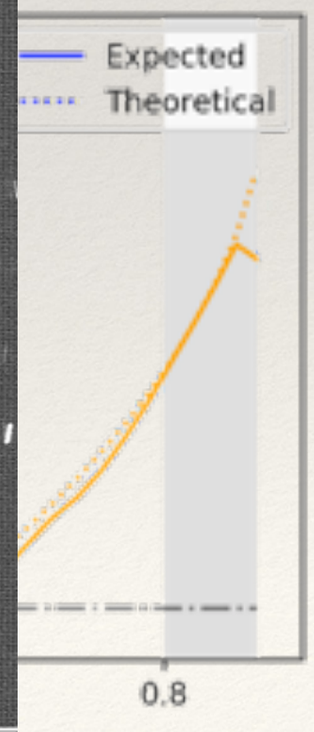
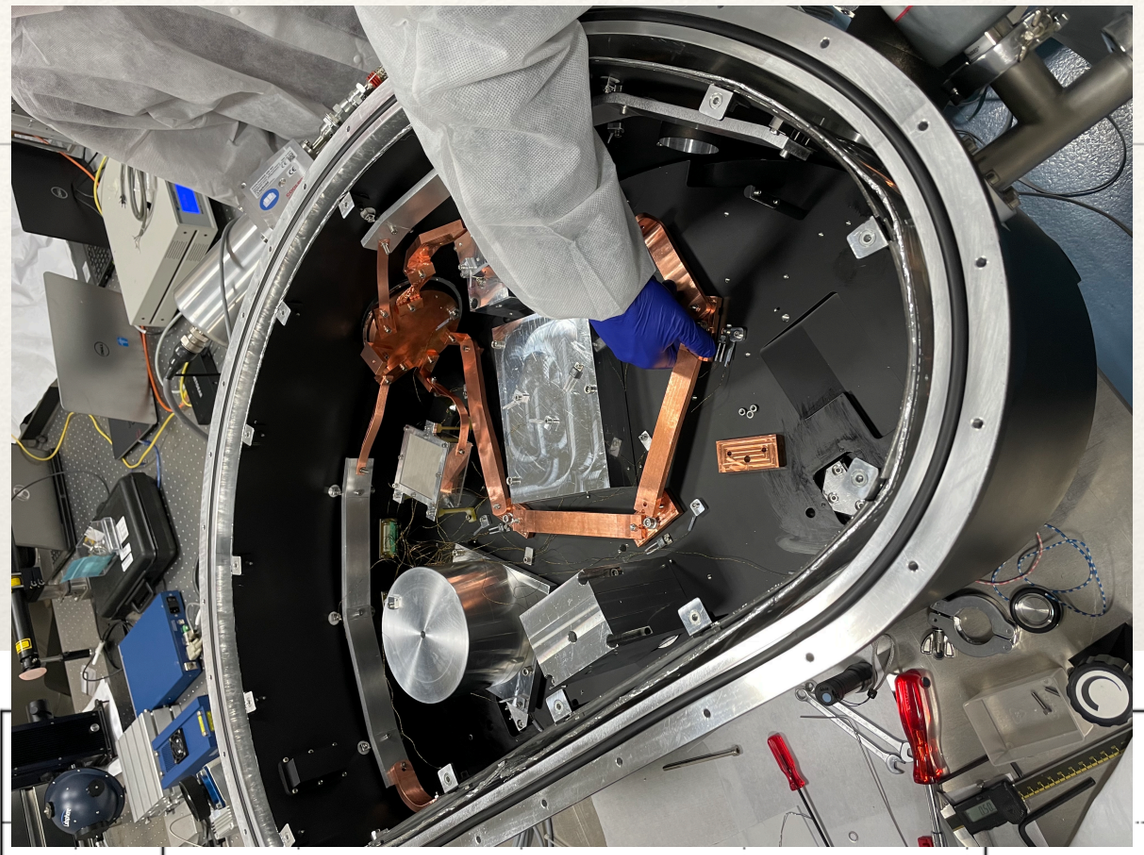
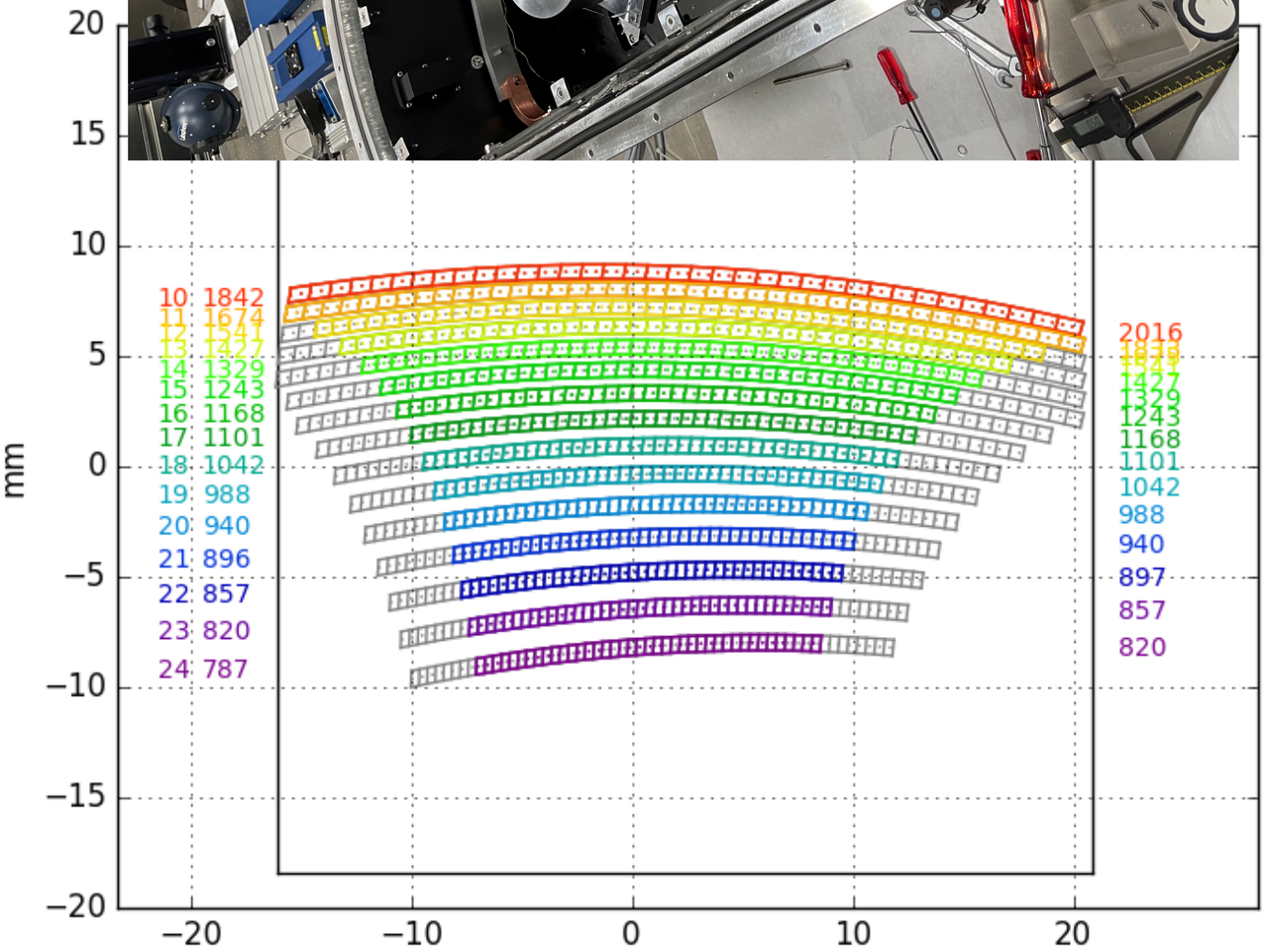


ThAr lamp



SOXS NIR arm




10 1842
11 1674
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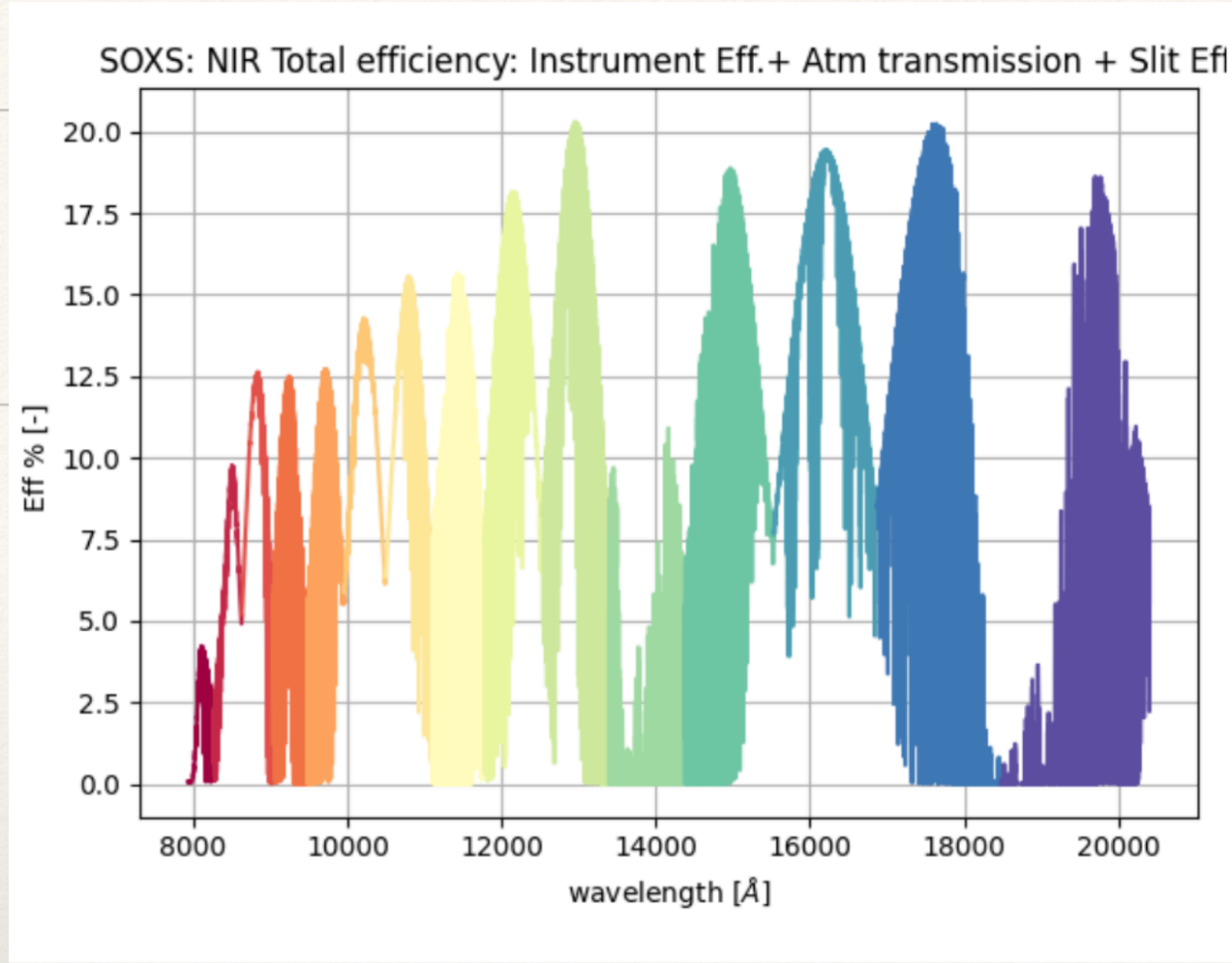
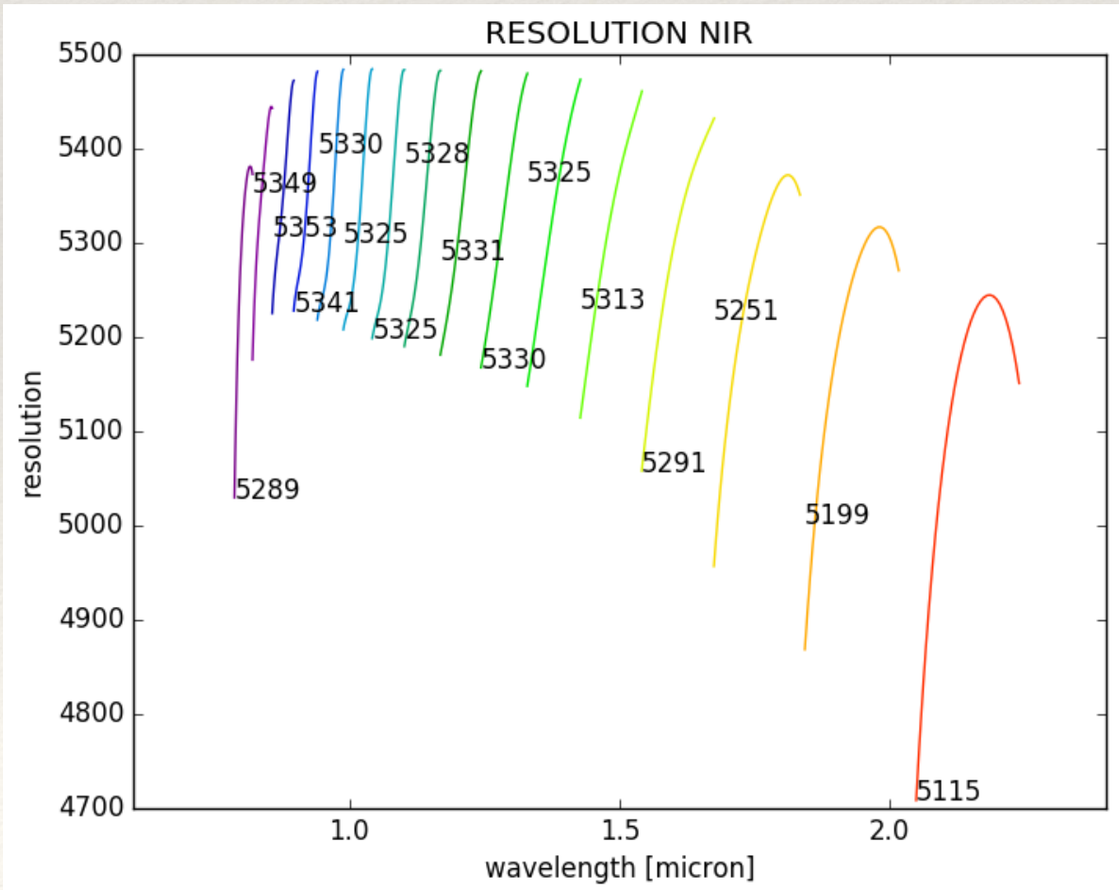

SOXS: NIR Total efficiency: Instrument Eff.+ Atm transmission + Slit Eff
Eff % [-]
wavelength [Å]


RESOLUTION NIR
resolution
wavelength [micron]
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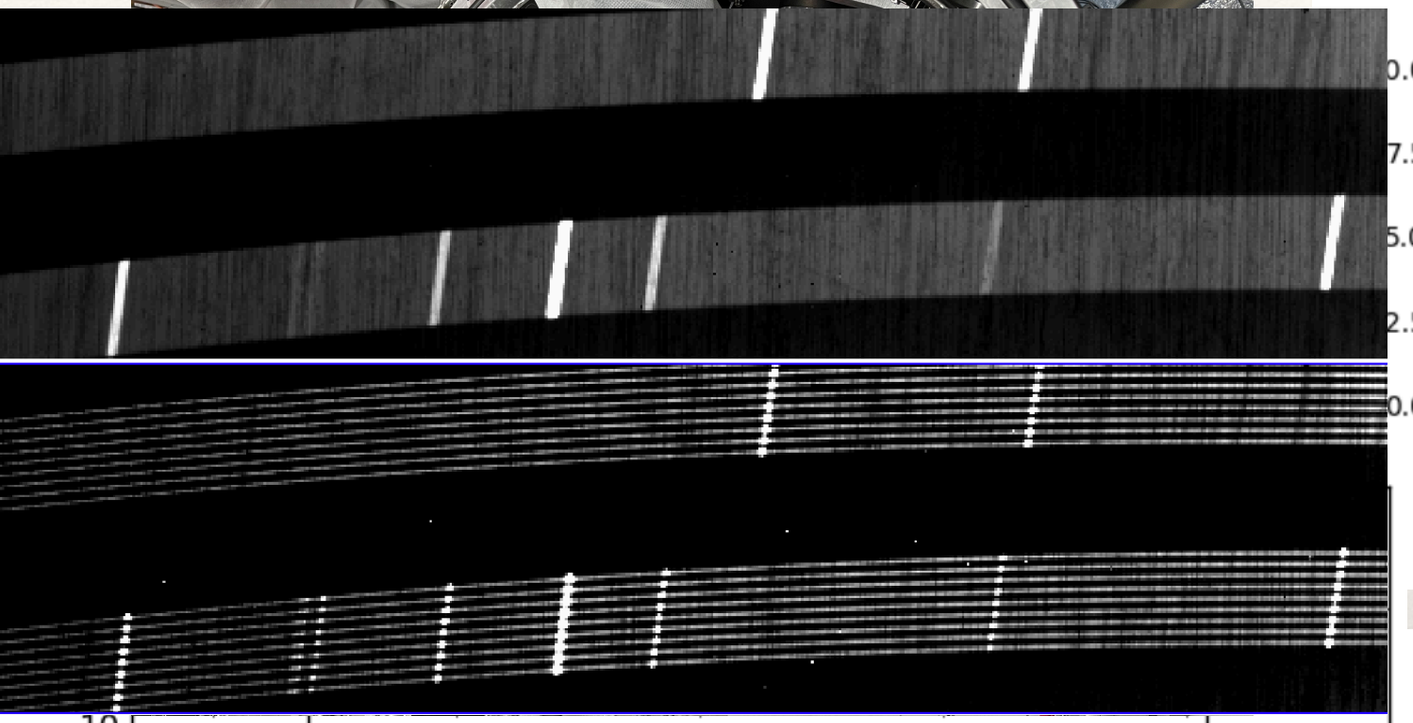
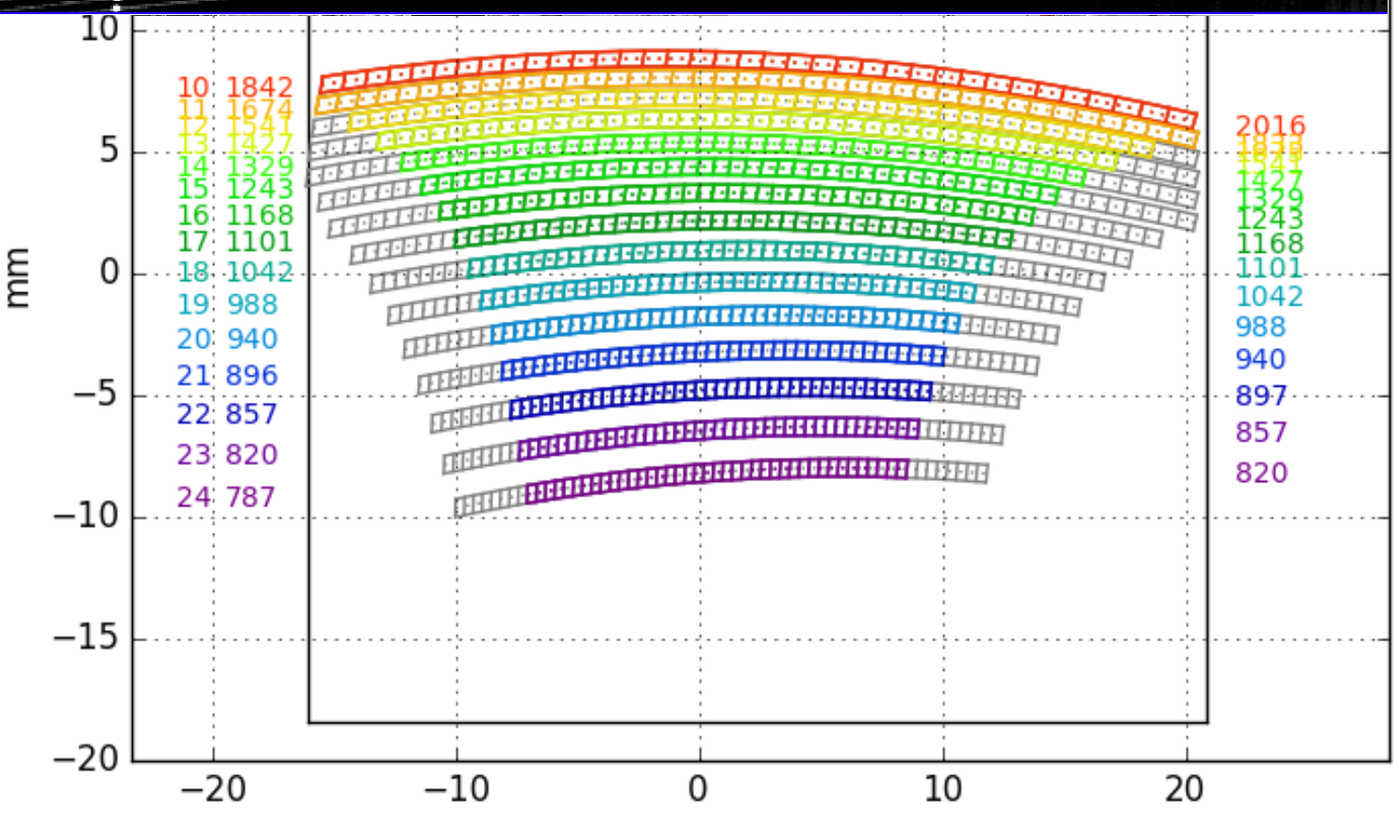
SOXS NIR arm

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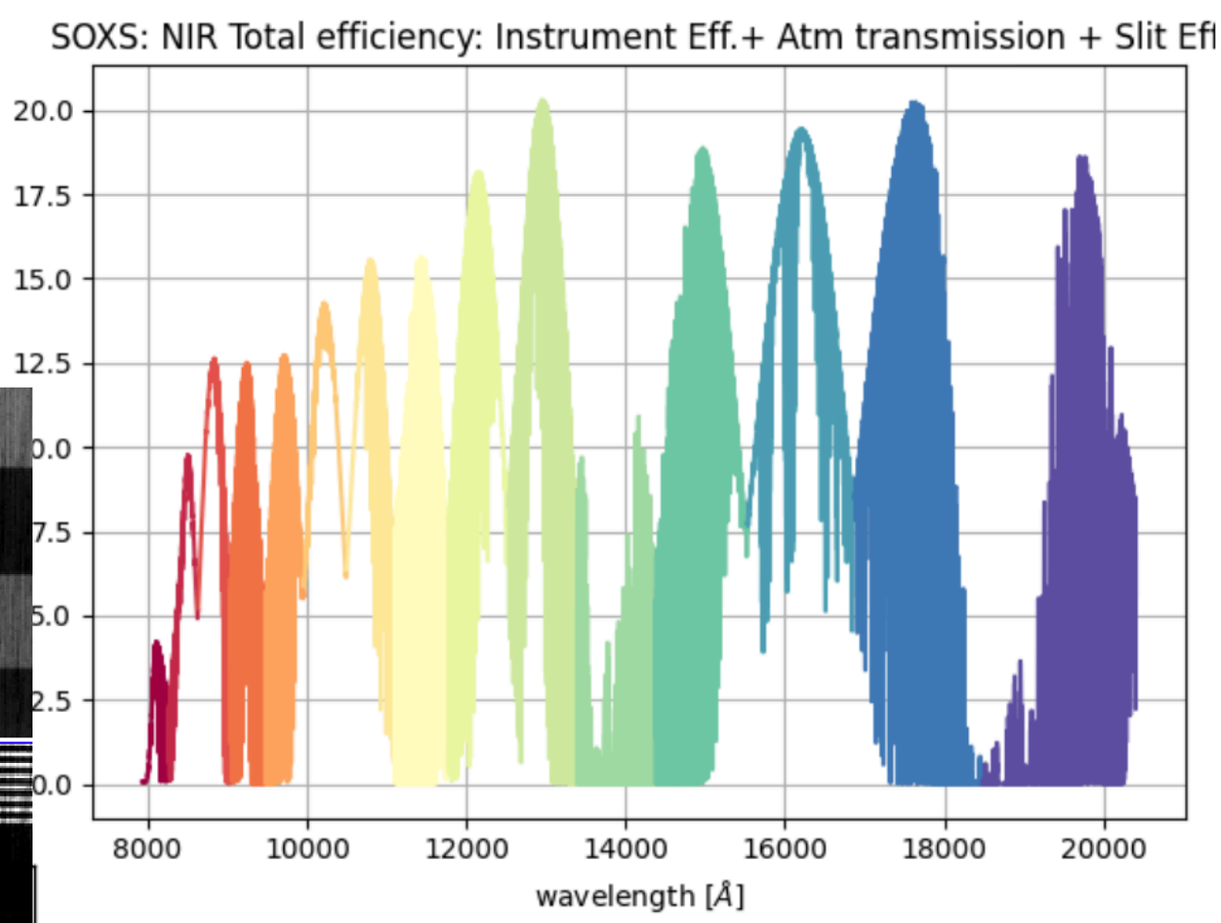
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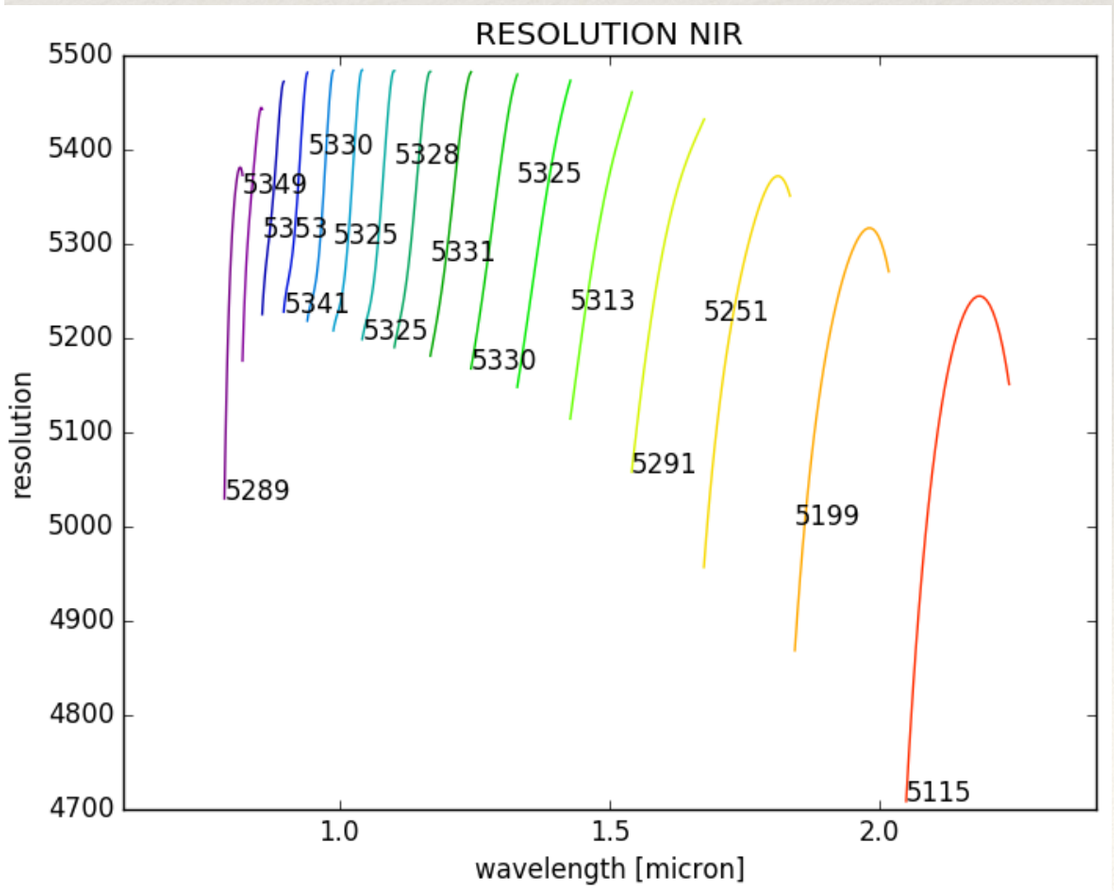
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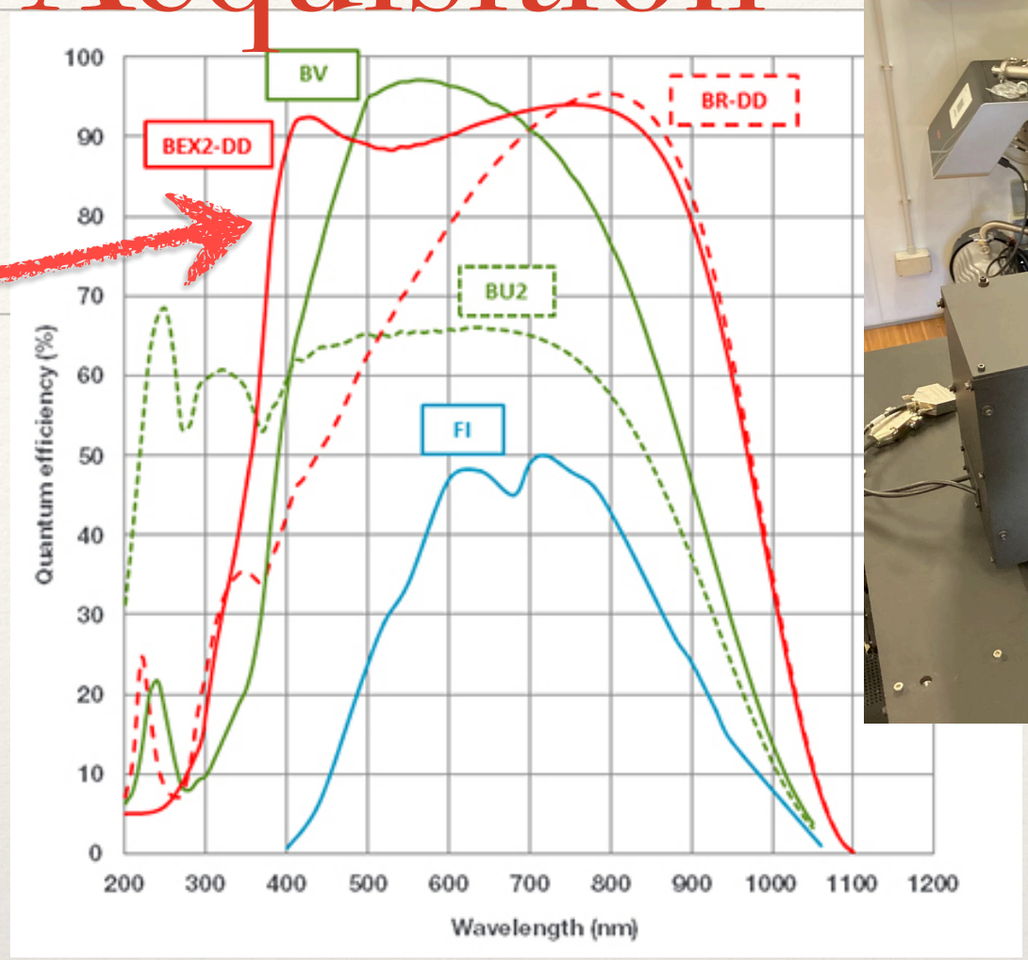
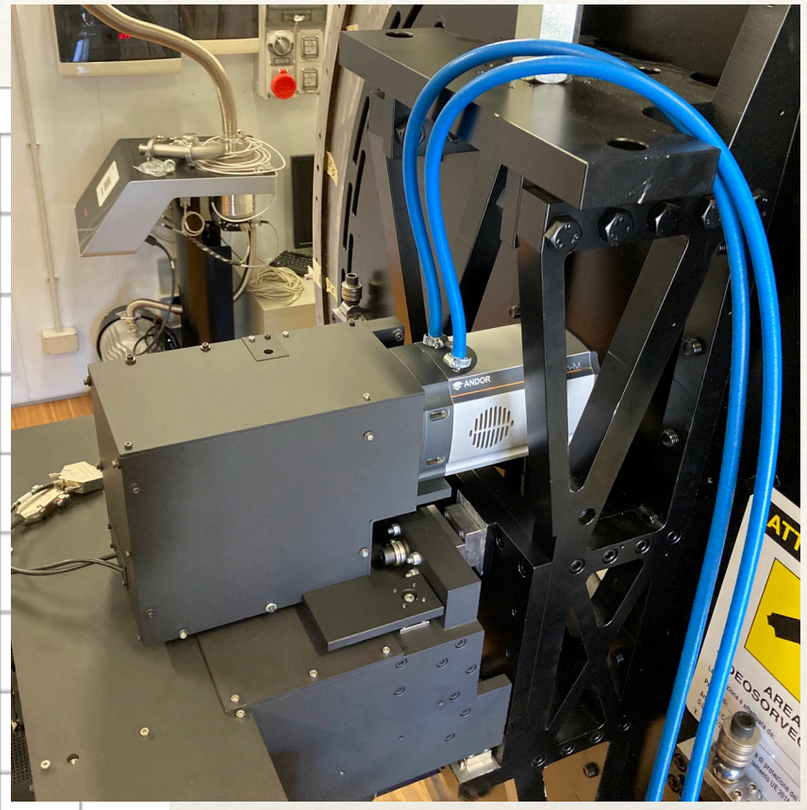
resolution
wavelength [micron]

(Imaging!) & Acquisition Camera

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



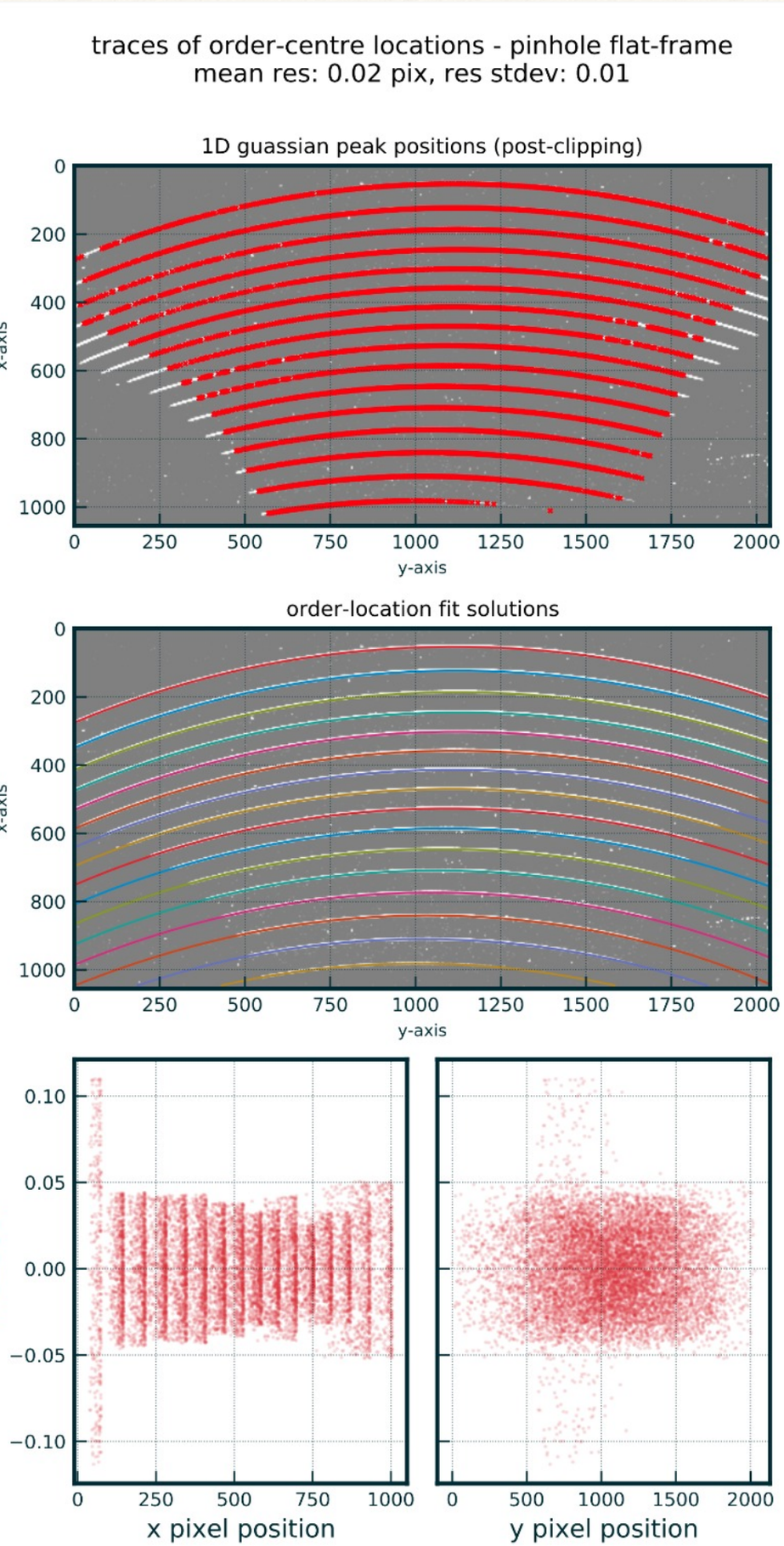


3.5'x3.5' Field of view

Limiting magnitude for a SNR=10

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

+ Y and V filters



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.

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”
- quality control

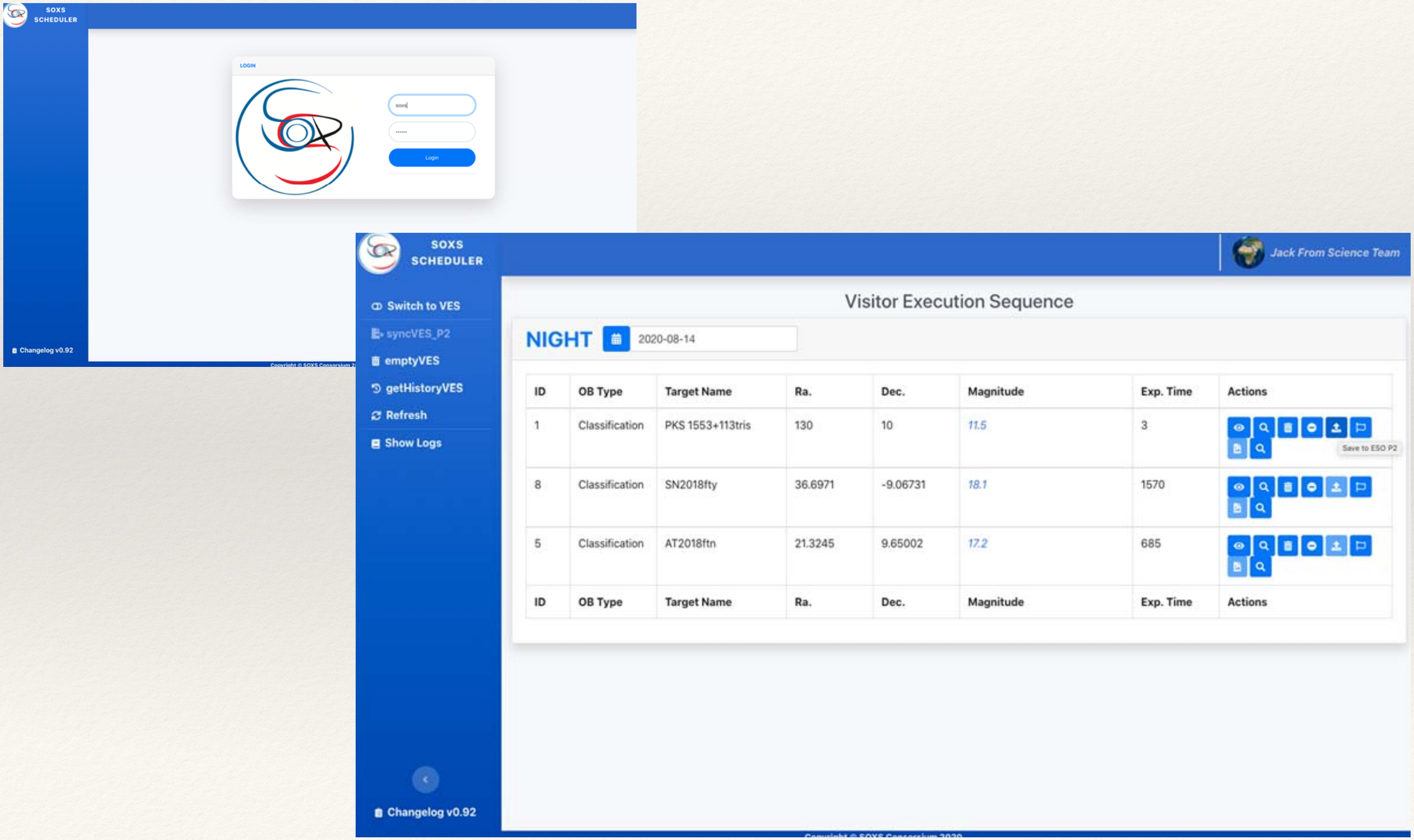
Mountain operations

After an initial period of training (of people) and instrument (set up and debug), no SOXS scientists will be in La Silla (unless for limited periods).

ESO people

- observations are carried out by the night operator at the NTT telescope
- stay in contact with SOXS people in case of schedule change (i.e. high priority transients)

SOXS Scheduler



Why do we need SOXS

Current & new optical survey: ATLAS, ZTF, Rubin/LSST

Space optical missions: Gaia, EUCLID, …

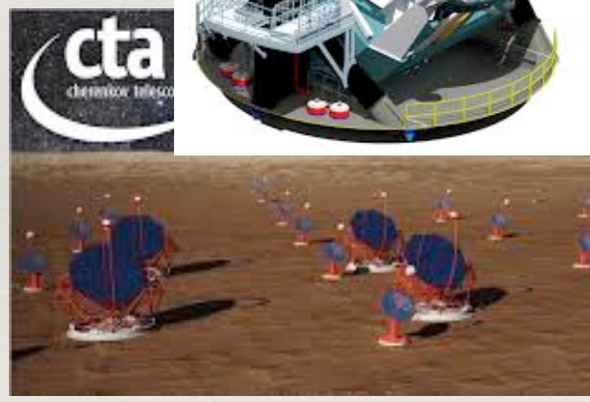
Space high-energy missions: Swift, Fermi, Einstein Probe, SVOM

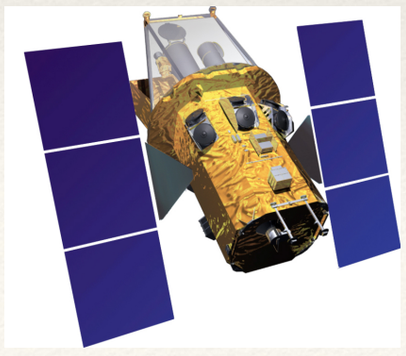
Radio new facilities: MeerKAT, SKA

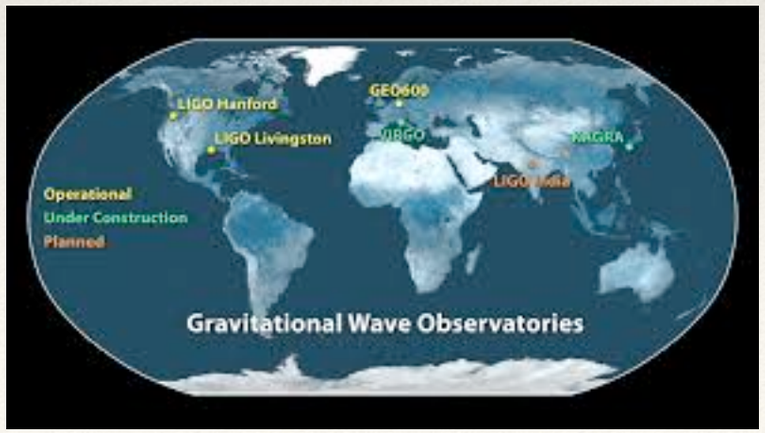
VHE: MAGIC, HESS, Astri, CTA

Messengers: LIGO-Virgo, KM3Net

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



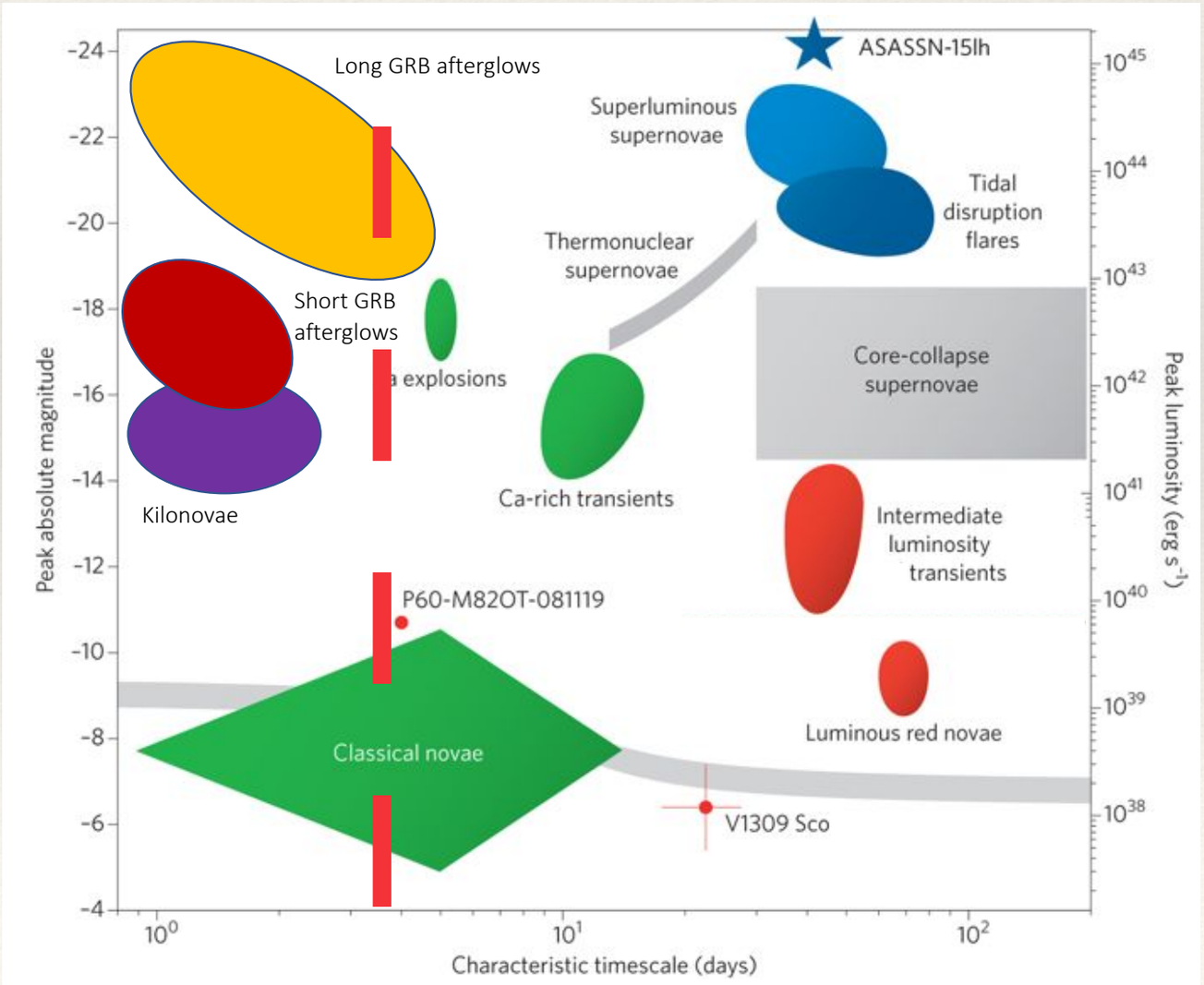




SOXS Science cases

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

- **Rapid follow-up**
- **Dense monitoring**
- **Always available**



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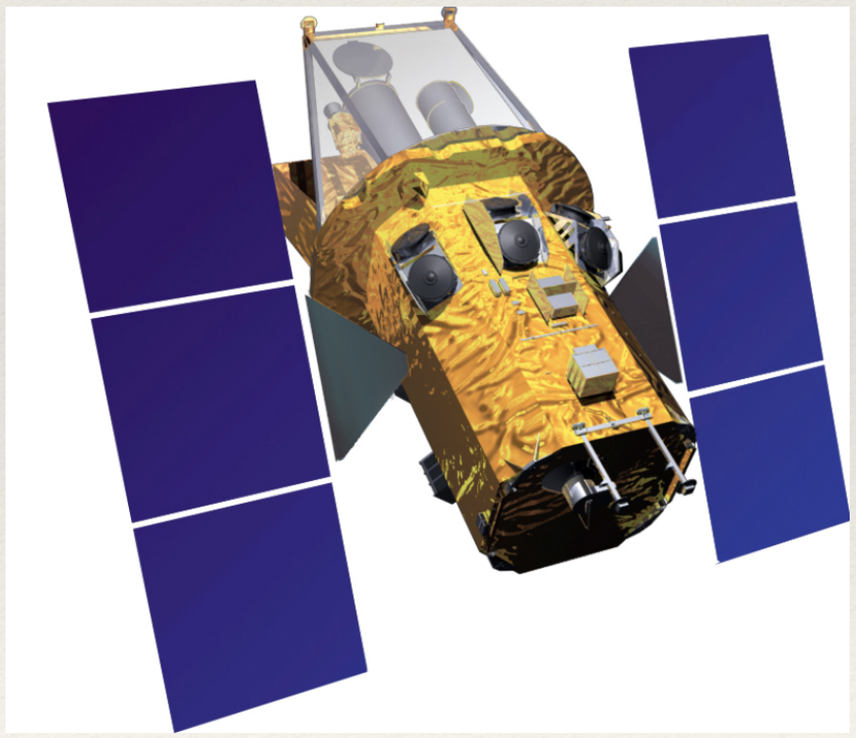
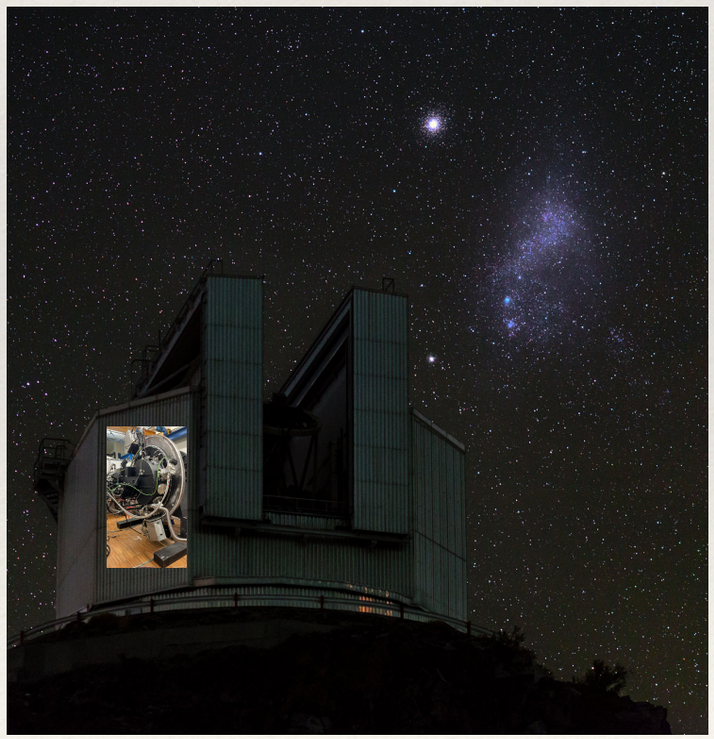




Science Working Groups

WG	WG Topic	WG Leader	WG Deputy
1	Small bodies and comets	Fitzsimmond	Dotto
2	Stellar variability, exoplanets and Young Stellar Objects	Pagano	Alcalà
3	Transient X-ray binaries, magnetars, ultra-luminous X-ray sources (NS &	Casella	Veledina
4	Cataclysmic variables, novae and white dwarfs	Della Valle	Ben-Ami
5	Supernovae Ia and thermonuclear transients	Stritzinger	Kotak
6	Fast and extreme transients (including SLSNe)	Arcavi	Mattila
7	Intermediate luminosity transients	Kotak	Pastorello
8	Core Collapse Supernovae	Gal-Yam	Pignata
9	AGN and blazars	Landoni	—
10	Tidal Disruption and Nuclear Events	Mattila	Arcavi
11	Gamma Ray bursts & Fast radio bursts	D'Avanzo	Fynbo
12	Gravitational wave and neutrino counterparts	Campana	Smartt
13	Classification	Benetti	Botticella

ETC

http://192.167.38.34/

Accessible from the SOXS home page
http://www.brera.inaf.it/~campana/SOXS/

ETC for spectroscopy and imaging

SOXS-ETC -- FDR-Version - 1.9 -- April 2023

Spectroscopy | Imaging

INPUTS - current version working mode:

First select the Input flux Distribution, then fill the related fields in the Light gray boxes. Dark gray boxes can not be modified accordingly.

Science Object

Target Input Flux Distribution

Attention! If you want to download some template spectrum, which can be loaded as User-Defined Spectrum, press here

- (•) Black body
- ( ) power-law - $F(\lambda) \propto \lambda^{index}$
- ( ) User-defined Spectrum: Table [lambda, flux] in [A, erg/s/cm2/A]
- ( ) Single emission line

Spatial distribution:

For explanation on how the extended source case is modeled press Here

- (•) Point source
- ( ) Extended source

Blackbody Temperature [K]:

5600

Power Law Index:

0

- (•) Use template spectrum: E (GALEV)
- ( ) Upload spectrum: **Table [lambda, flux] in [A, erg/s/cm2/A]**

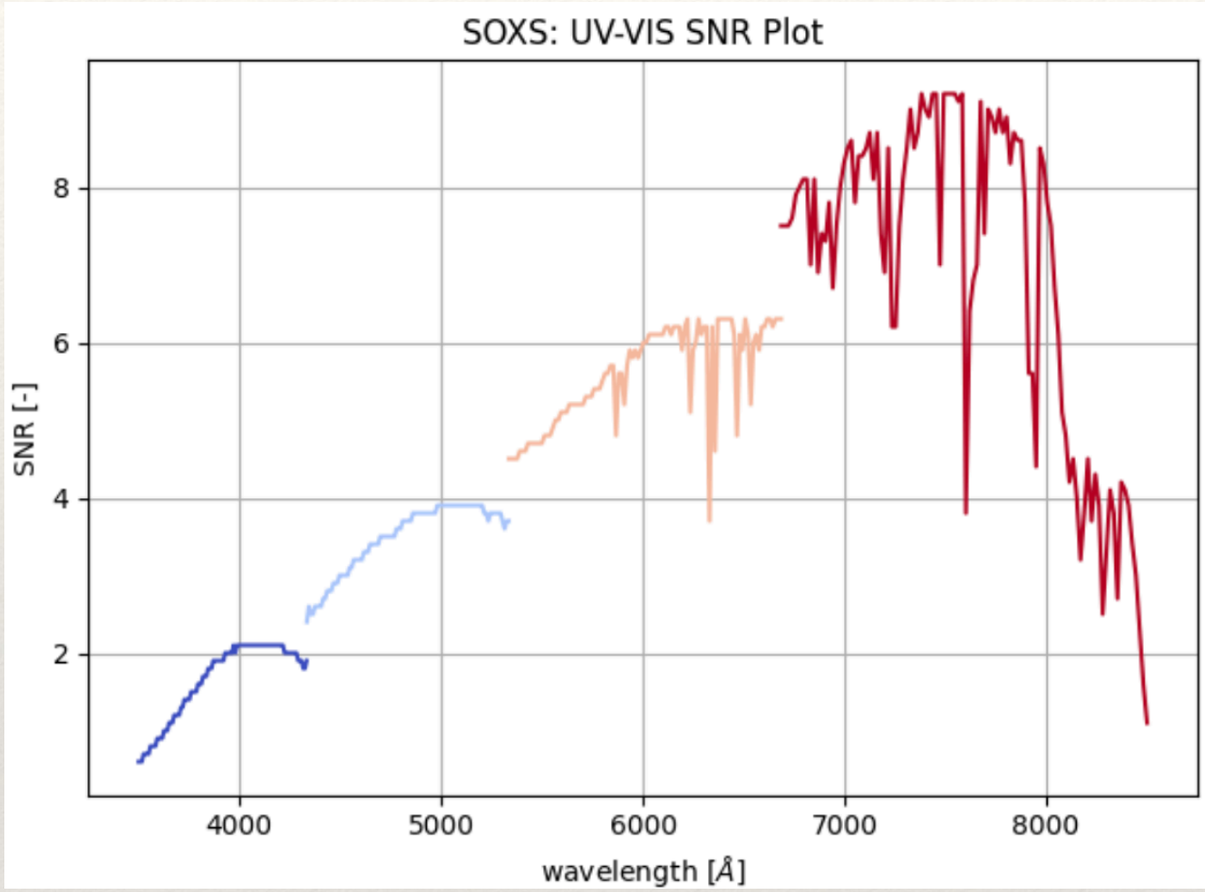
Choose file No file chosen

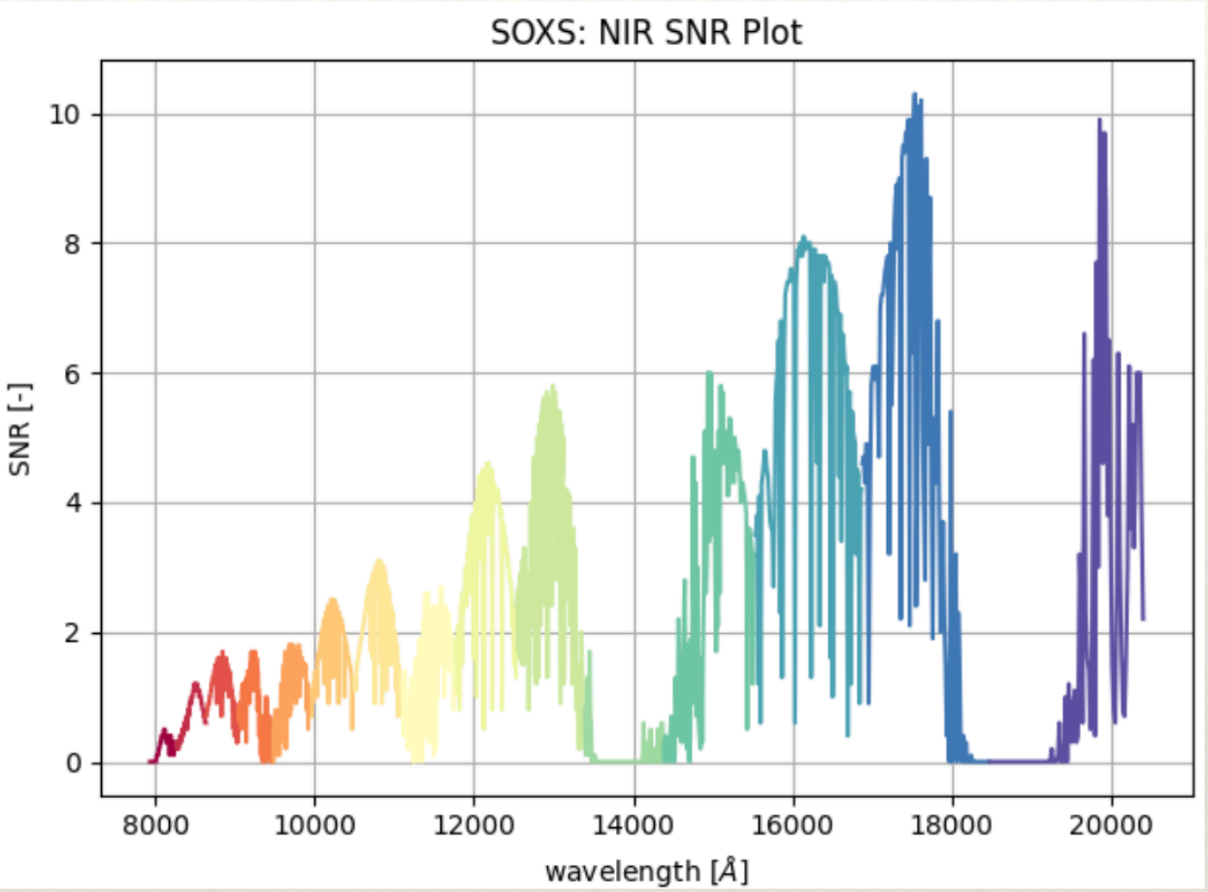
mag: [Magnitudes are given per $arcsec^2$ for extended sources]

21,5

ETC - Output

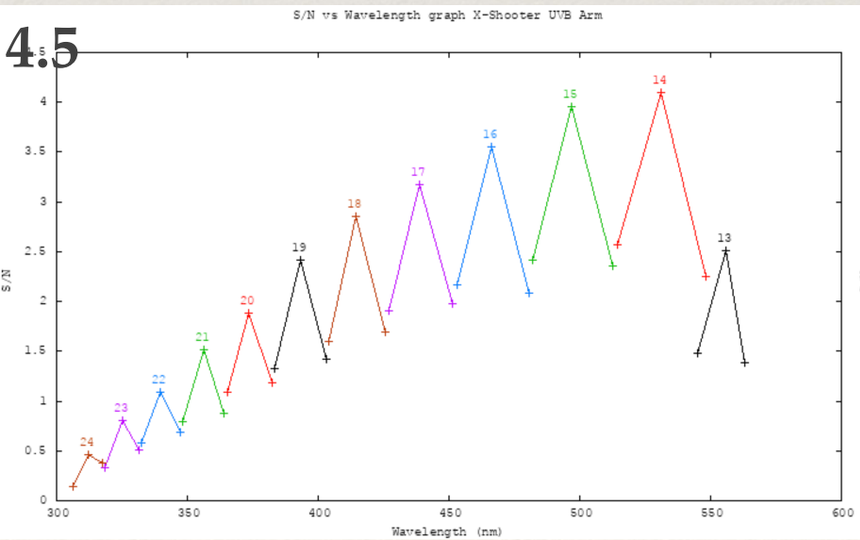
[power-law index = 0, R = 21 (AB), seeing = 1″, Moon = 0, airmass = 1.2, slit = 1″, texp = 1800 (UV-VIS), 2x900 (NIR)]





Comparison with Xshooter ETC

4.5



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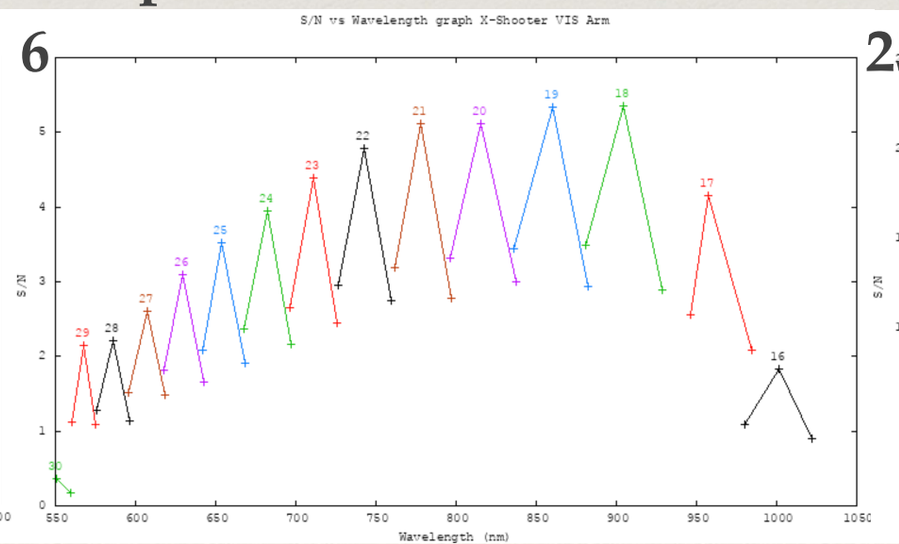

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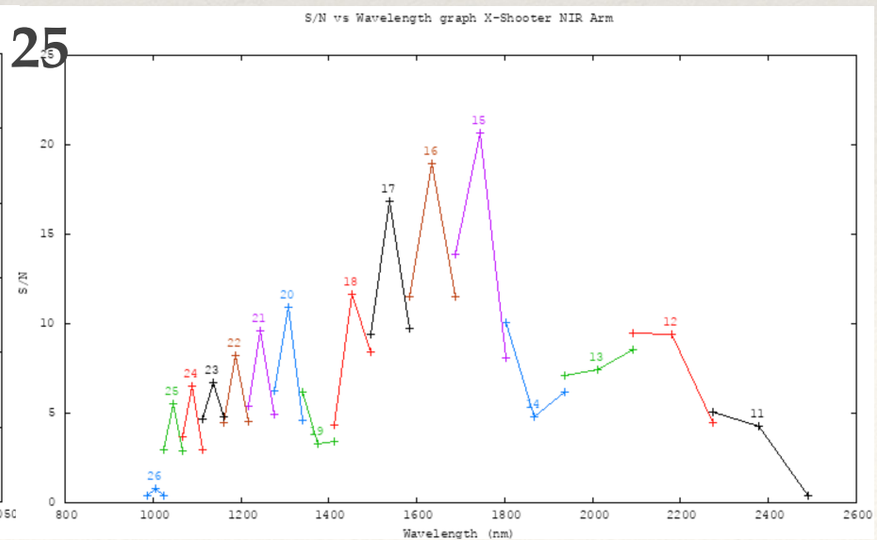


Imaging & Acquisition camera

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

Conclusions

- *SOXS: single-object, broad-band spectrograph (350-2000nm) with imaging capabilities at ESO/NTT*

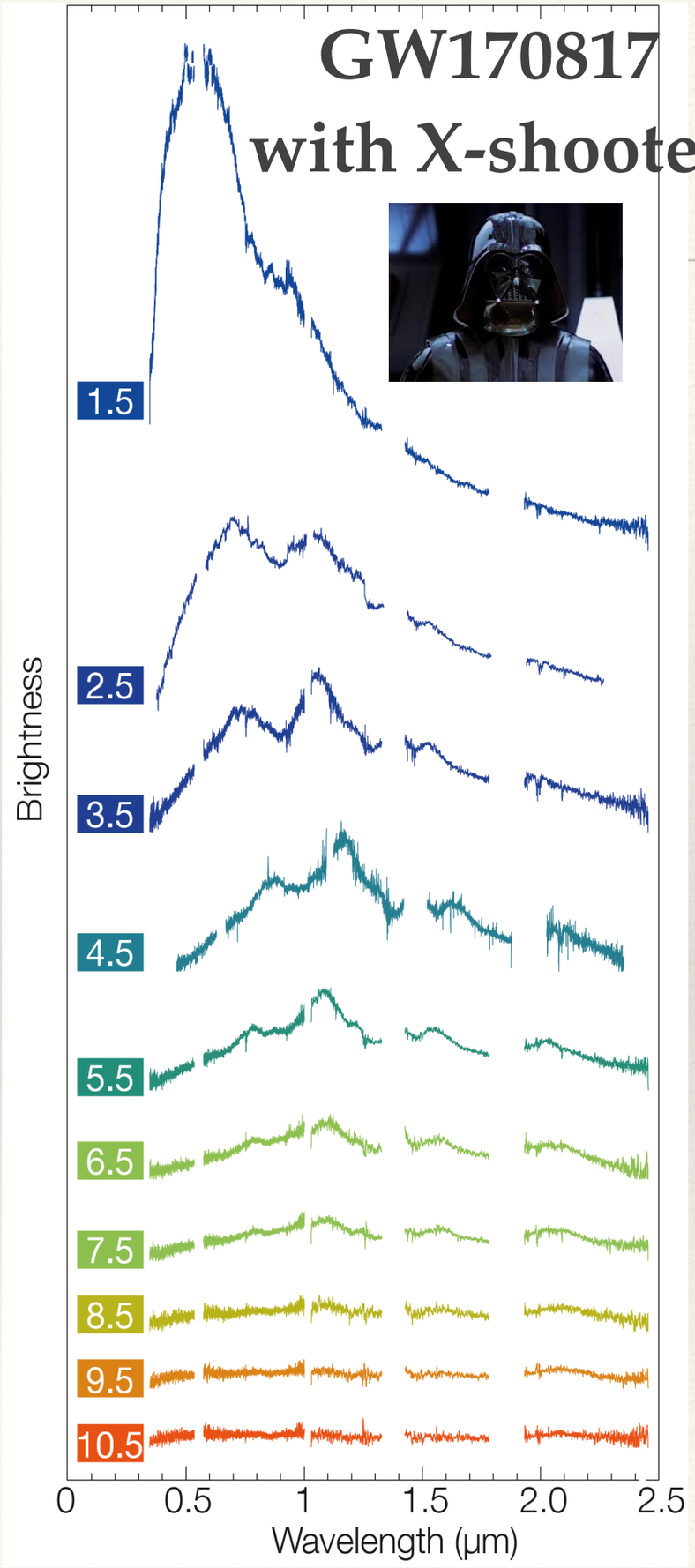
- *The instrument is ready, starting PAE now*

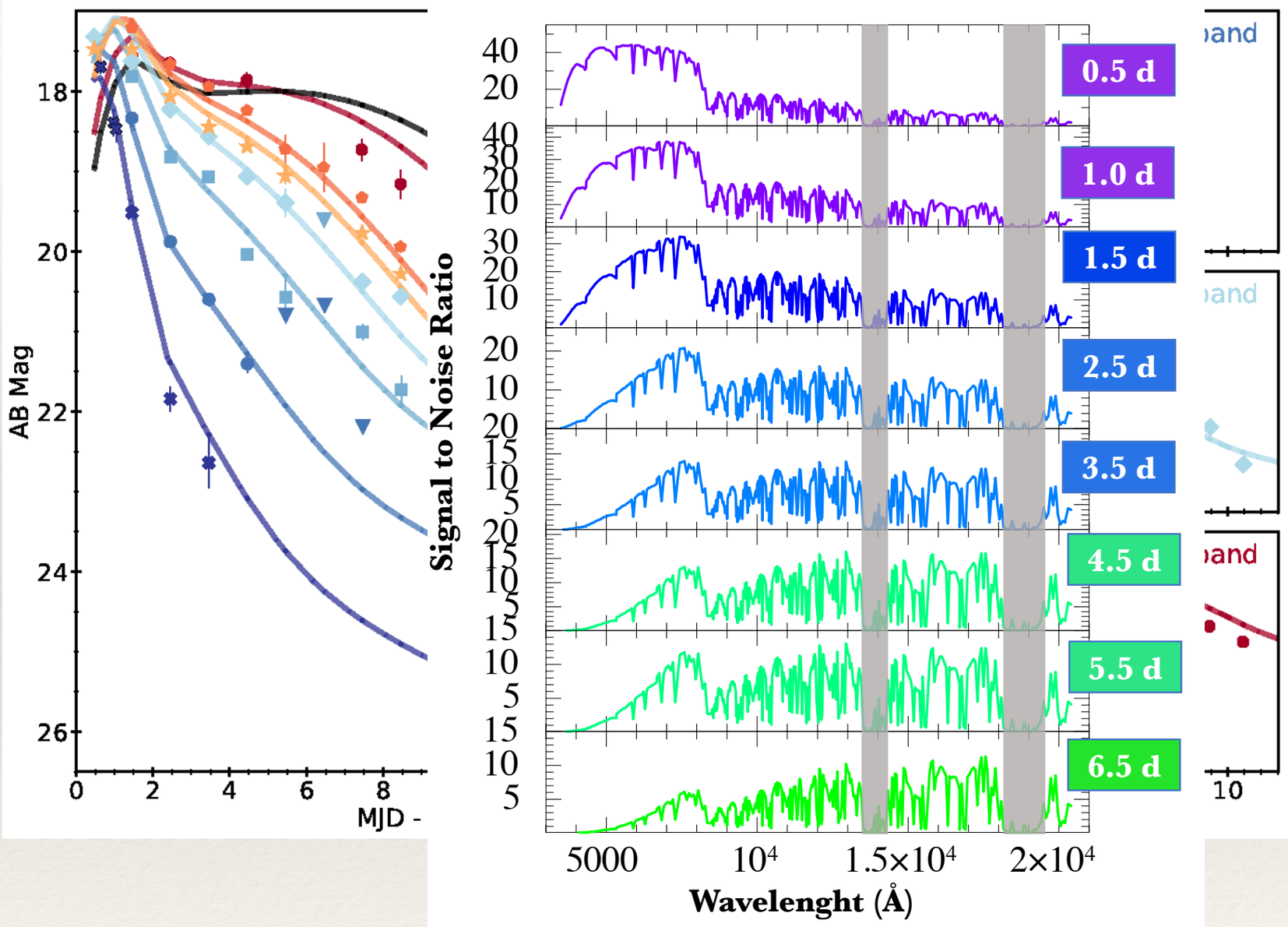
- *First light in early 2025, start of GTO April 2026*

- *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)*

Thanks

What can SOXS do?





SOXS ETC

http://192.167.38.34/