SOXS (Son Of X-Shooter): Scientific capabilities & ETC

Paolo D'Avanzo
INAF - Osservatorio Astronomico di Brera

on behalf of the SOXS team

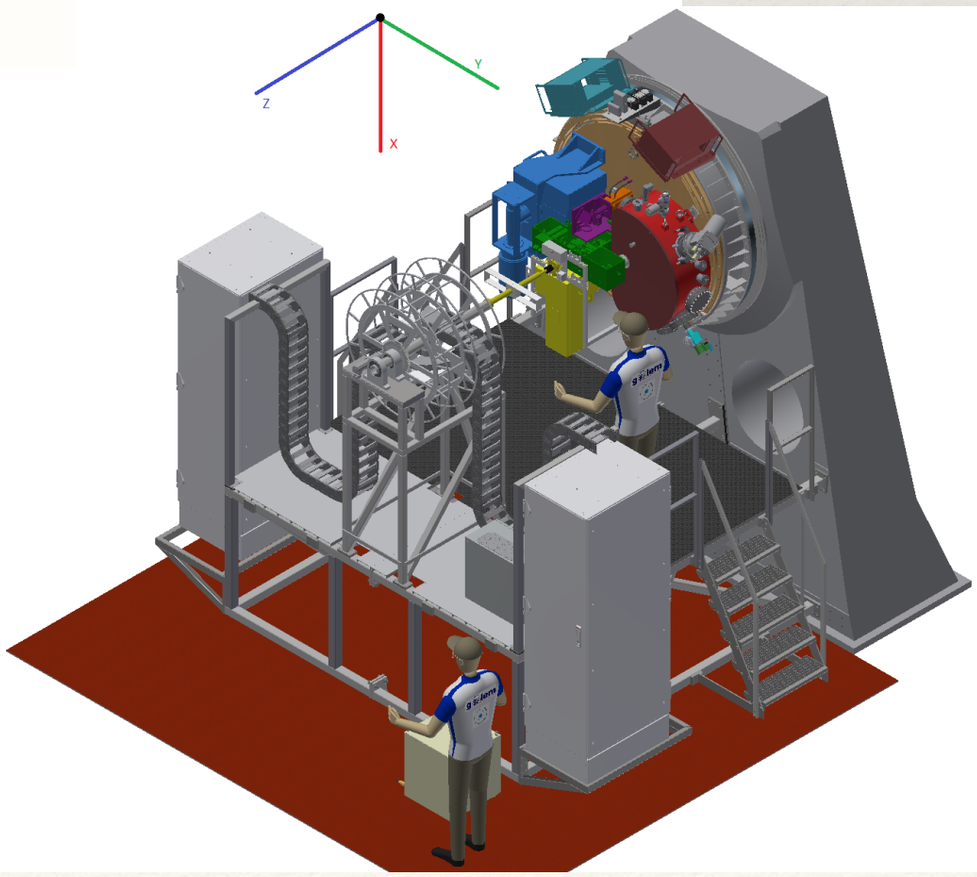
SOXS Consortium Science Meeting: Napoli 25 - 27 June 2024

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)

Pietro's
&
Kalyan's talks

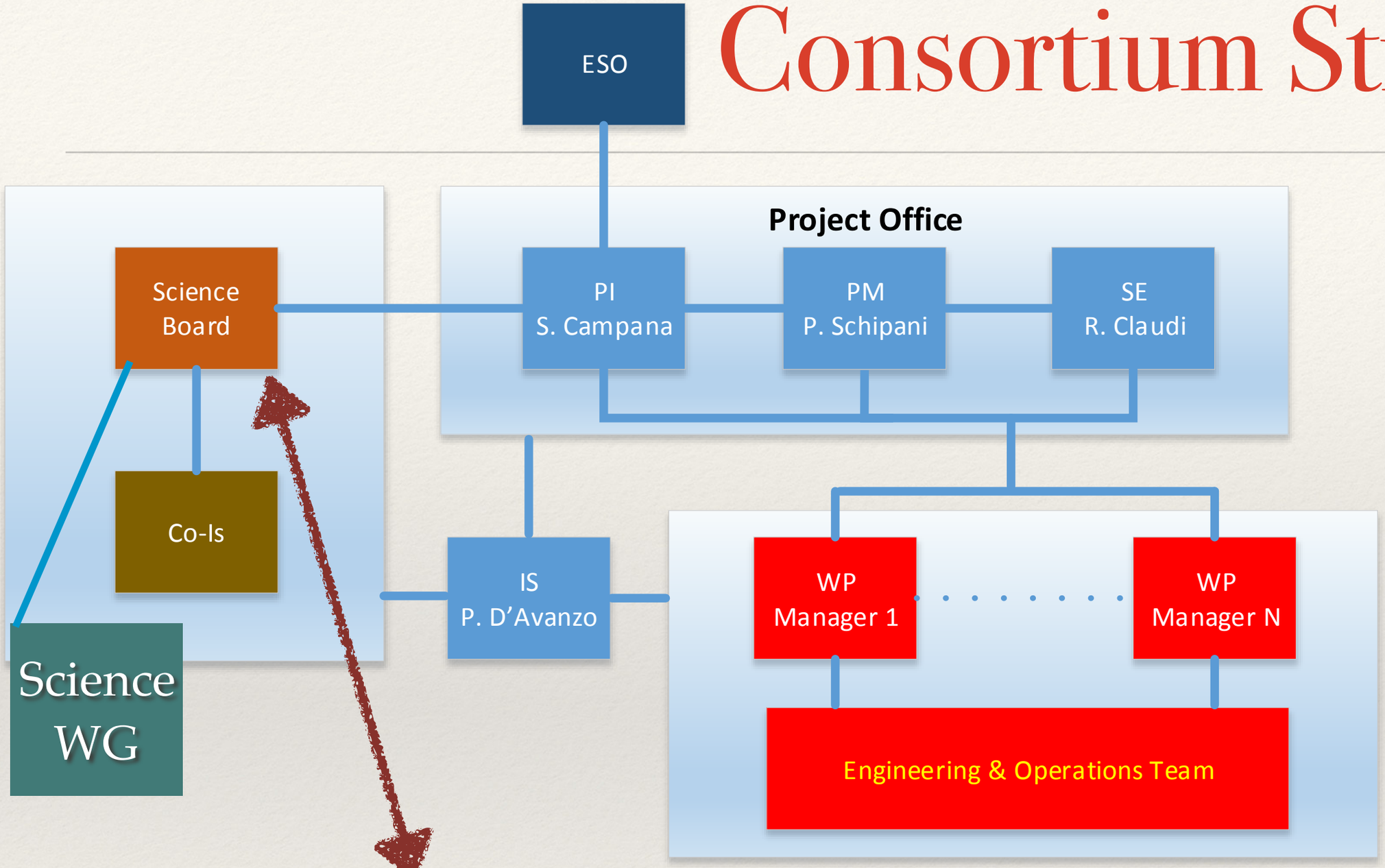


SOXS Consortium

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

Consortium Structure



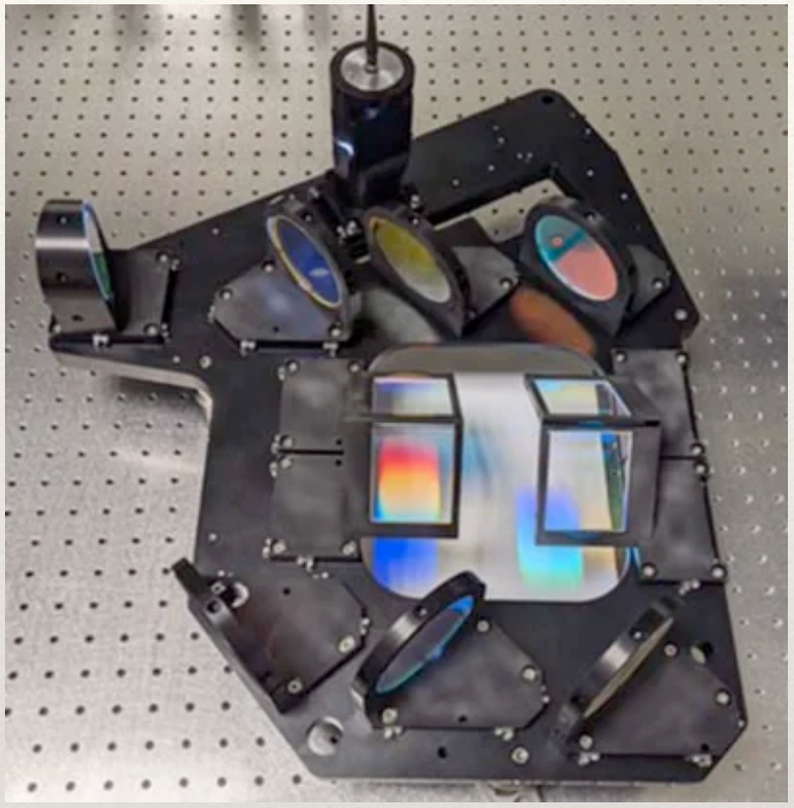
- E. Cappellaro (INAF-OAPadova) - Italy
- M. Della Valle (INAF-OANapoli) - Italy
- A. Gal-Yam (Weizmann) – Israel
- S. Smartt (Univ. Belfast) – UK
- I. Arcavi (Tel Aviv University) – Israel
- S. Mattila (FINCA) – Finland
- M. Stritzinger (Aarhus U.) – Denmark
- S. Campana (INAF-OABrera) - Italy

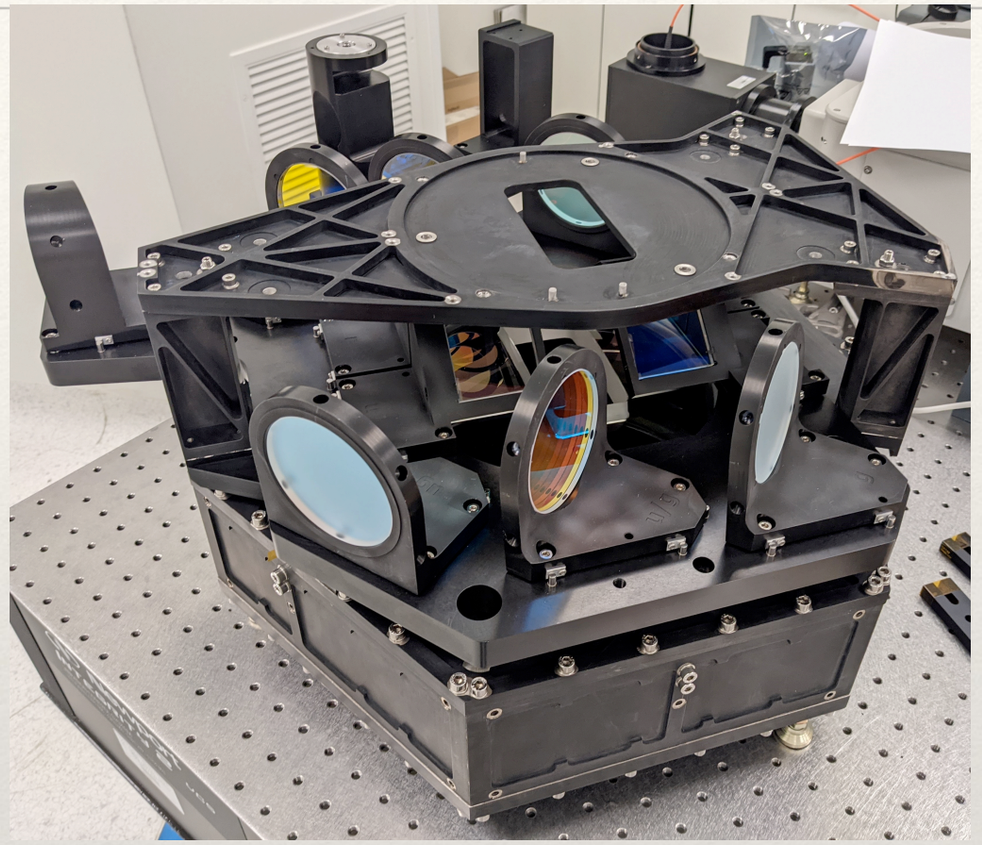
Work-Packages & People

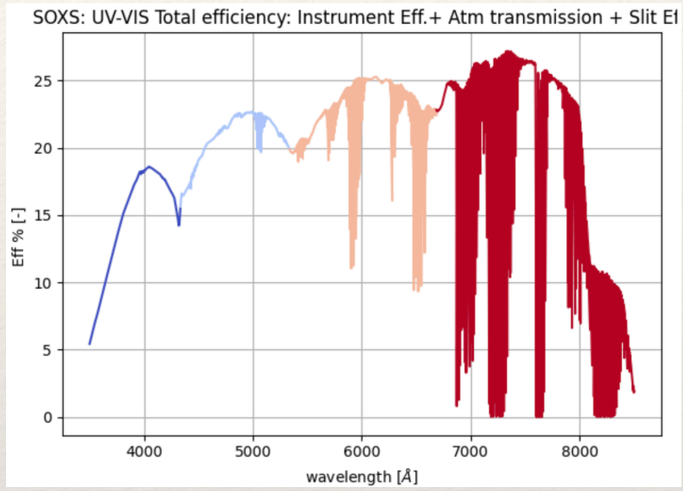
Optics WP Manager - Matteo Munari (INAF - Osservatorio astronomico di Catania)
Mechanics WP Manager - Matteo Aliverti (INAF - Osservatorio astronomico di Brera)
Electronics WP Manager - Giulio Capasso (INAF - Osservatorio astronomico di Capodimonte)
Software WP Manager - Andrea Baruffolo (INAF - Osservatorio 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)

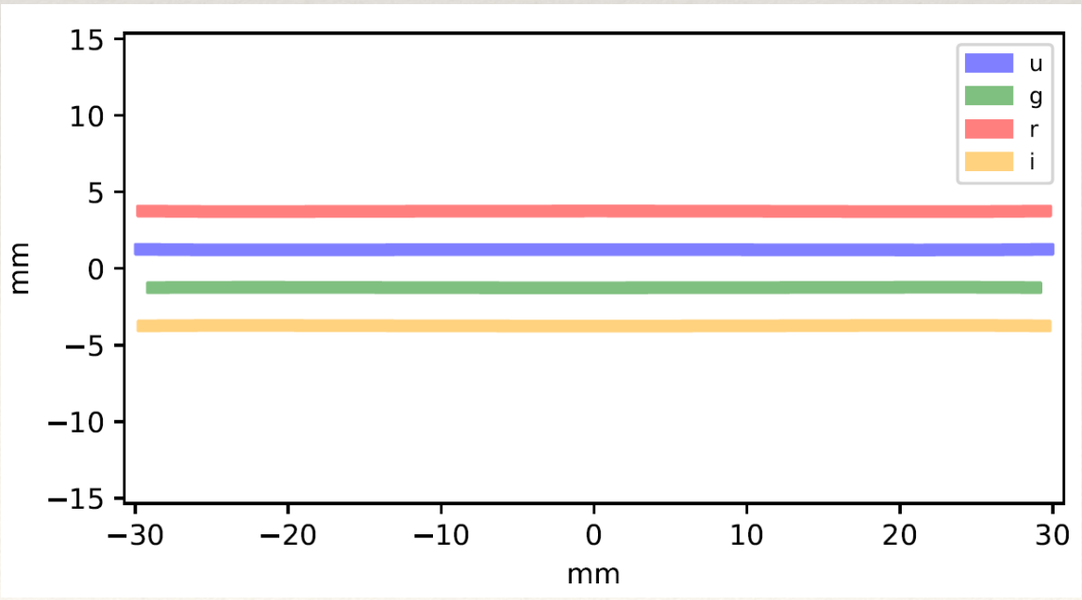
SOXS UV-VIS arm

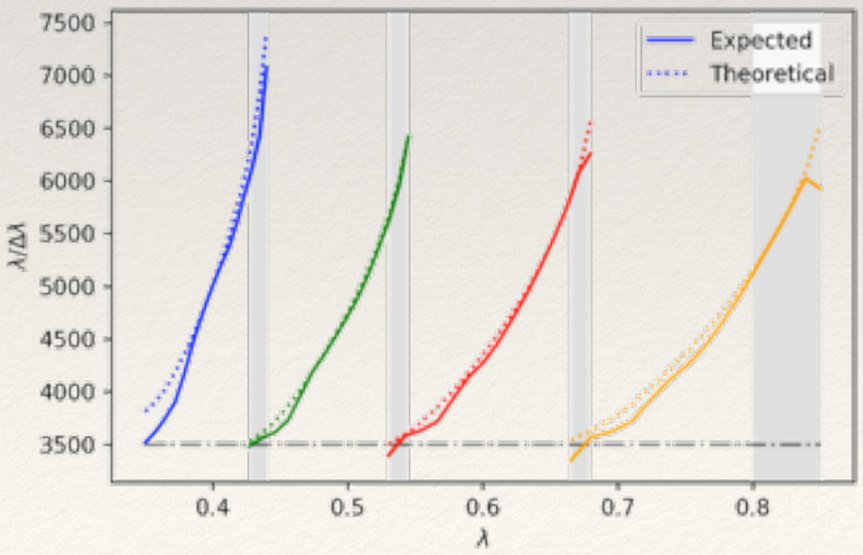
מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE







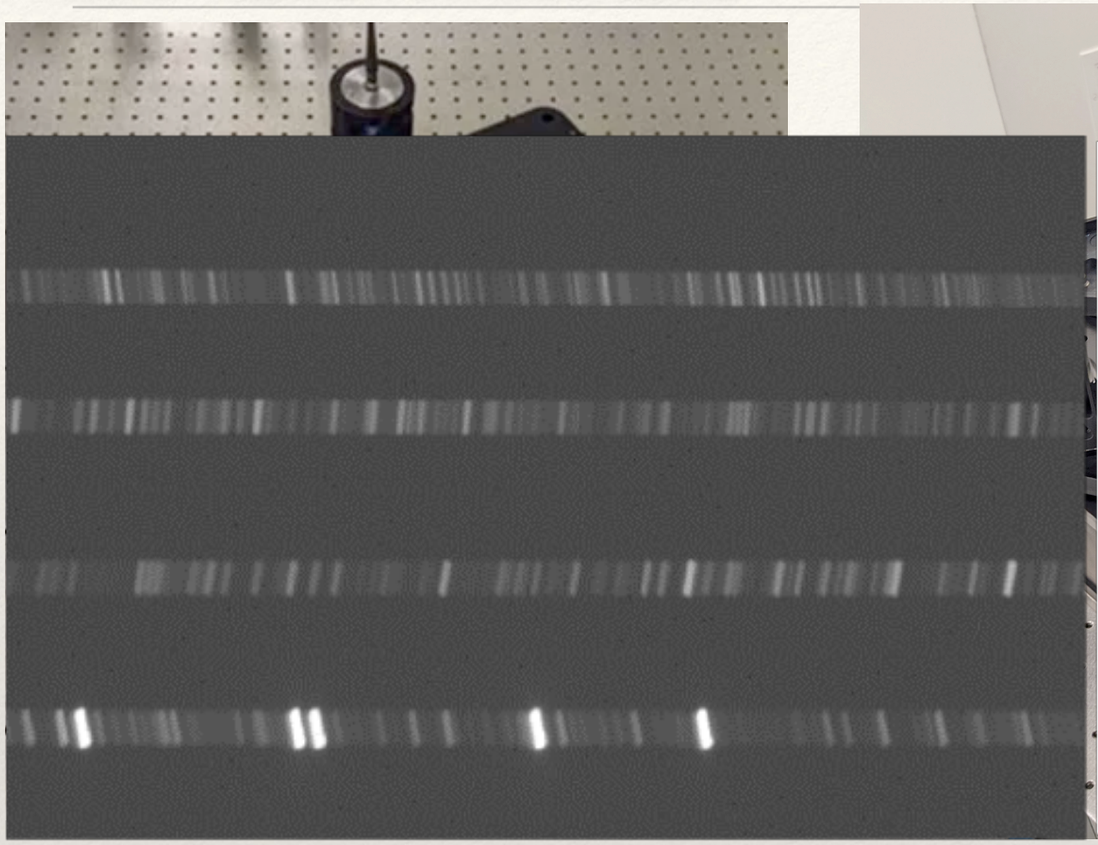


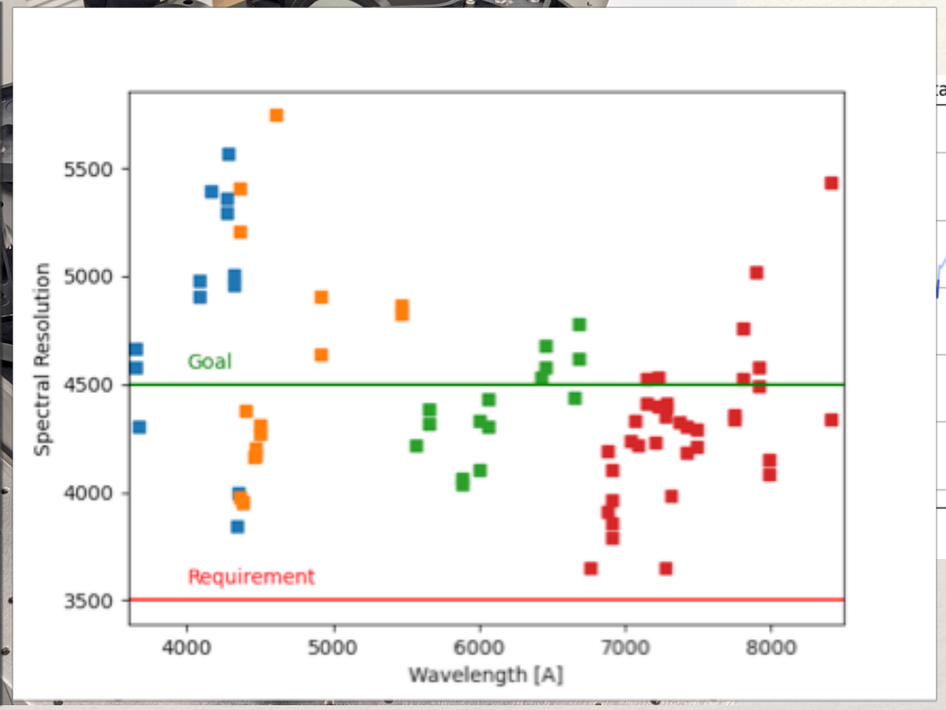


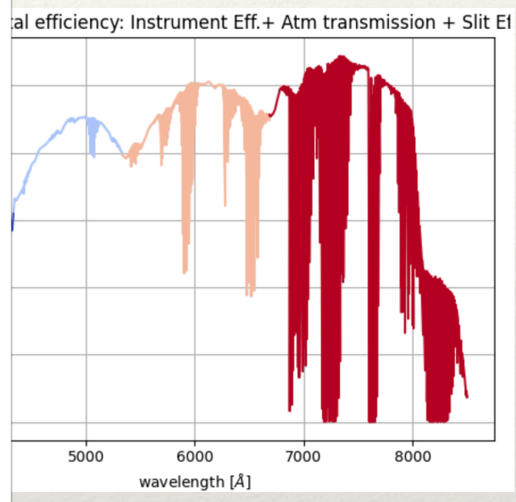
u: 350 - 440 nm
g: 427 - 547 nm
r: 527 - 680 nm
i: 664 - 850 nm

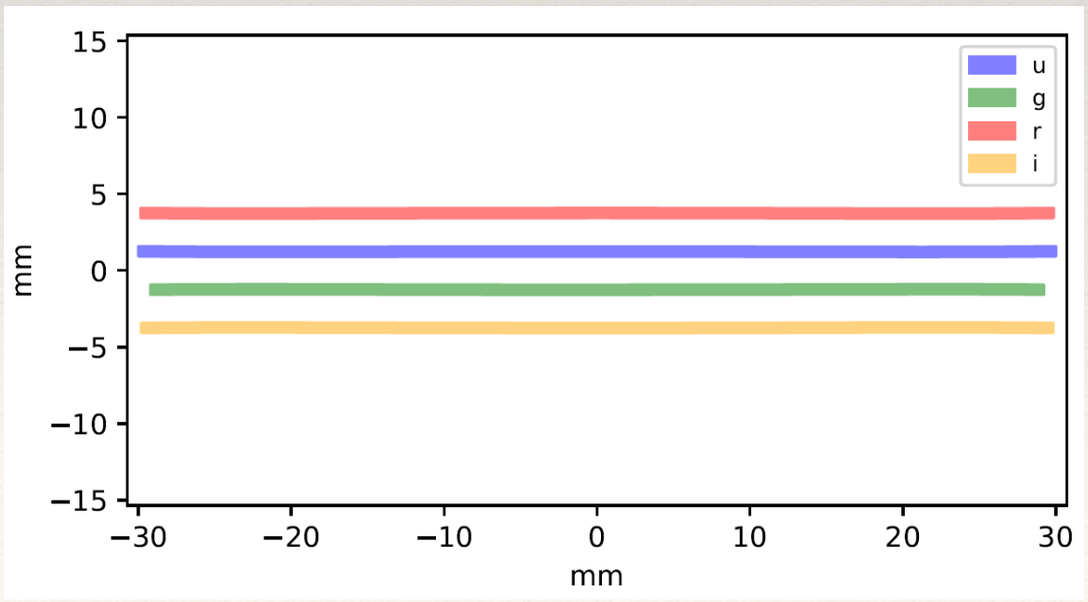
SOXS UV-VIS arm

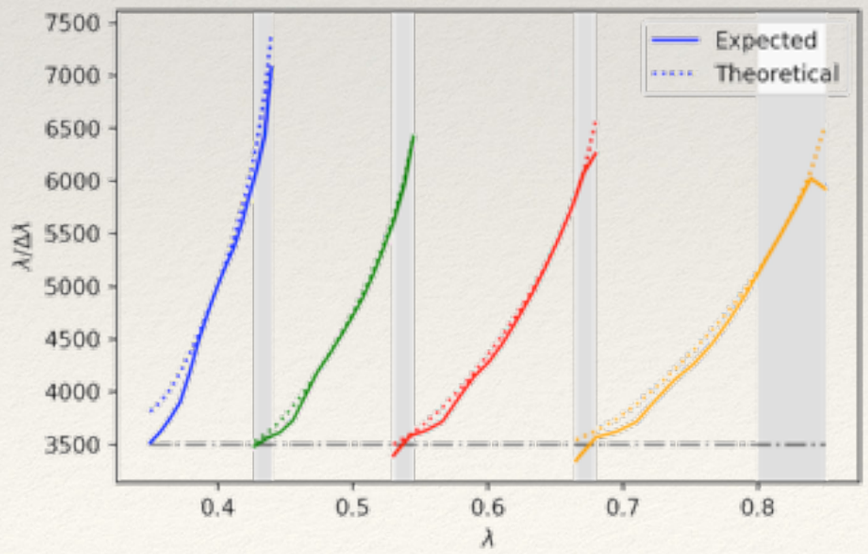
מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE











u: 350 - 440 nm
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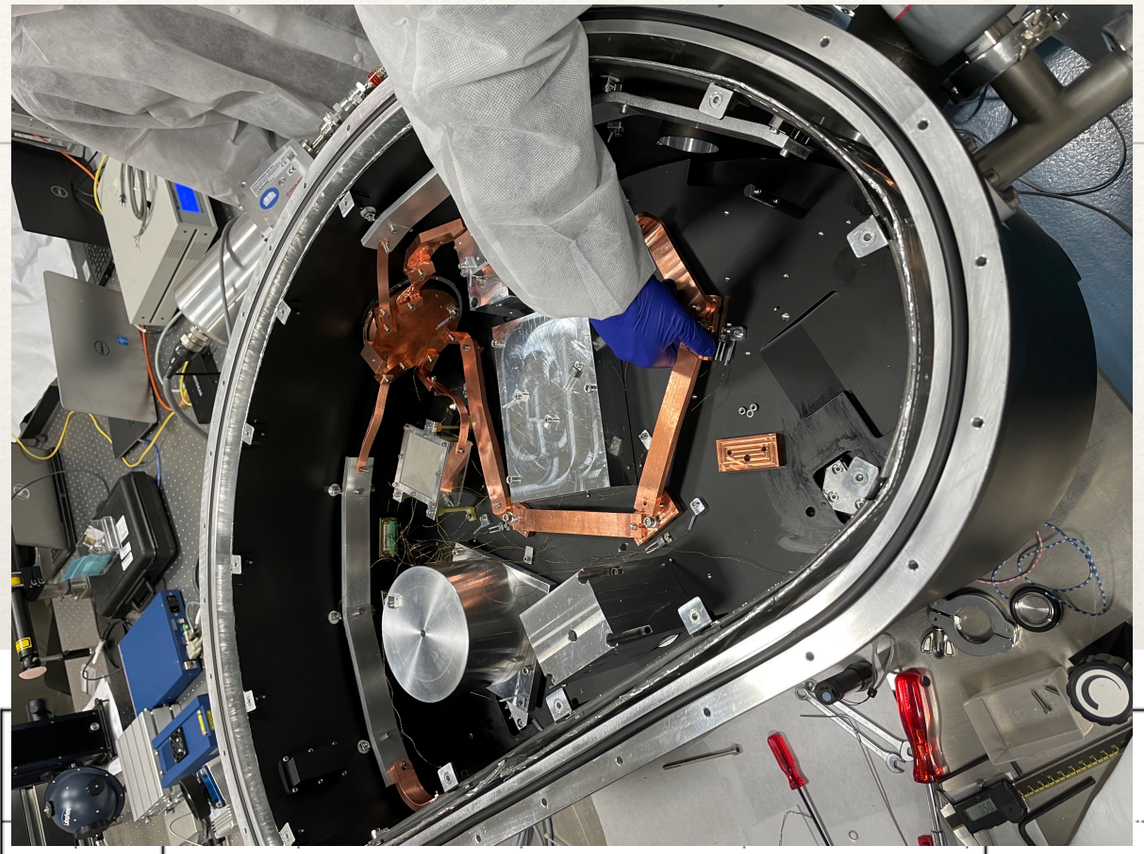
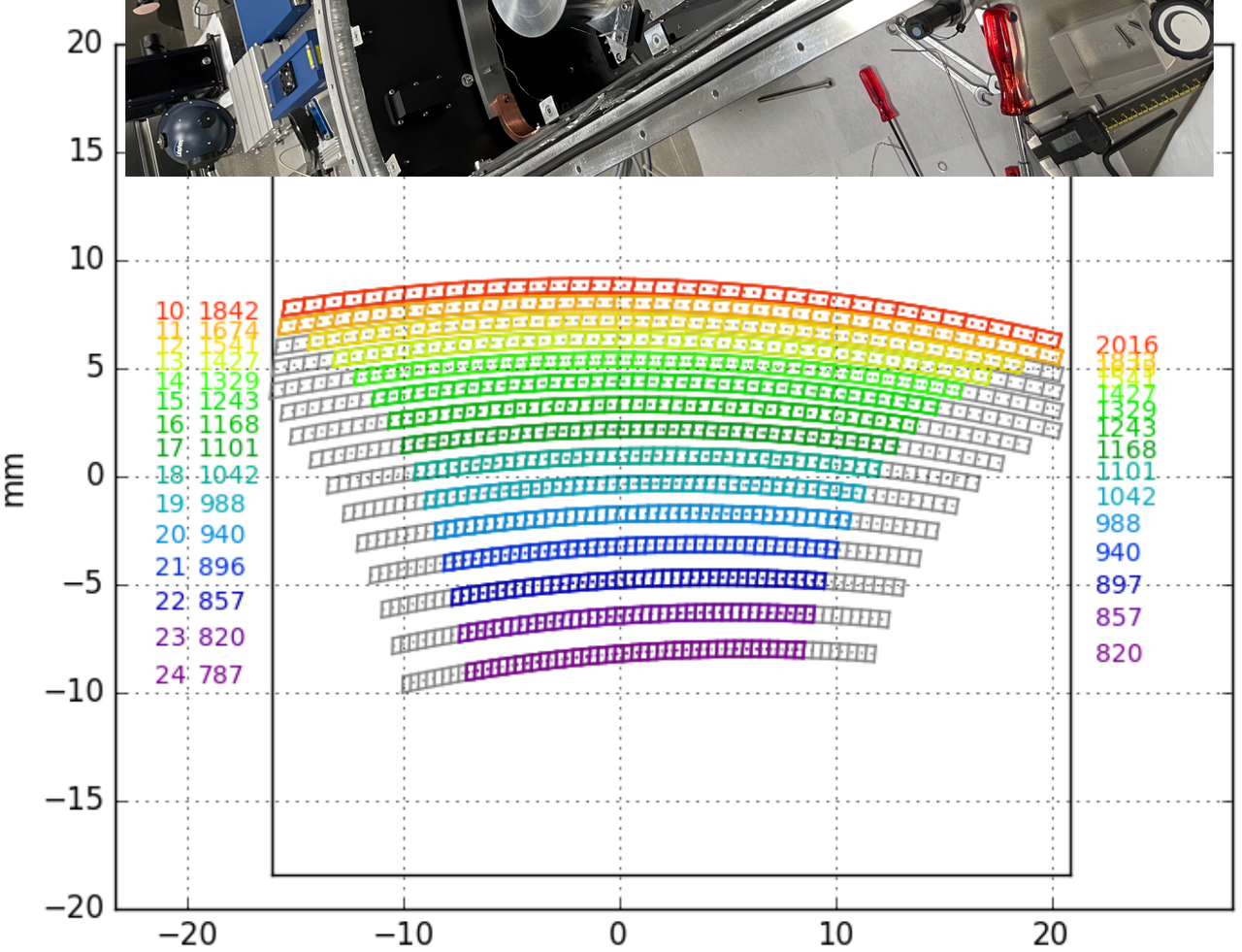
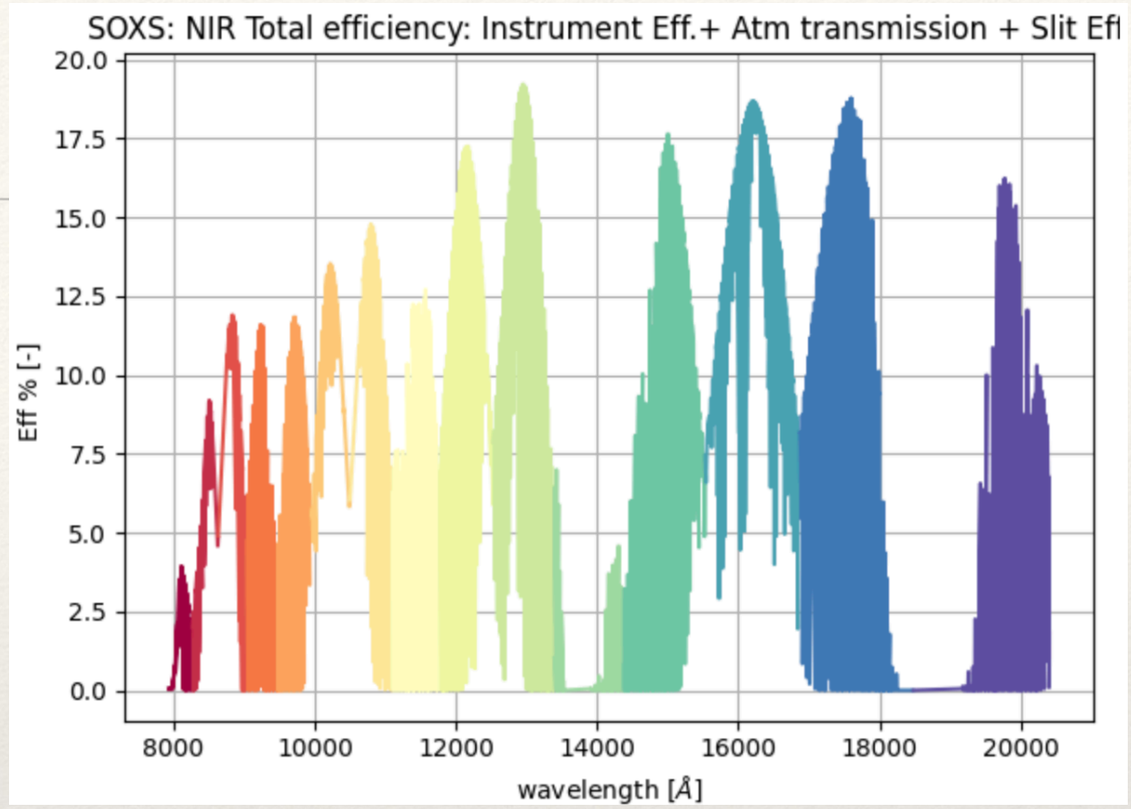
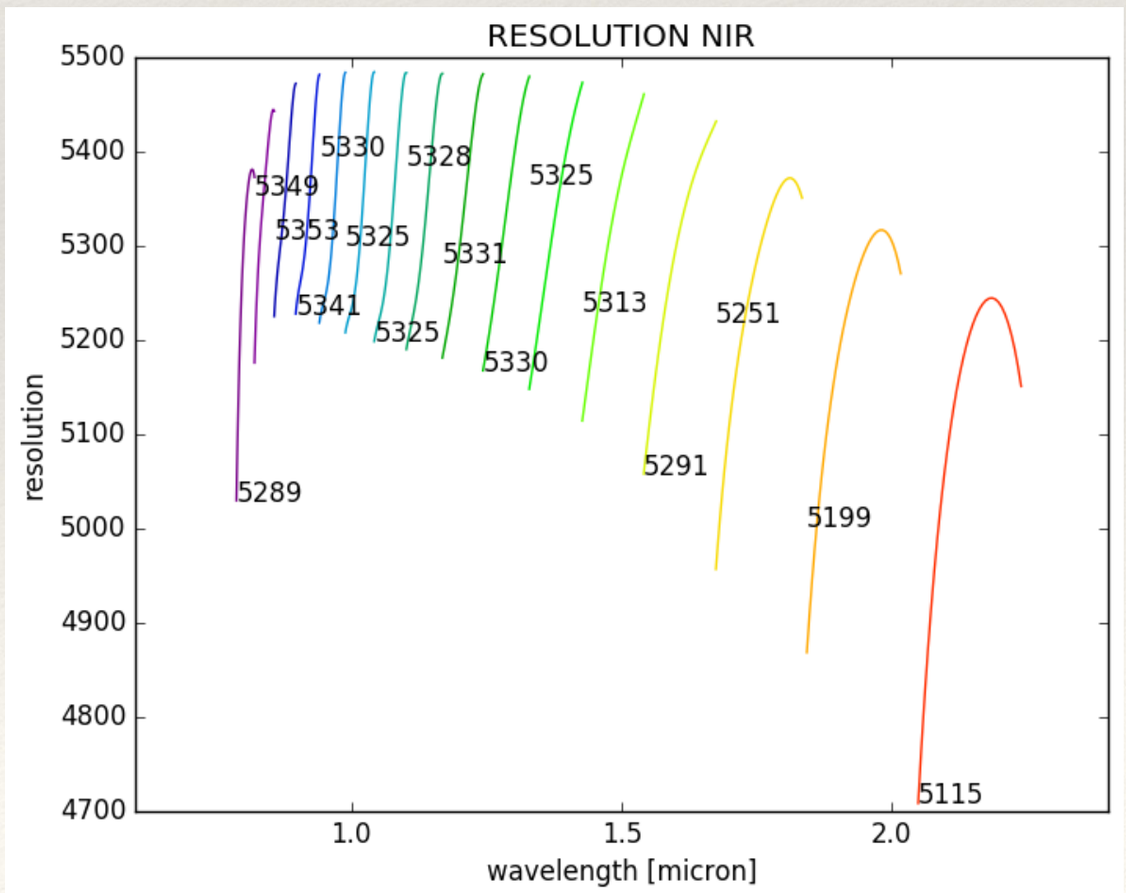
SOXS NIR arm

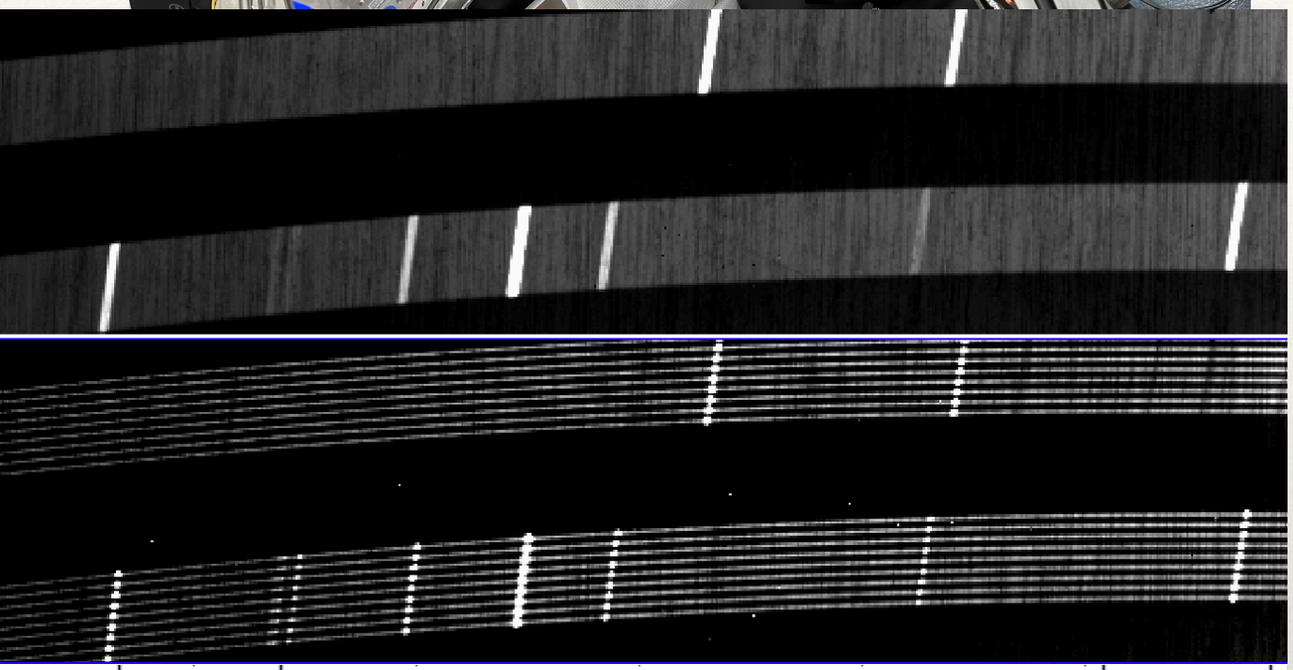


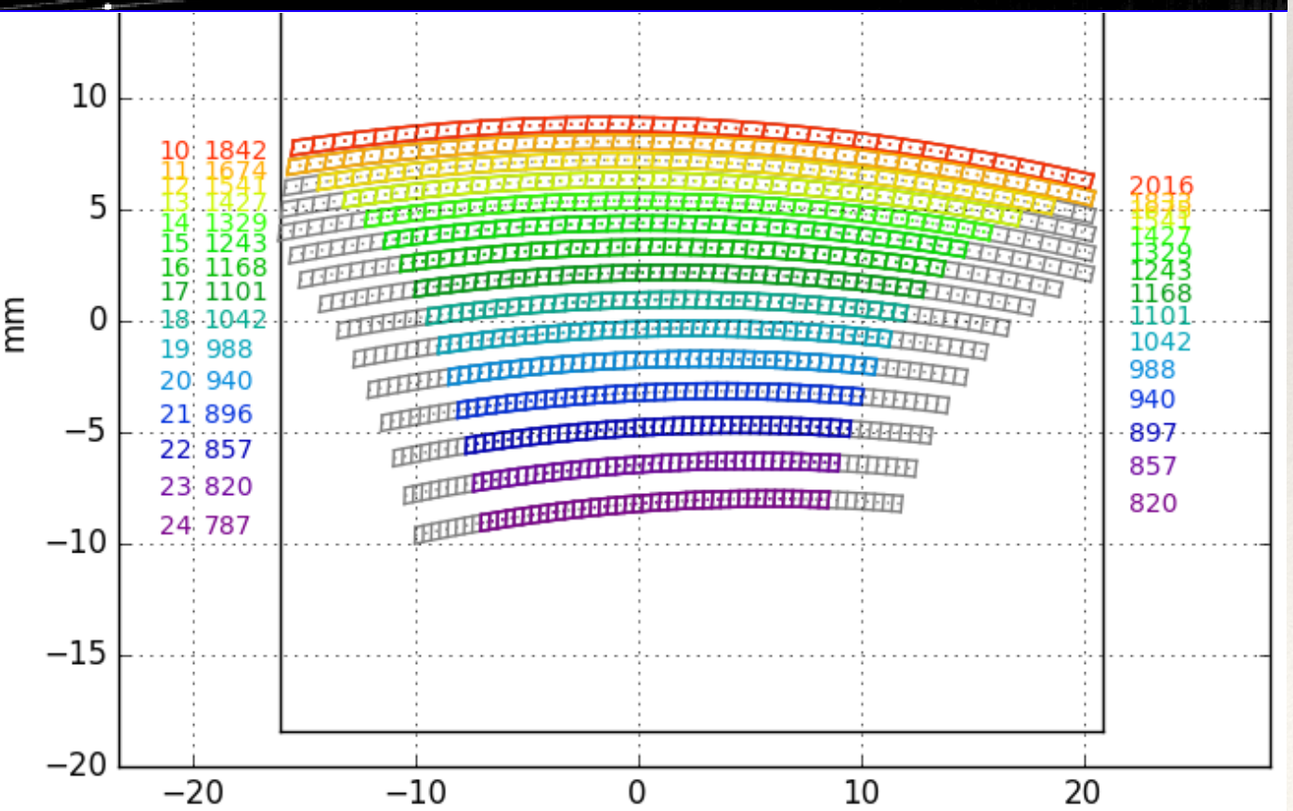

mm
10 1842
11 1674
12 1541
13 1427
14 1329
15 1243
16 1168
17 1101
18 1042
19 988
20 940
21 896
22 857
23 820
24 787
2016
1427
1329
1243
1168
1101
1042
988
940
897
857
820


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


RESOLUTION NIR
resolution
wavelength [micron]
5330
5328
5325
5349
5353
5325
5331
5341
5325
5313
5330
5251
5291
5289
5199
5115

SOXS NIR arm

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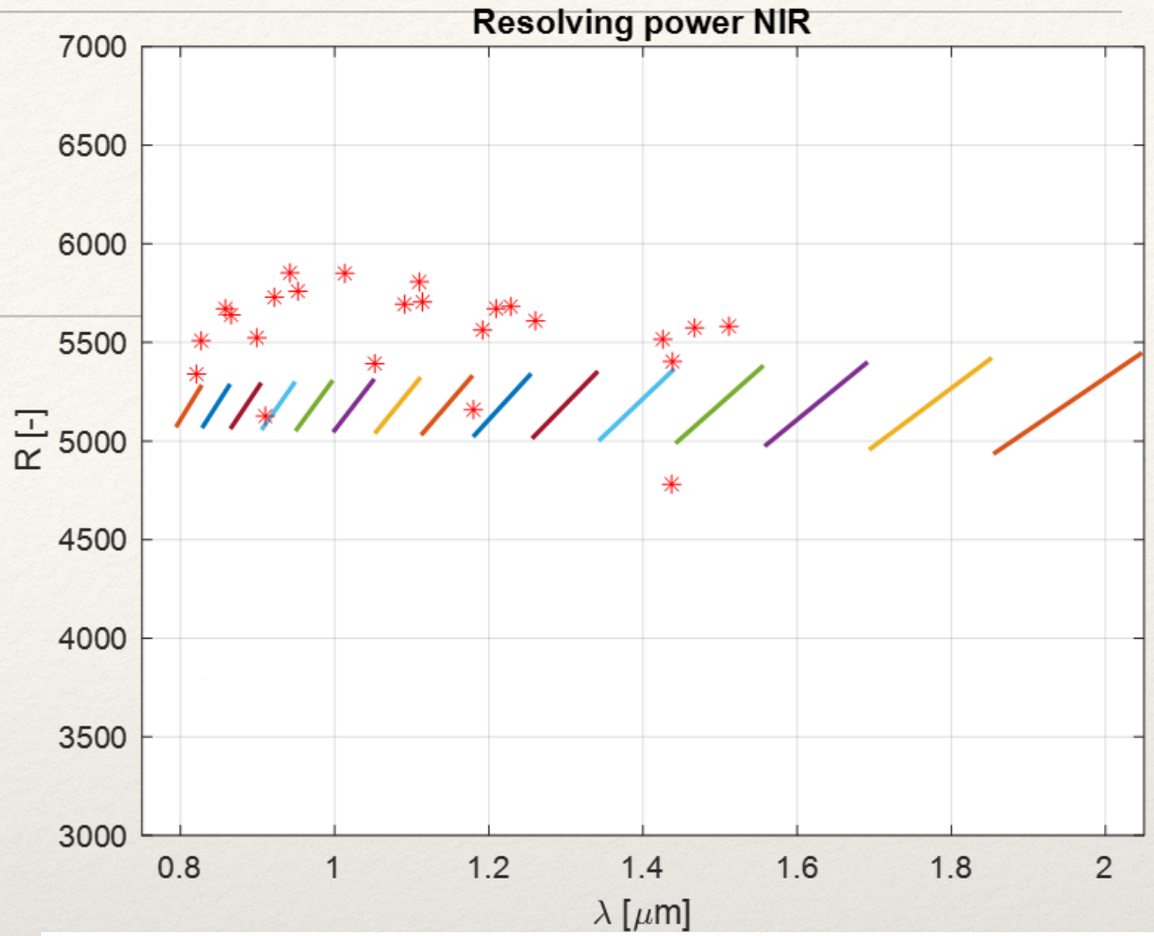
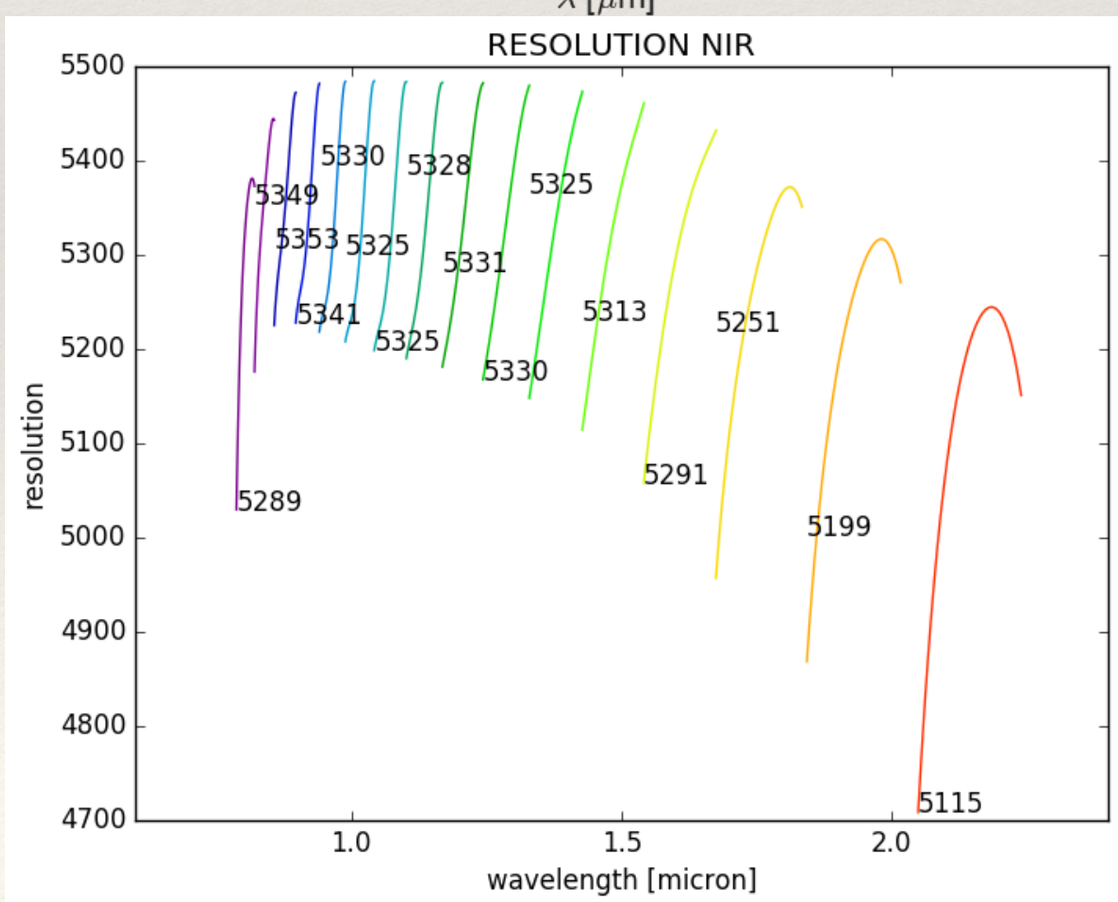
897
857
820


Resolving power NIR
R [-]
λ [μm]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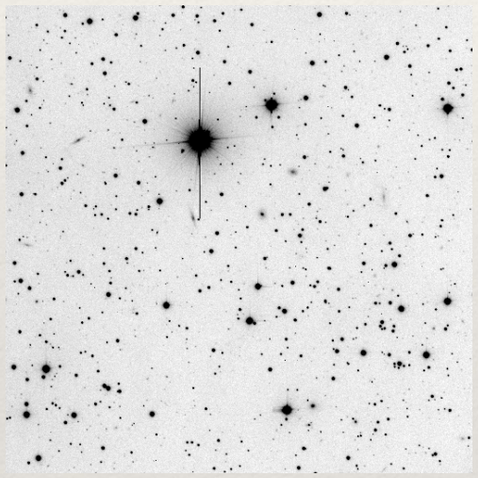
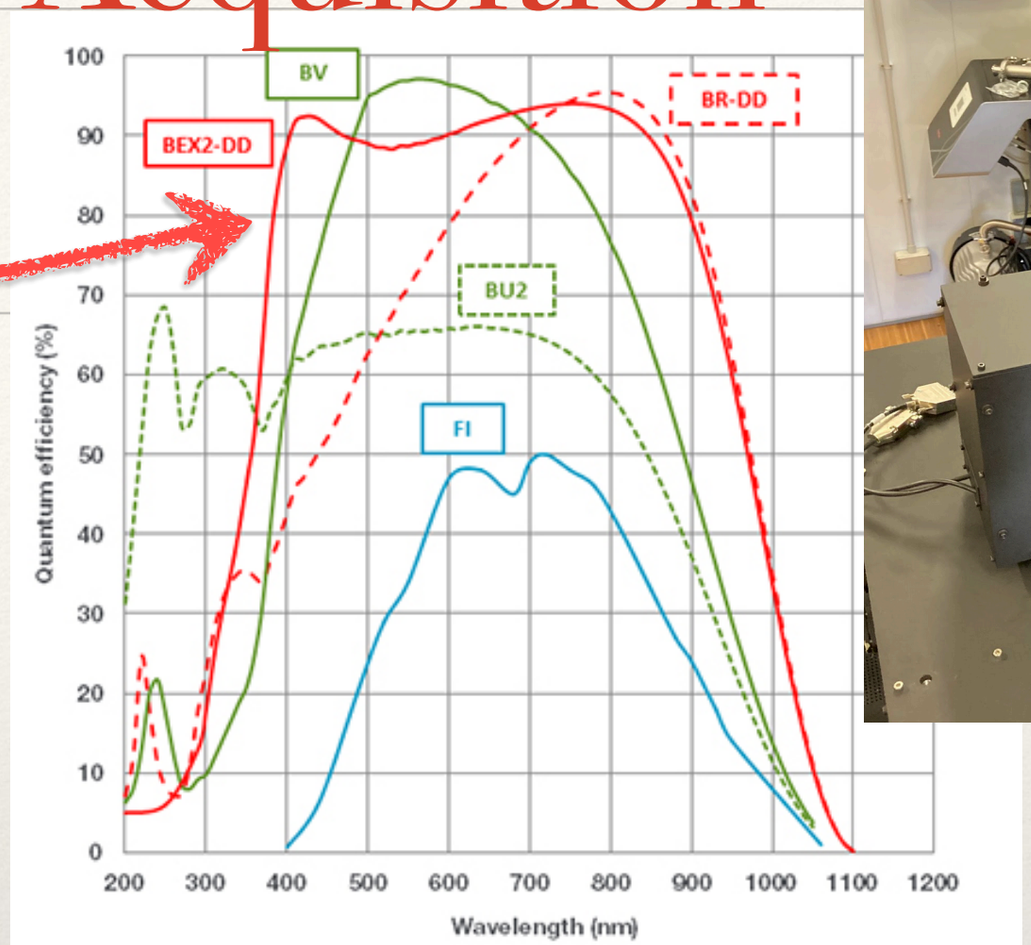
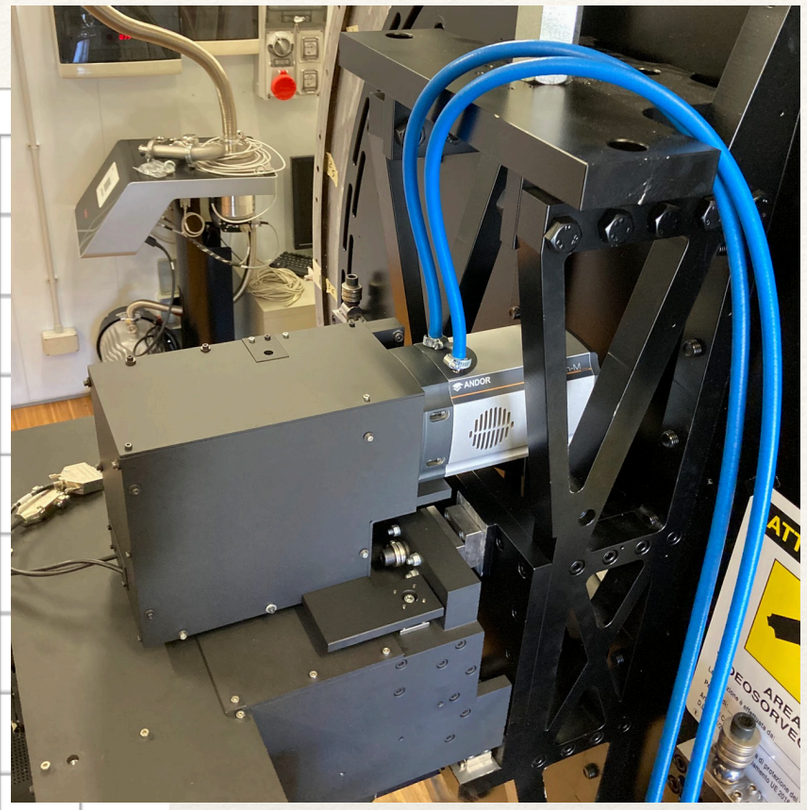
(Imaging!) & Acquisition Camera

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

3.5’x3.5’ Field of view



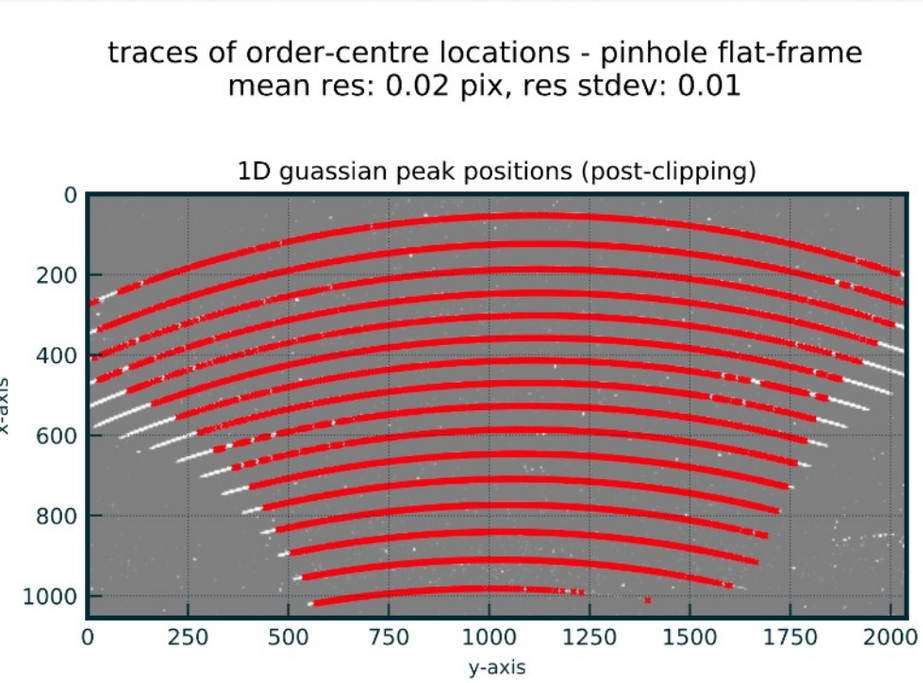


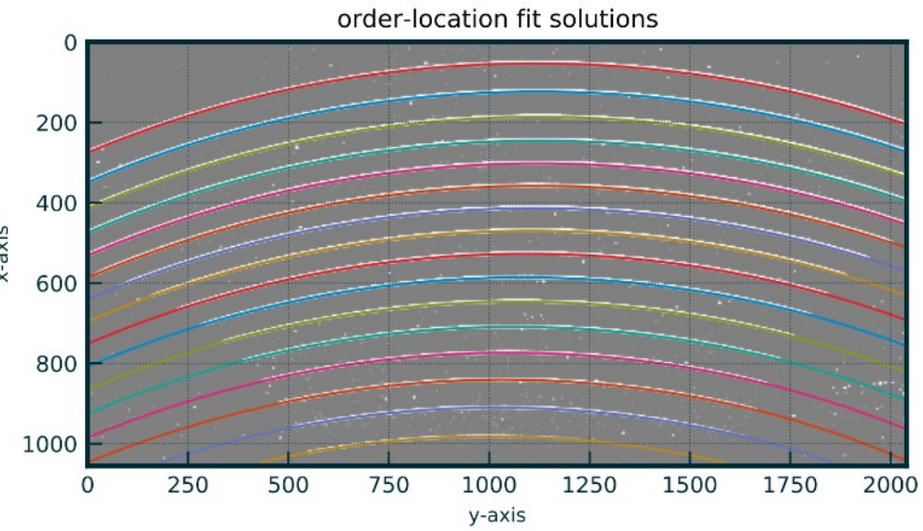


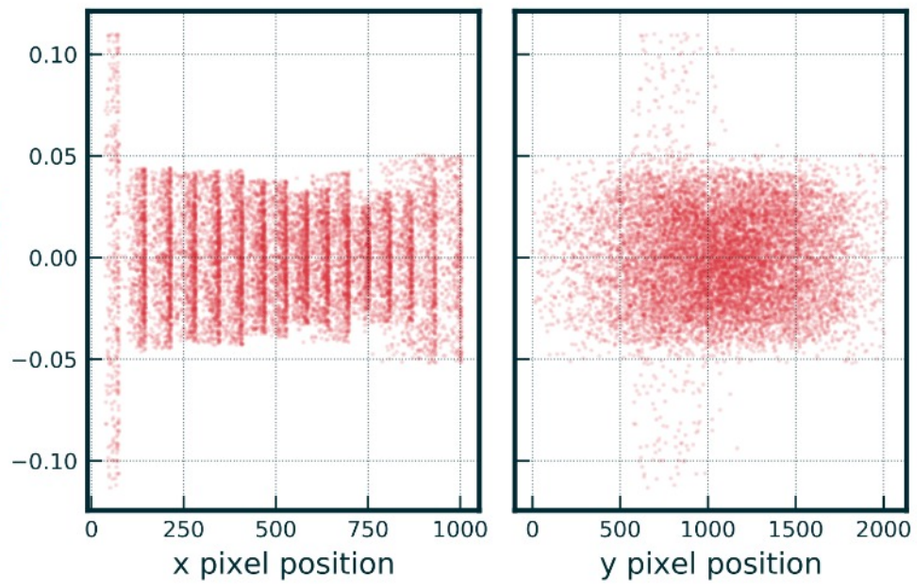
Limiting magnitude for a SNR=10

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

Queen's University Belfast

Dave Young's talk

- 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

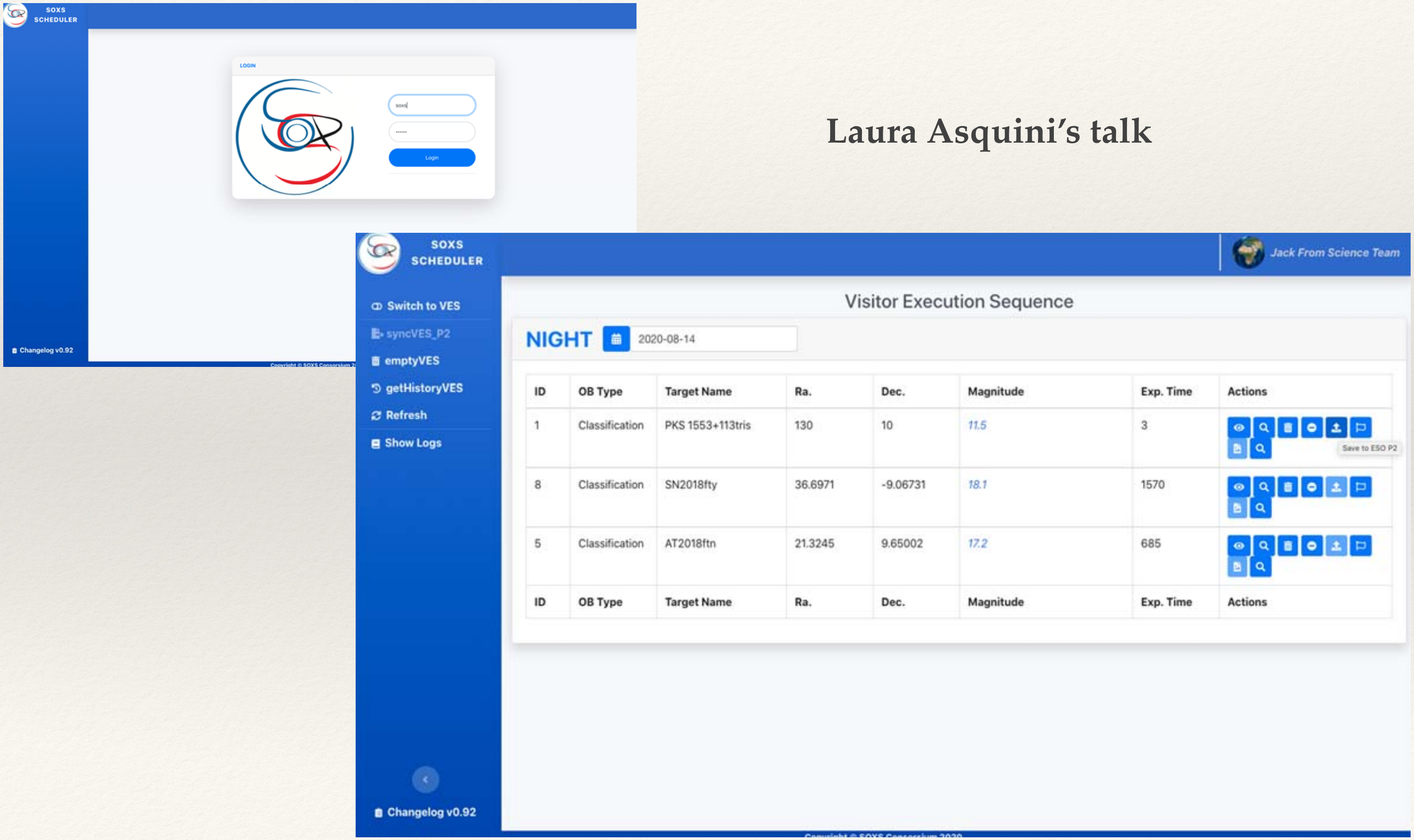
Operations

SOXS DUTIES

Laura Asquini's talk

- 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

SOXS Scheduler



Laura Asquini's talk

Why do we need SOXS

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

Space optical missions: Gaia, EUCLID, …

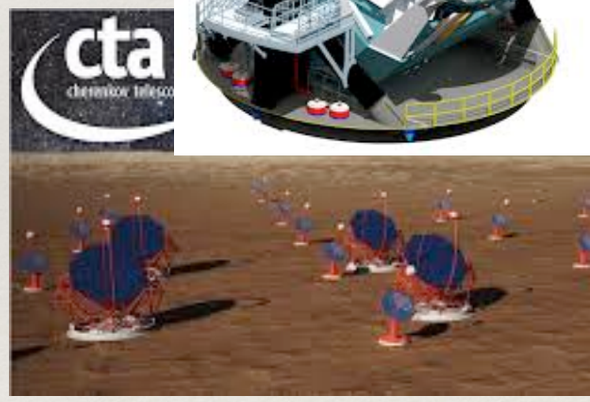
Space high-energy missions: Swift, Fermi, Einstein Probe, SVOM

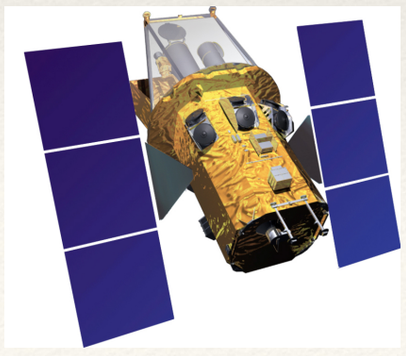
Radio new facilities: MeerKAT, SKA

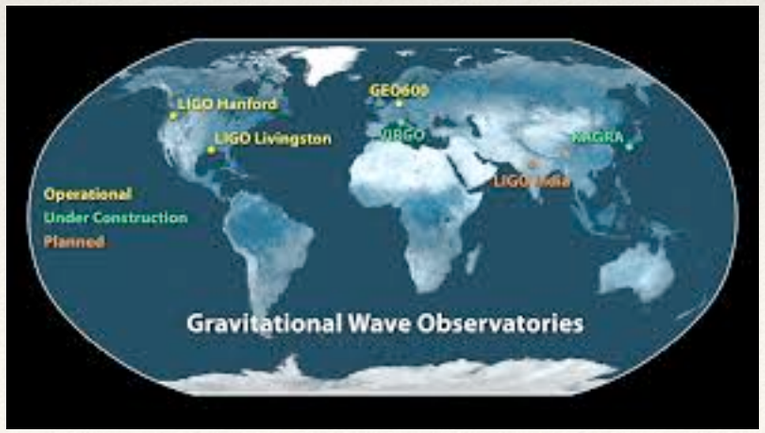
VHE: MAGIC, HESS, Astri, CTA

Messengers: LIGO-Virgo, KM3Net

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



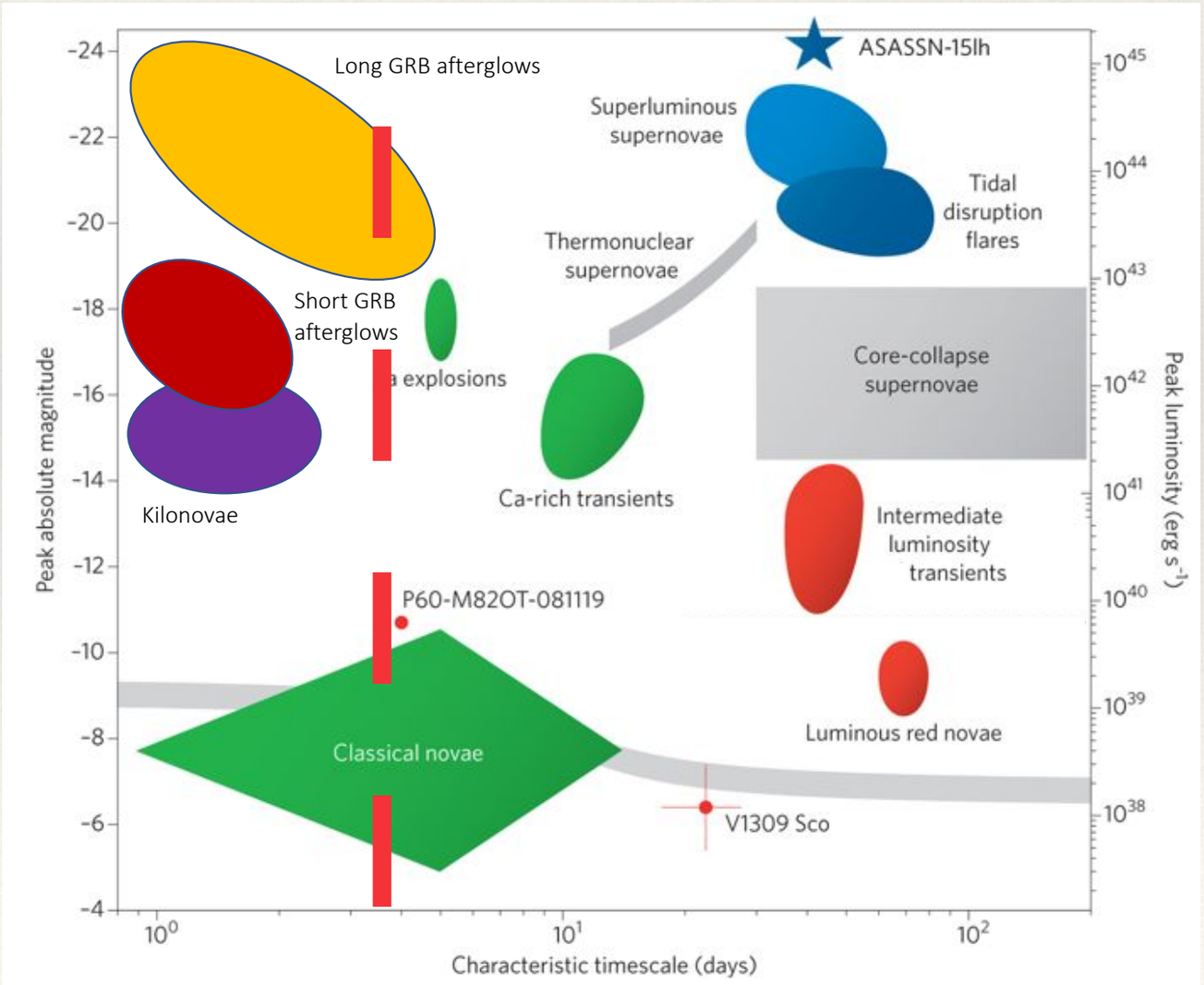




SOXS Science cases

- 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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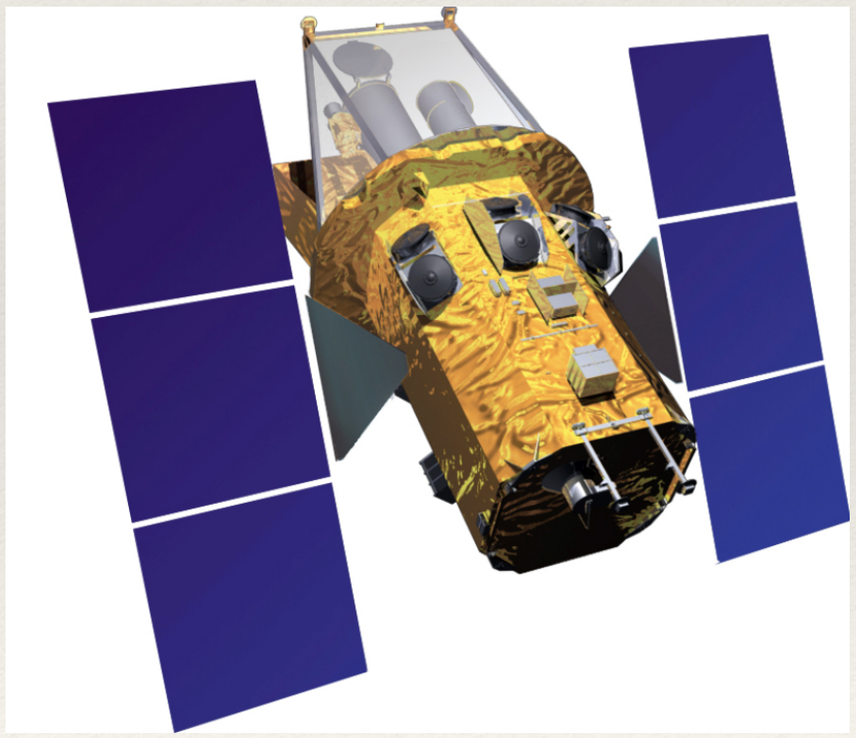
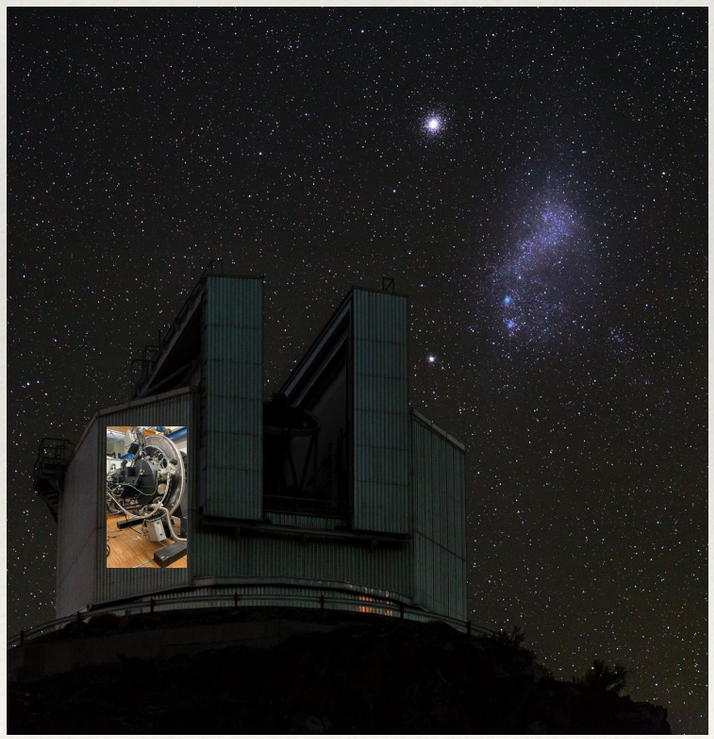




Science Working Groups

Talks on Wed & Thu

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

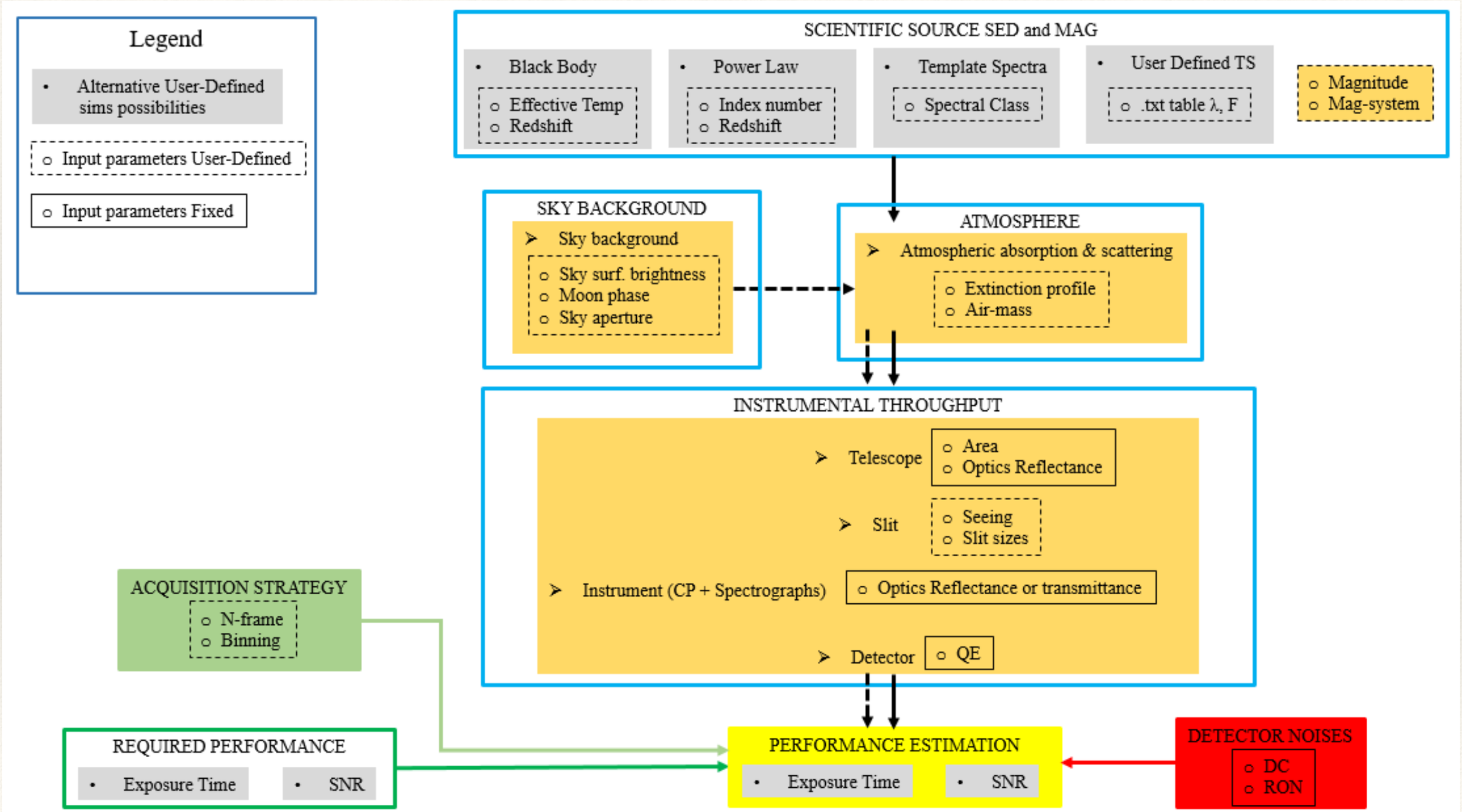
- (•) Use template spectrum: E (GALEV)
- ( ) Upload spectrum: **Table [lambda, flux] in [A, erg/s/cm2/A]**

Choose file No file chosen

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

21,5

ETC - Structure



ETC - Input

Science Object

Target Input Flux Distribution

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

- ○ Black body
- ○ power-law - F(λ) ∝ λ ^{index}
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◉ 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

Redshift :

0

Lambda [A]:

5013

FWHM [A] (warning: min acceptable FWHM for UV-VIS = 0.32 A, for NIR = 0.63 A):

1

Flux [10^-16 erg/cm^2/s]:

2

Band m R

Magsystem AB

Sky Conditions

Moon - FLI [-]:

0

Airmass. [-]:

1,2

Precipitable Water Vapor [mm] -- (10 default value - 3.5 La Silla mean value): 30.0

Seeing [arcsec]:

1

Instrument set-up: Slit selection - Acquisition time - Detectors modes:

Slit size UV-VIS [arcsec]: 1.0

Slit size NIR [arcsec]: 1.0

Exposure time [sec], Single Exposure UV-VIS:

900

Number of Exposures [-], UV-VIS:

1

Detector Integration Time (DIT) [sec], Single Exposure NIR:

900

Number of DIT (NDIT) [-], NIR:

1

Number of Integrations (NINT) [-], NIR:

1

Binning X (spectral direction) 1

Binning Y (spatial direction) 1

Dark Current [e-/px/s] NIR:

0,0015

Input for Calculation Database

Calculation-Plots: Wavelengths DataBase (Default DB is 15 SRE per order) 100 SRE -- NO Orders Over

Calculation-SNR: SNR per SRE (0) -- SNR per PIX (1) 0

RUN ETC:

☑ Include exposure times for S/N:

10

Output selection:

Table ☑

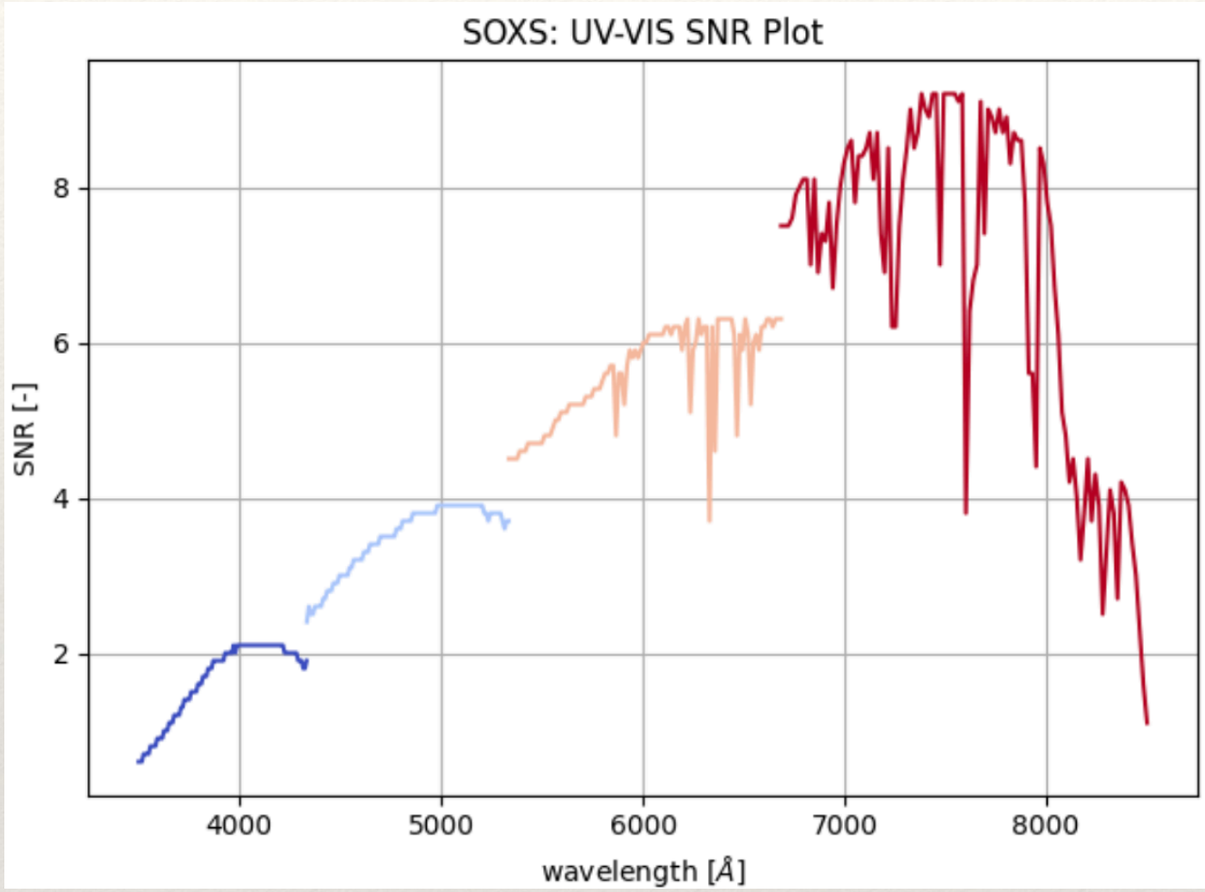
Graph ☑ Toggle All / No Graphs

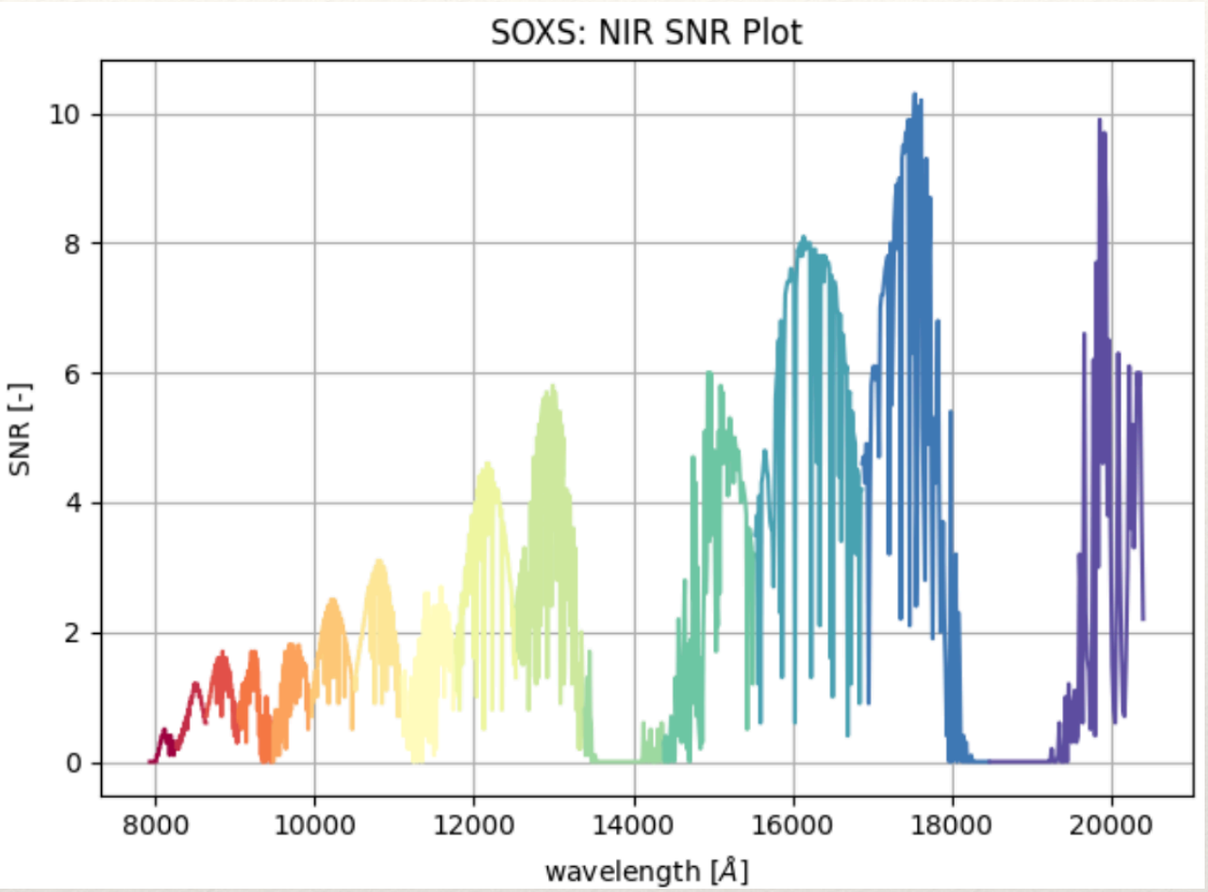
- ☑ SNR
- ☑ Total Efficiency
- ☑ Source Spectrum
- ☑ Sky Radiance
- ☑ Atmospheric Transmission
- ☑ Object Counts
- ☑ Sky Counts
- ☑ Squared Noises
- ☑ Maximum Intensity
- ☐ Exposure times for S/N

CALCULATE Spectroscopy

ETC - Output

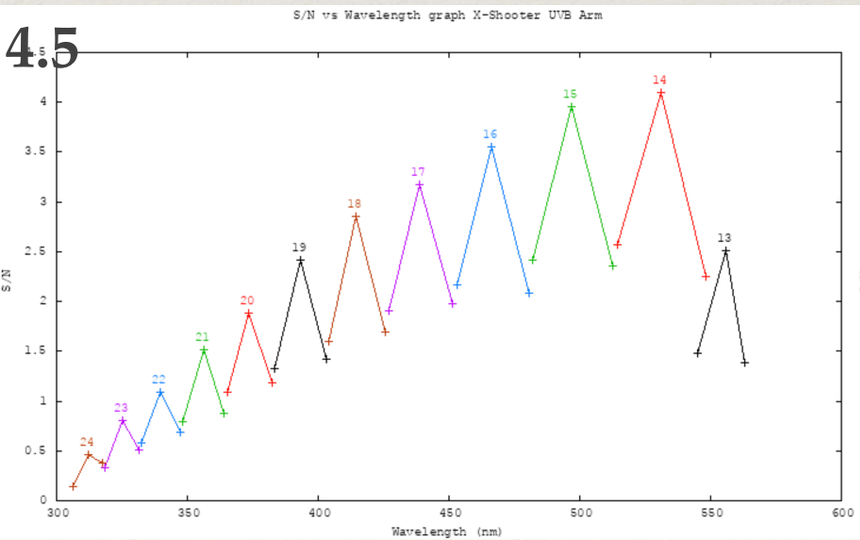
[power-law index = 0, R = 21 (AB), seeing = 1″, Moon = 0, airmass = 1.2, slit = 1″, texp = 1800 (UV-VIS), 2x900 (NIR)]



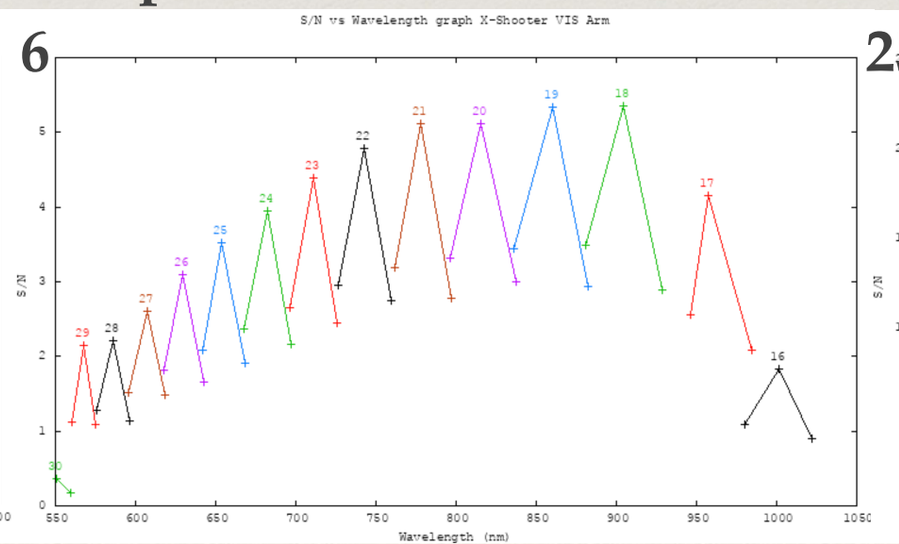


Comparison with Xshooter ETC

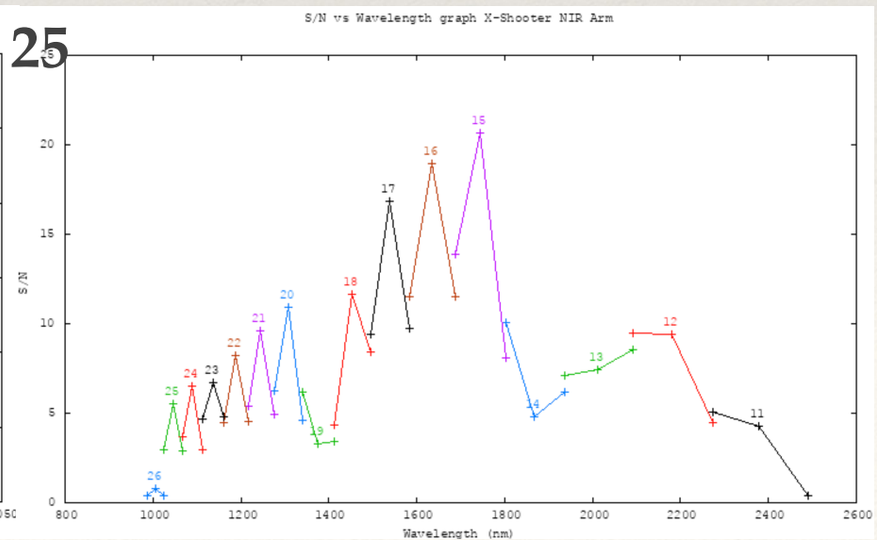
4.5



6



25



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