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

Sergio Campana
INAF - Osservatorio astronomico di Brera

on behalf of the SOXS team

Hack100 meeting - Trieste June 10, 2022

My (personal) tribute to Margherita Hack

IL COLLEGIO
FONDAZIONE GHISLIERI

filosofia (16 maggio 1989);

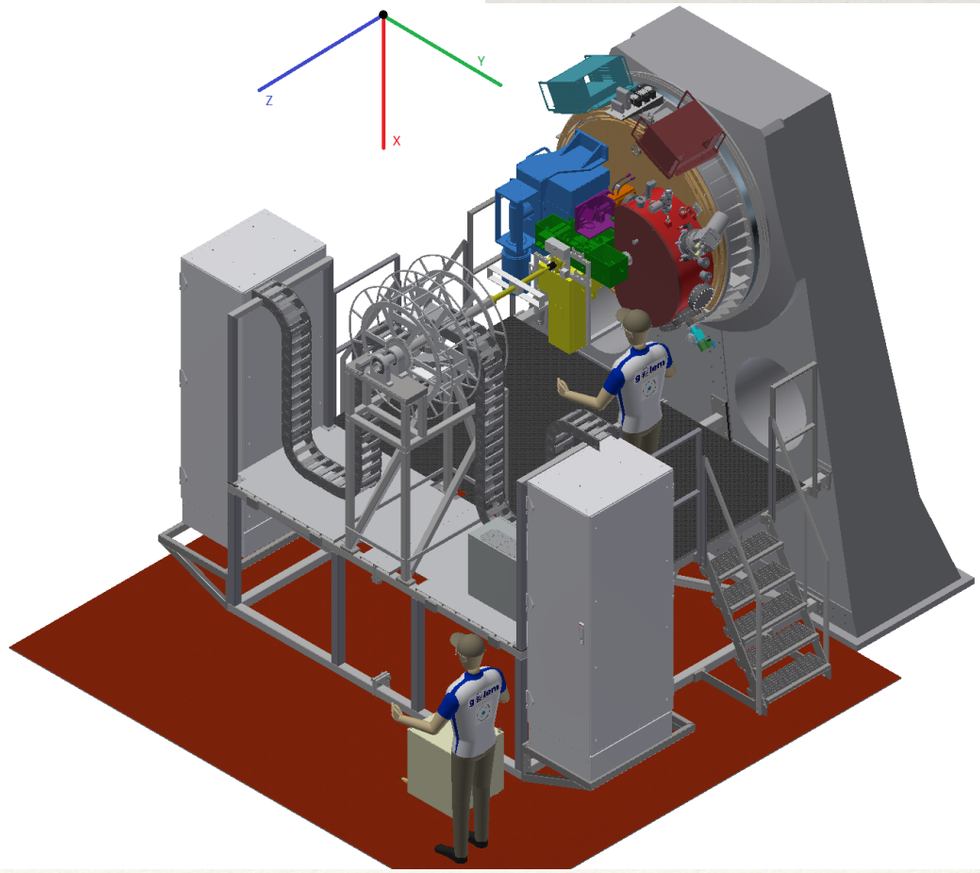
e inoltre:

- prof. Gian Luigi Beccaria (Università di Torino), *Poesia di Saba* (22 novembre 1988);
- prof. Margherita Hack (Università di Trieste), *Il mezzo interstellare e la materia oscura* (13 dicembre 1989);
- proff. Paolo Ca[illegible]

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)



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	12/2022	02/2023	3 months
Commissioning & SV & PAC	03/2023	09/2023	6 months
Operations & GTO	2023	2028	

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 Univ.

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)

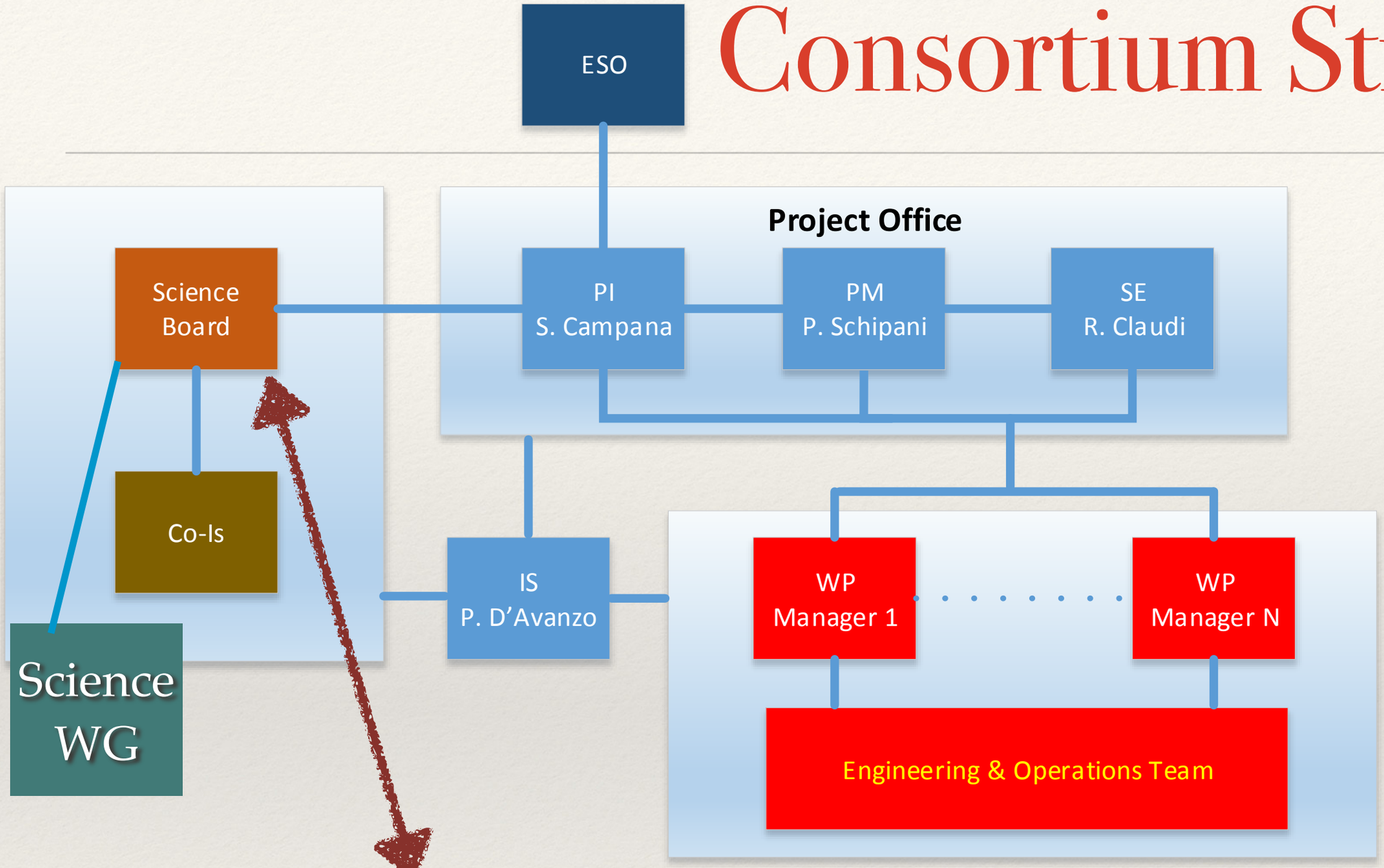
FINCA ~7% (Calibration Unit)

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

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)

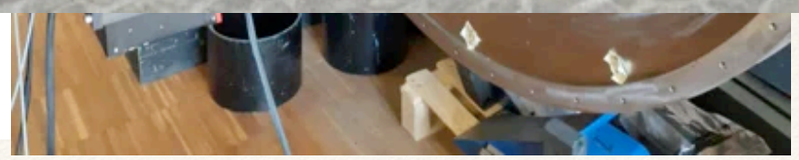
Acquisition Camera WP Manager - Anna Brucalassi (Millenium Institute & INAF)

Calibration Unit Optics WP Manager - Haynino Kuncaraycti (Turku University)

Operations software lead WP Manager - Marco Landoni (INAF - Osservatorio astronomico di Brera)

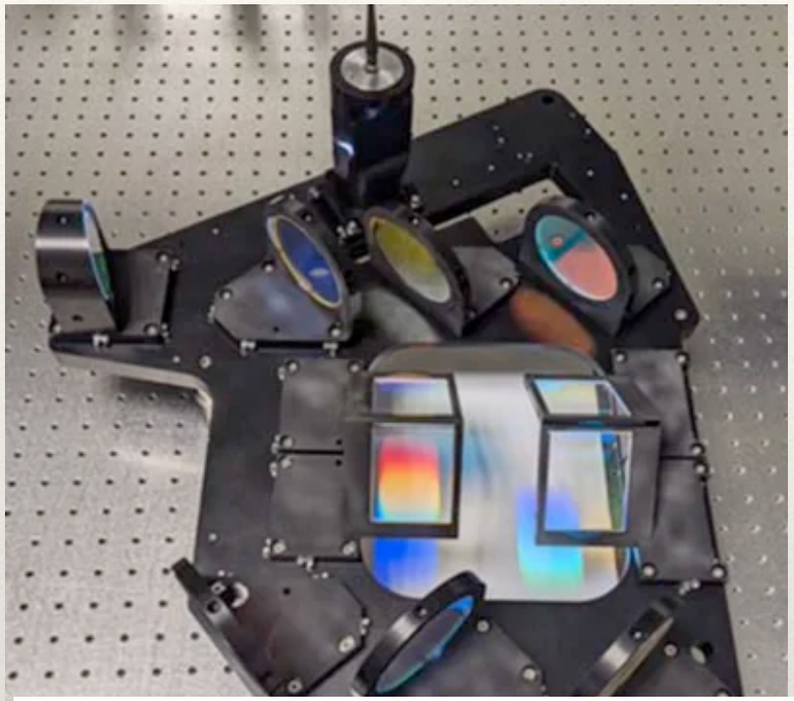
Pipeline WP Manager - David Young (Queens' University Belfast)

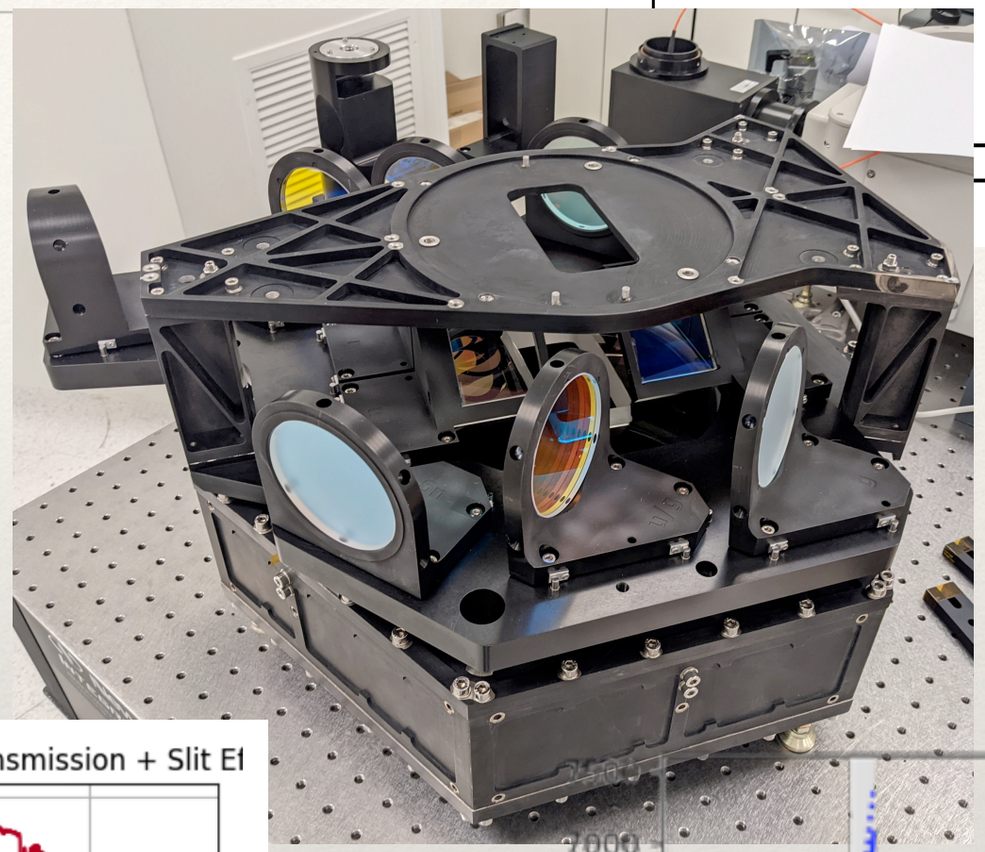
Ar 1s
Ne 1
D2 5
ThAr 60s

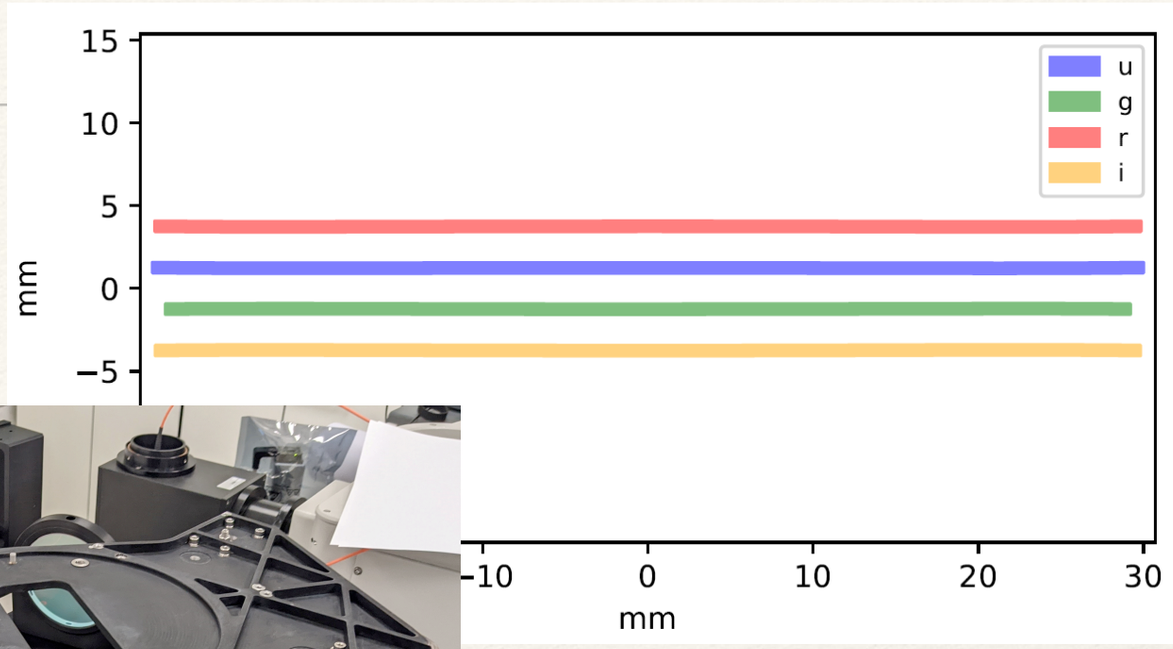


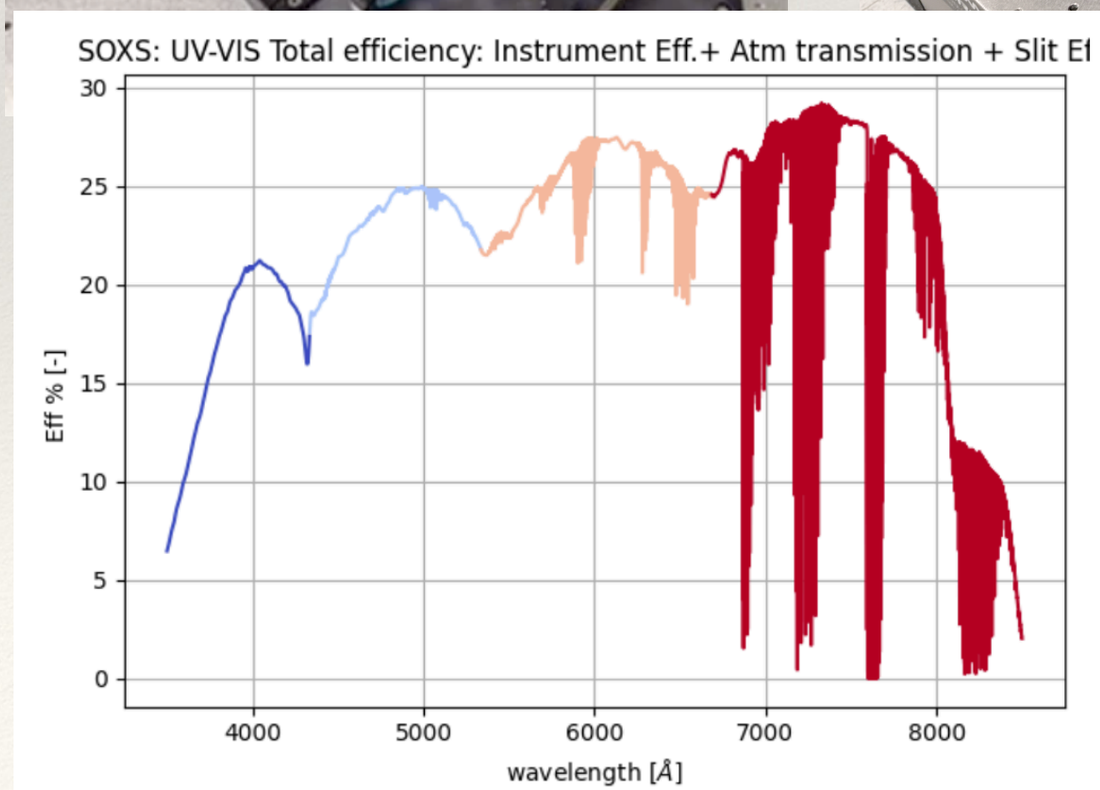
SOXS UV-VIS arm

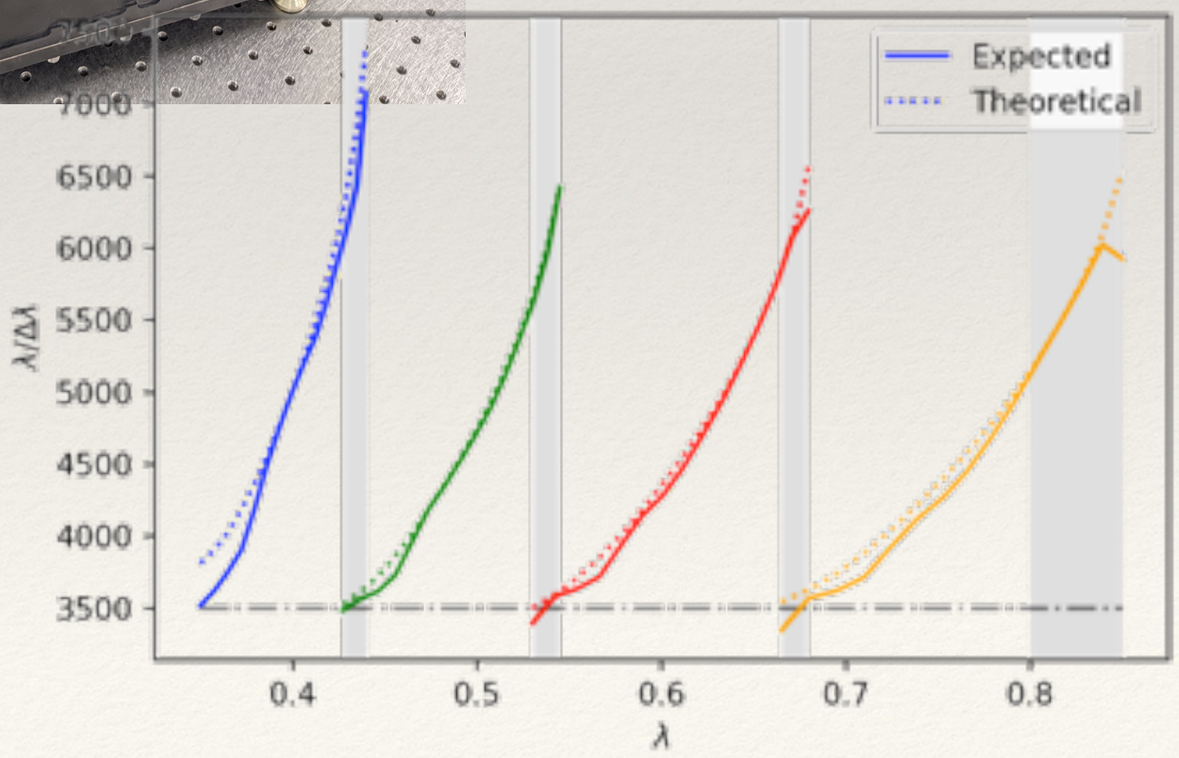
מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE



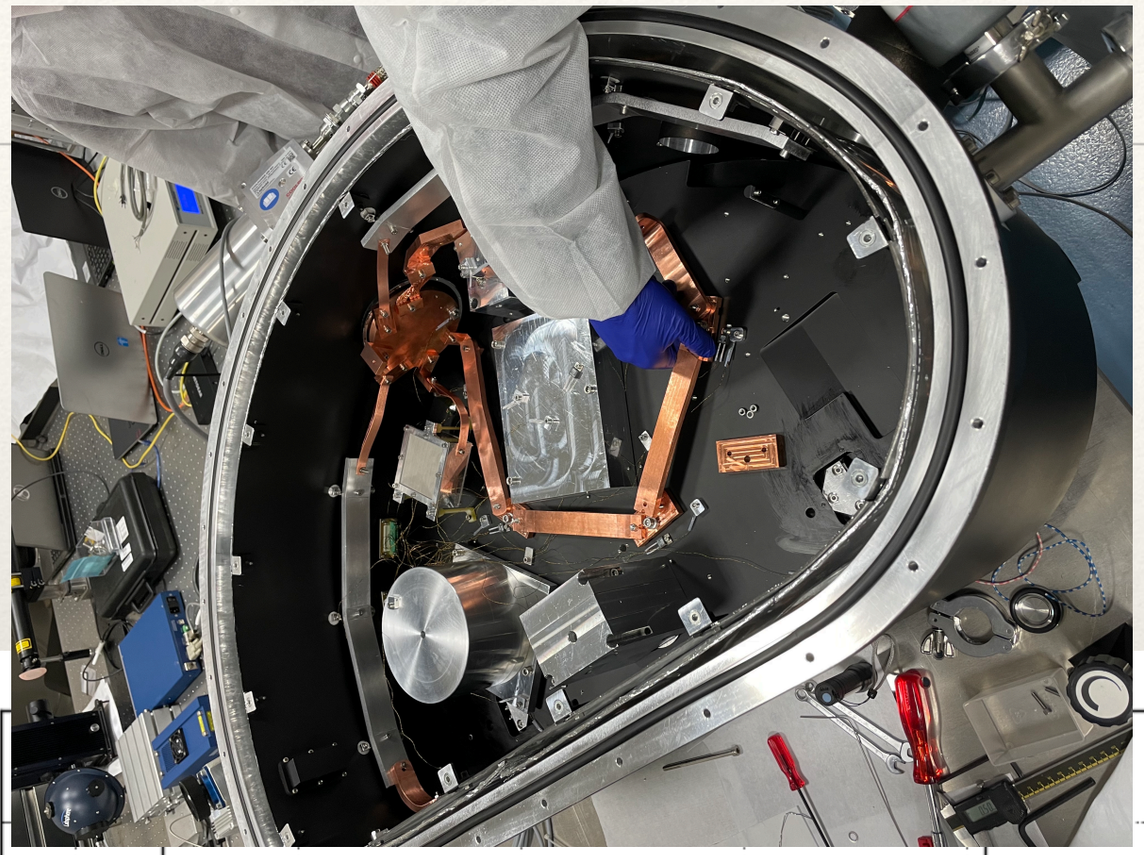


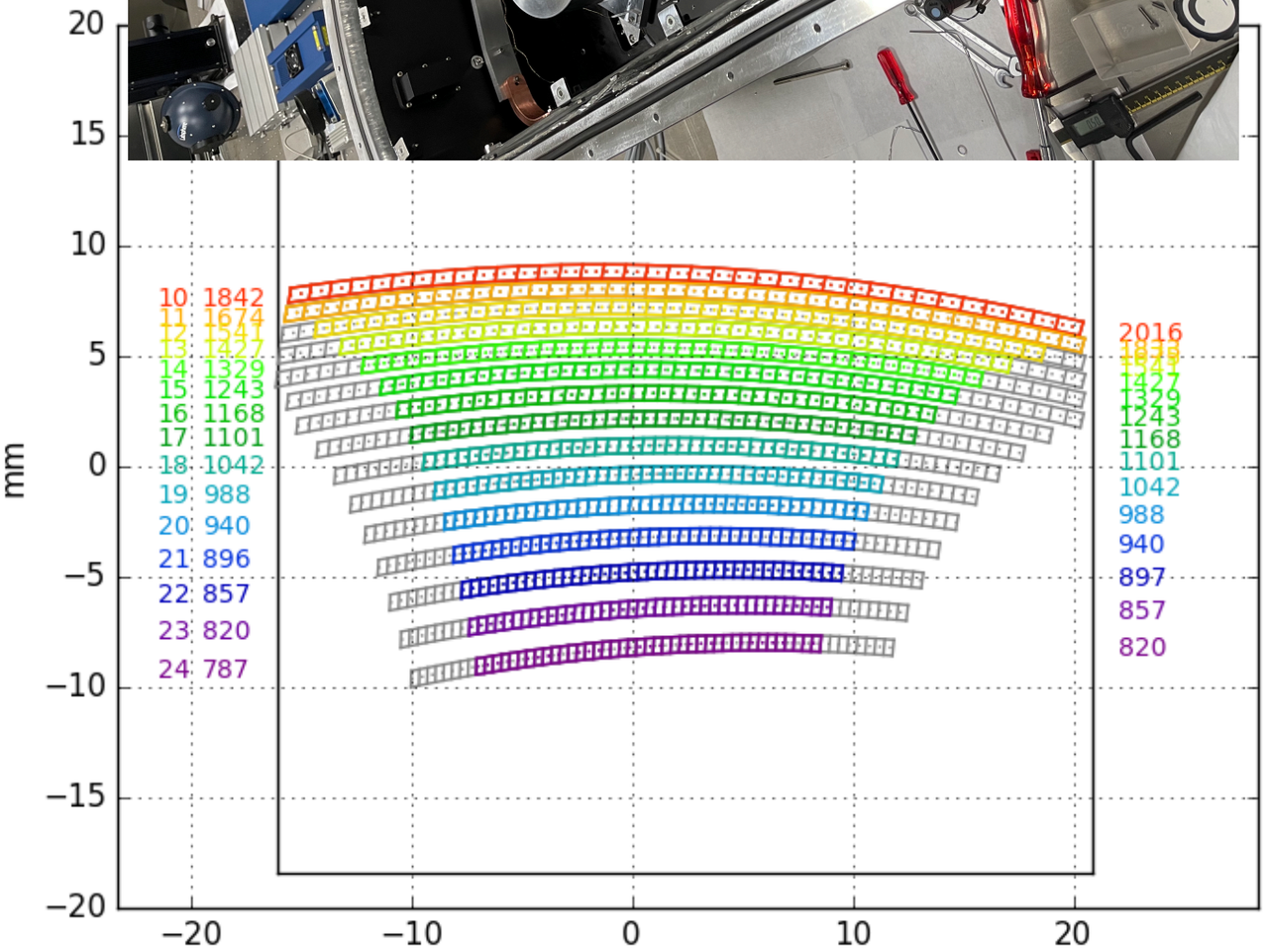






SOXS NIR arm




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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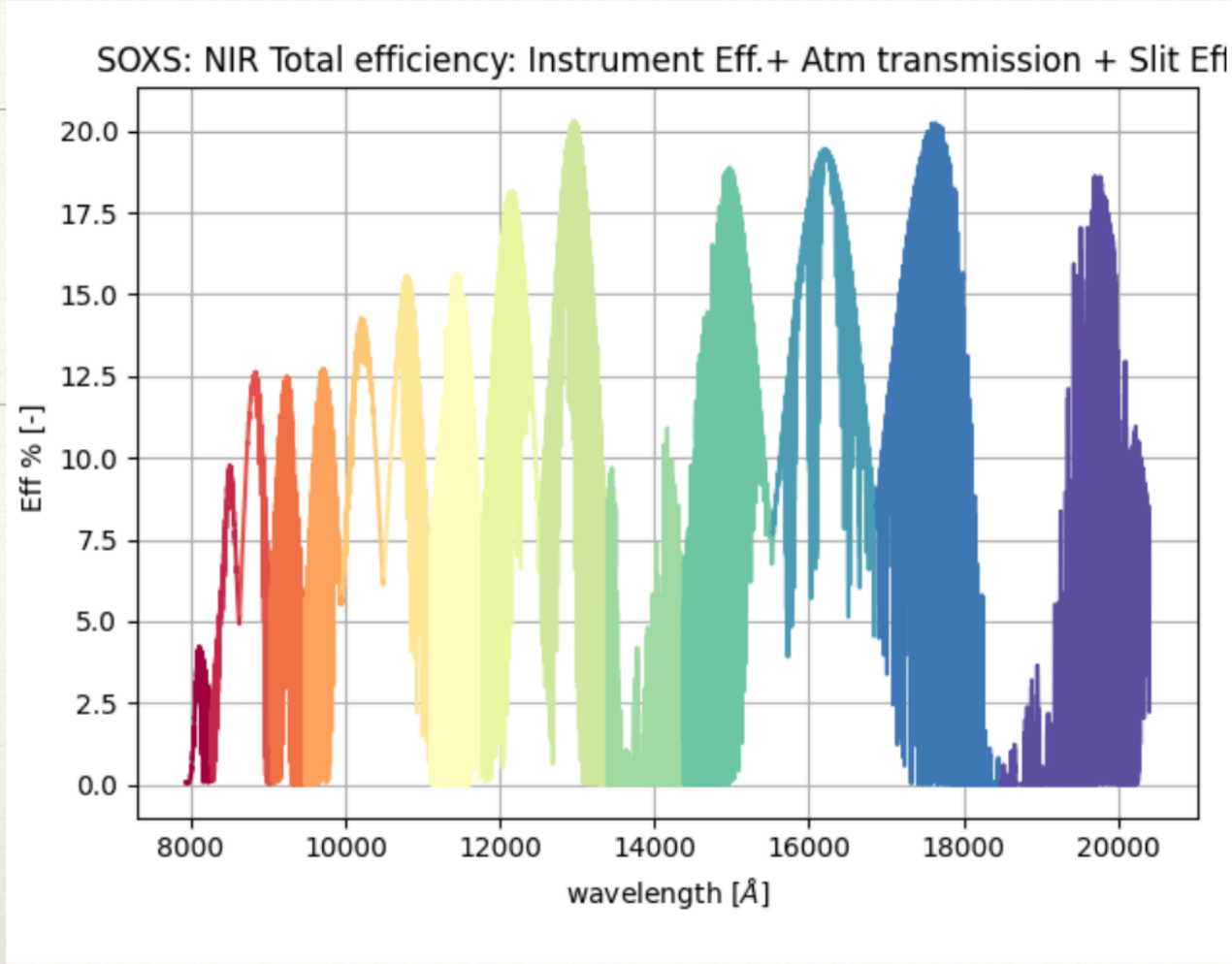
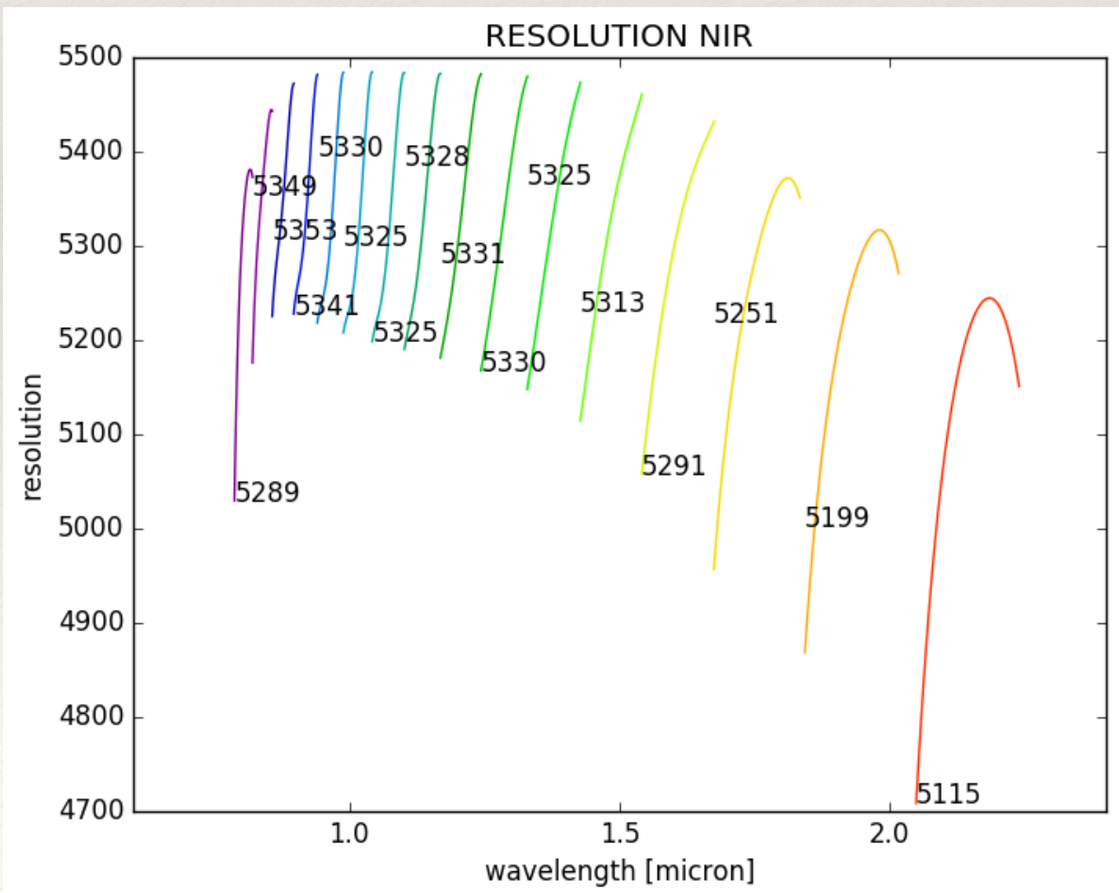
1168
1101
1042
988
940
897
857
820


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


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

Kulkarni's comparison

Instrument efficiencies

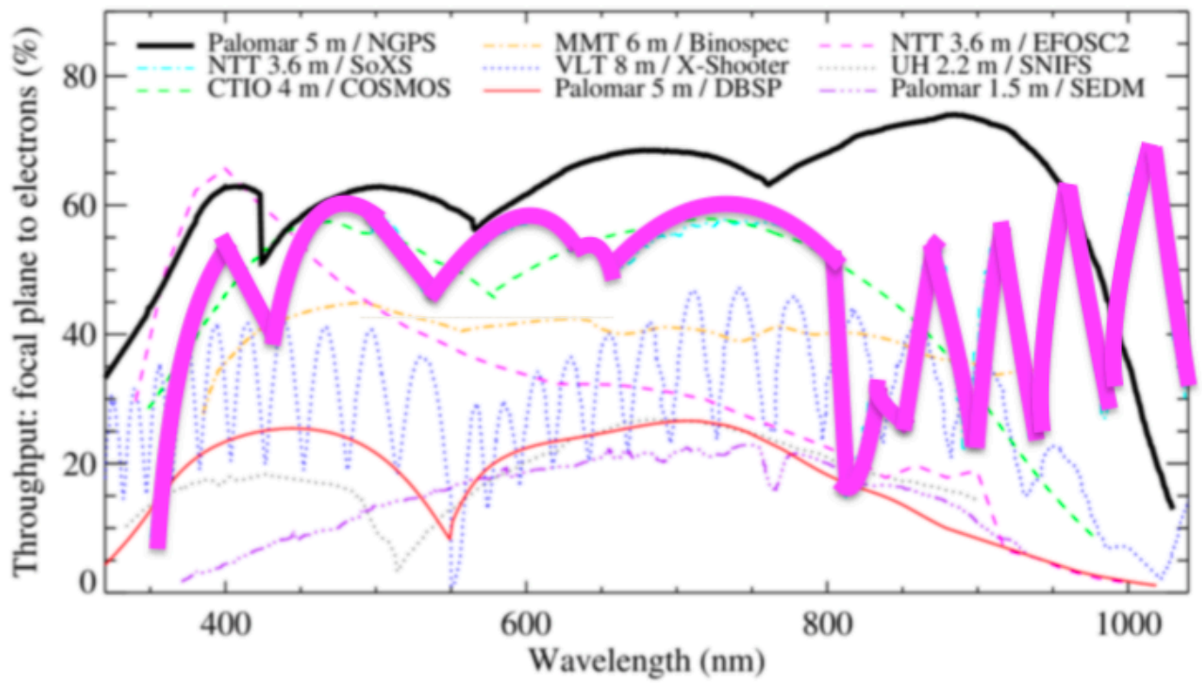
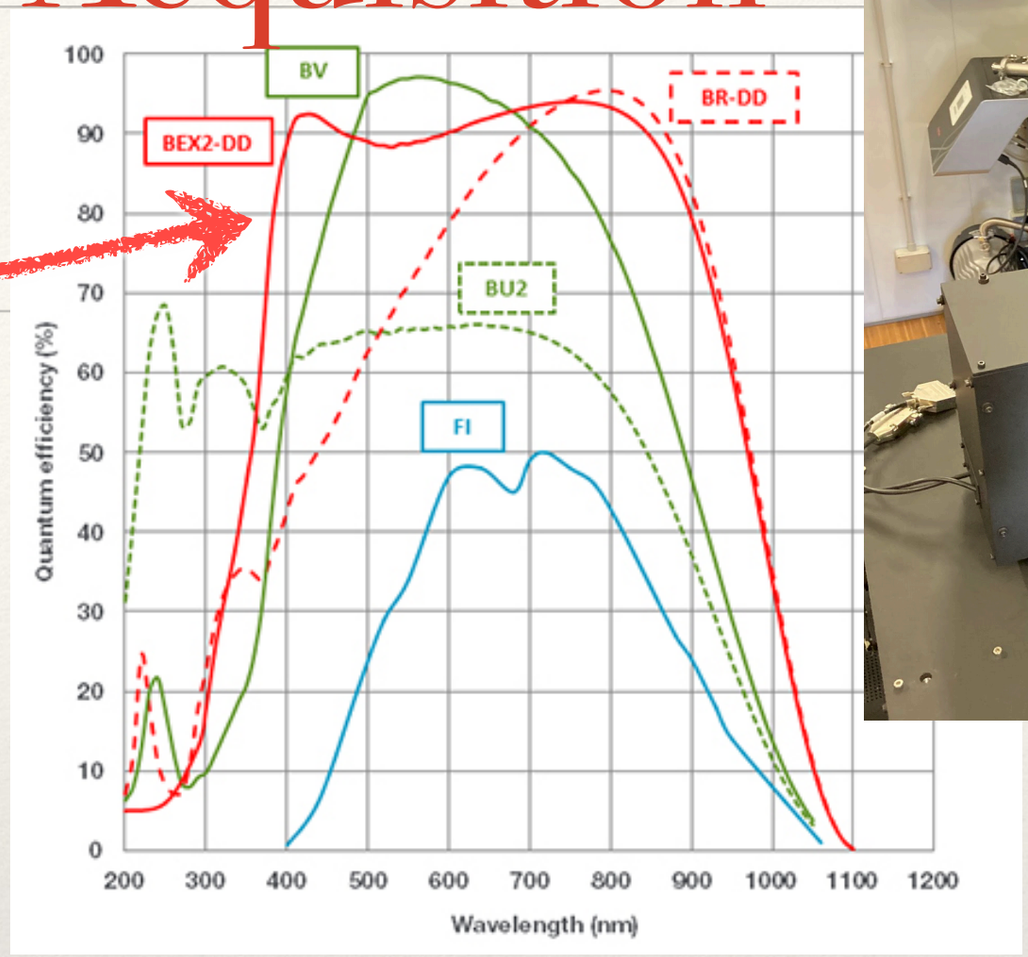


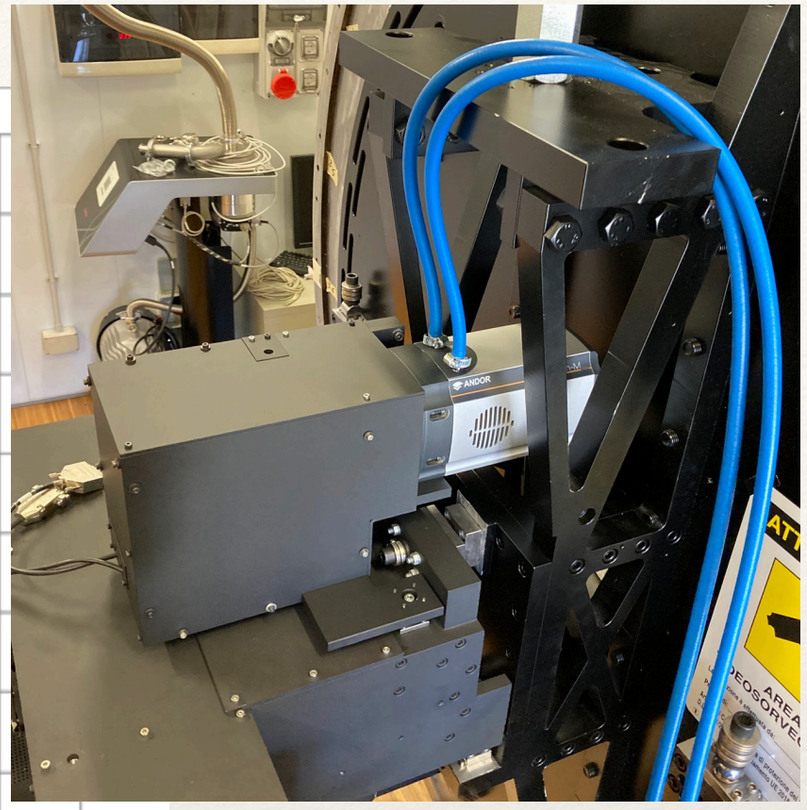
Figure 5. The throughput from the focal plan to photoelectrons of the Next Generation Palomar Spectrograph (NGPS; solid line). The throughput for other spectrographs varies between this measure to "from sky to photoelectrons". References: Son of X-Shooter (SoXS, Claudi et al. 2018, M. Genoni, pers. comm.), 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

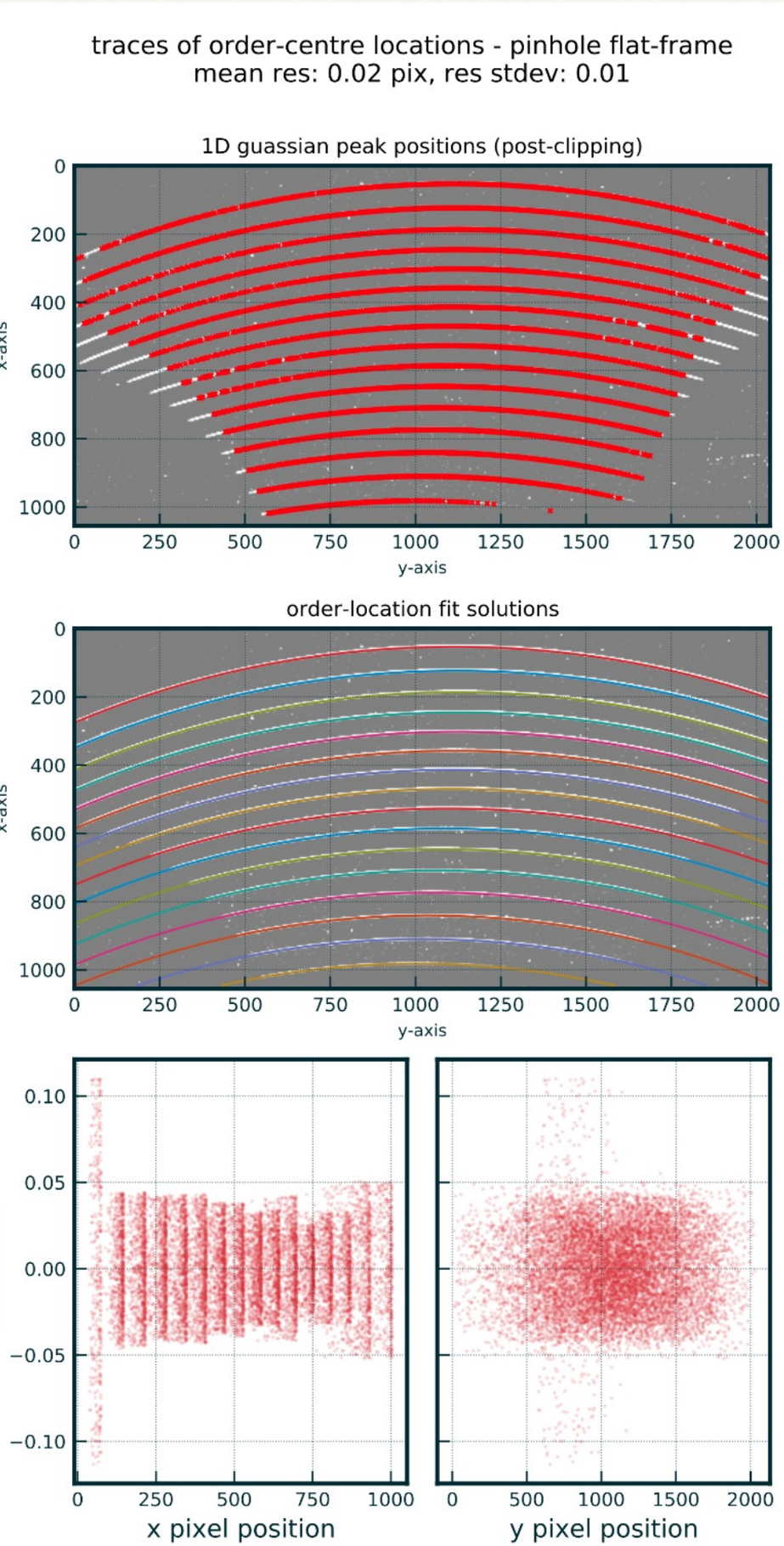




3.5’x3.5’ Field of view

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

Queen's University Belfast

- 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

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).

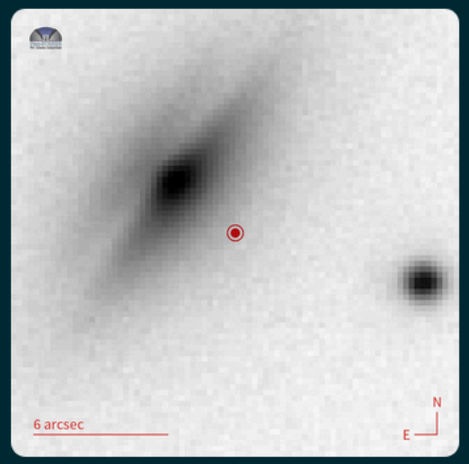
ESO people

- 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)

overview | comments 0 | photometry | context | ticket history

identity

AT2018jli



akas:

Gaia18drt

list: inbox

pessto id: 27204699

object info

ra & dec:

16:12:35.87 +28:12:41.4

[243.14950 28.21152]

galactic coords:

46.53182 45.77650

abs peak mag:

-18.11

pre-disc non-detection:

54 days ago

(2018-10-13)

discovery date:

1 days ago

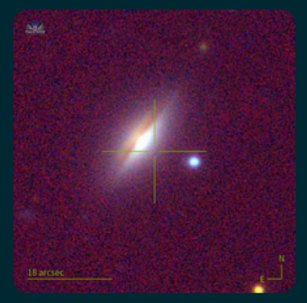
(2018-12-05)

date added to marshall:

(+10hr)

(2018-12-06)

host info



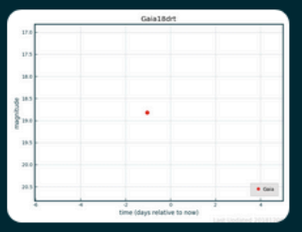
exact sdss location

sdss nearest object

contextual classification:

SN - The transient is possibly associated with *2MASX J16123610+2812434*; a 16.00 mag galaxy found in the NED catalogue. It's located 1.80" S, 2.60" W (3.3 Kpc) from the galaxy centre. A host z=0.052 implies a transient *M* = -18.11.

lightcurve



discovery magnitude:

18.82 G-Gaia-band 2018-12-05 + 1d

latest magnitude:

18.73 Gaia G-band 2018-12-05 + 1d

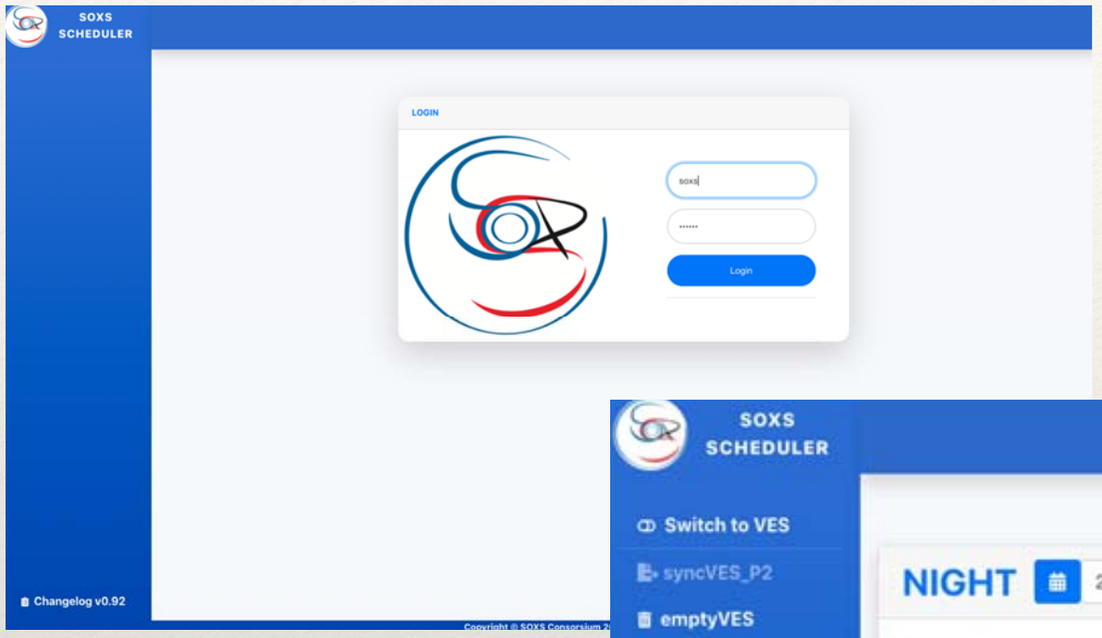
current mag estimate:

18.73

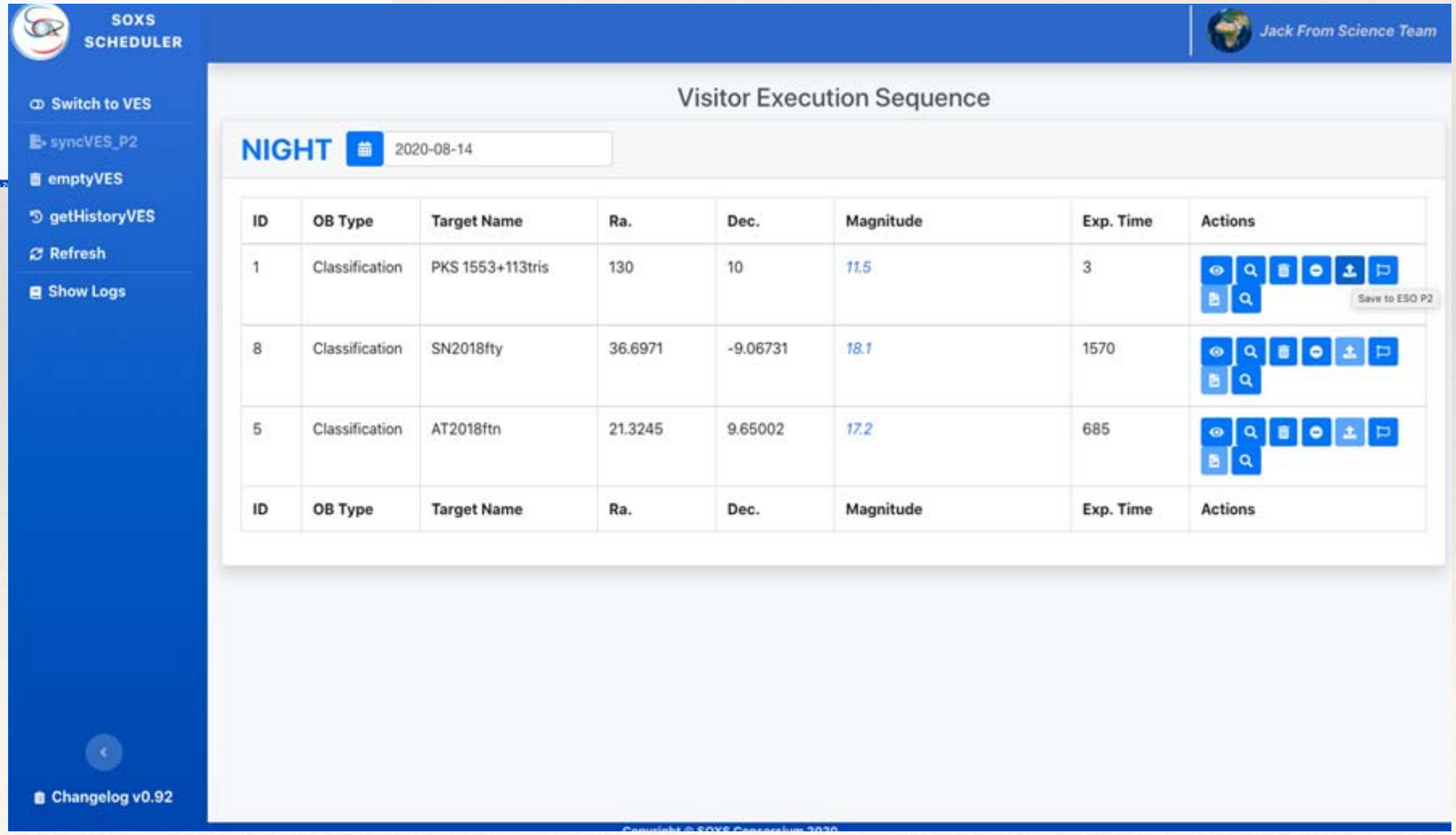
actions

OB

SOXS Scheduler

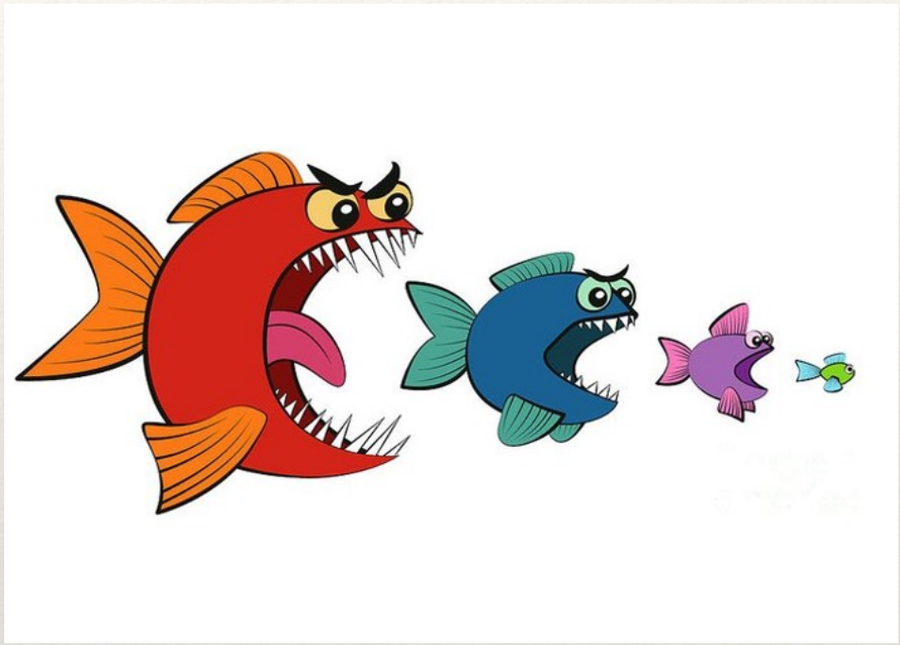


Including Marshall@SOXS



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)

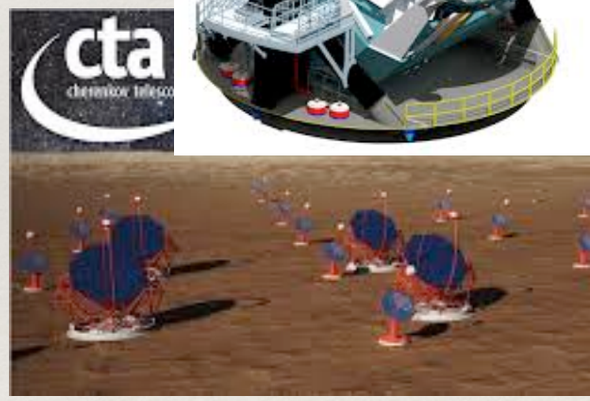


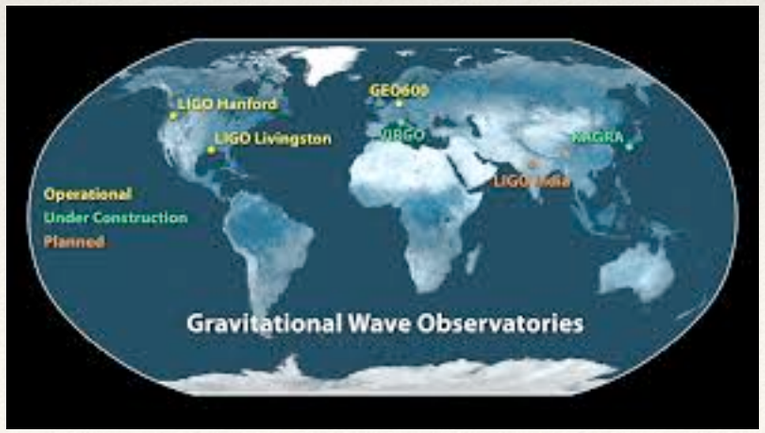
Difficult to identify a single driving science case

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

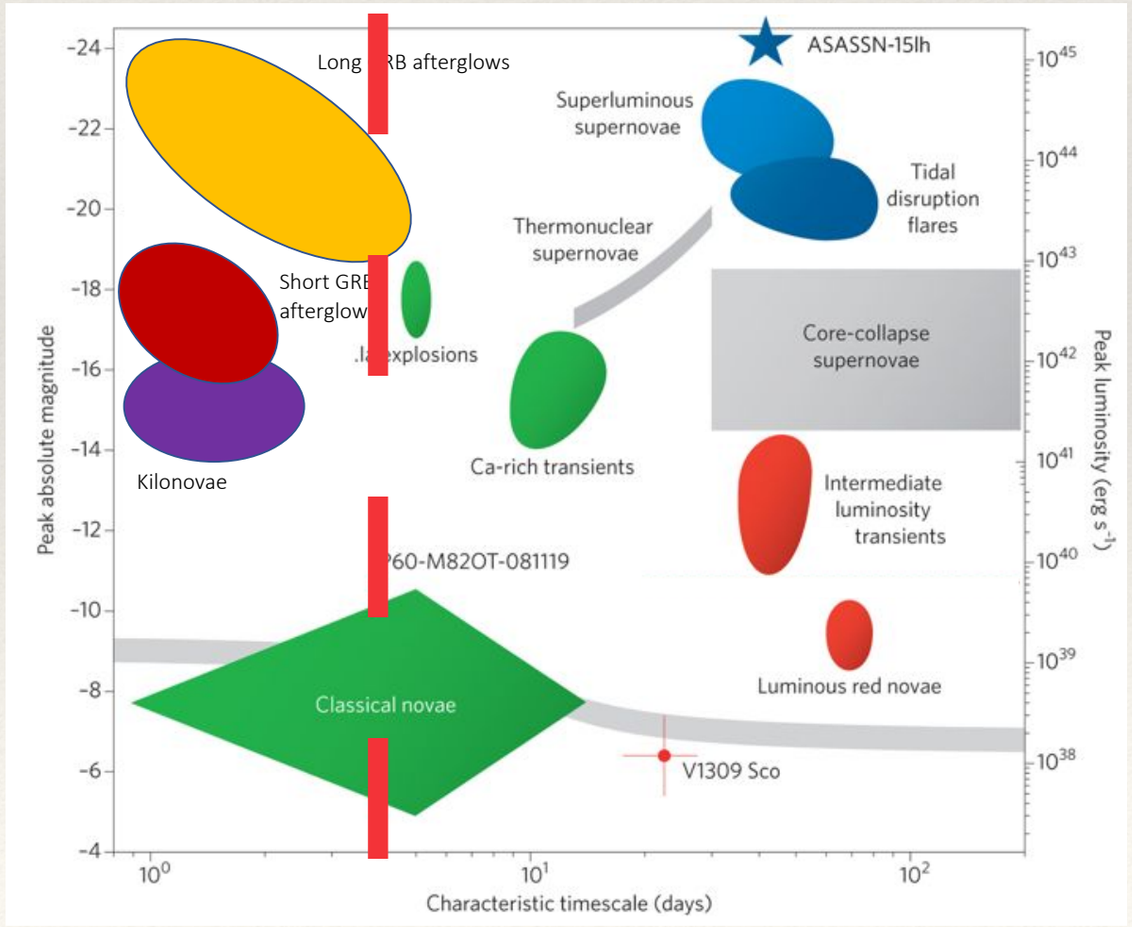
- Classification (service)
- **SN (all flavours)**
- **GW & ν**
- **TDE & Nuclear transients**
- **GRB & FRB**
- Blazars & AGN
- X-ray binaries & magnetars
- Novae & WDs
- Young Stellar Objects & Stars
- Asteroids & Comets
- Unknown

ExtraGalactic

Galactic

Solar System

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



Science Working Groups

WG	WG Topic	WG Leader	WG Deputy	Number of participants
1	Small bodies and comets	Fitzsimmond	Dotto	11
2	Stellar variability, exoplanets and Young Stellar Objects	Pagano	Alcalà	20
3	Transient X-ray binaries, magnetars, ultra-luminous	Casella	Veledina	20
4	Cataclysmic variables, novae and white dwarfs	Della Valle	Ben-Ami	9
5	Supernovae Ia and thermonuclear transients	Stritzinger	Kotak	15
6	Fast and extreme transients (including SLSNe)	Arcavi	Mattila	18
7	Intermediate luminosity transients	Kotak	Pastorello	20
8	Core Collapse Supernovae	Gal-Yam	Pignata	23
9	AGN and blazars	Landoni	—	19
10	Tidal Disruption and Nuclear Events	Mattila	Arcavi	10
11	Gamma Ray bursts & Fast radio bursts	D'Avanzo	Fynbo	10
12	Gravitational wave and neutrino counterparts	Campana	Smartt	29
13	Classification	Benetti	Botticella	**27**

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

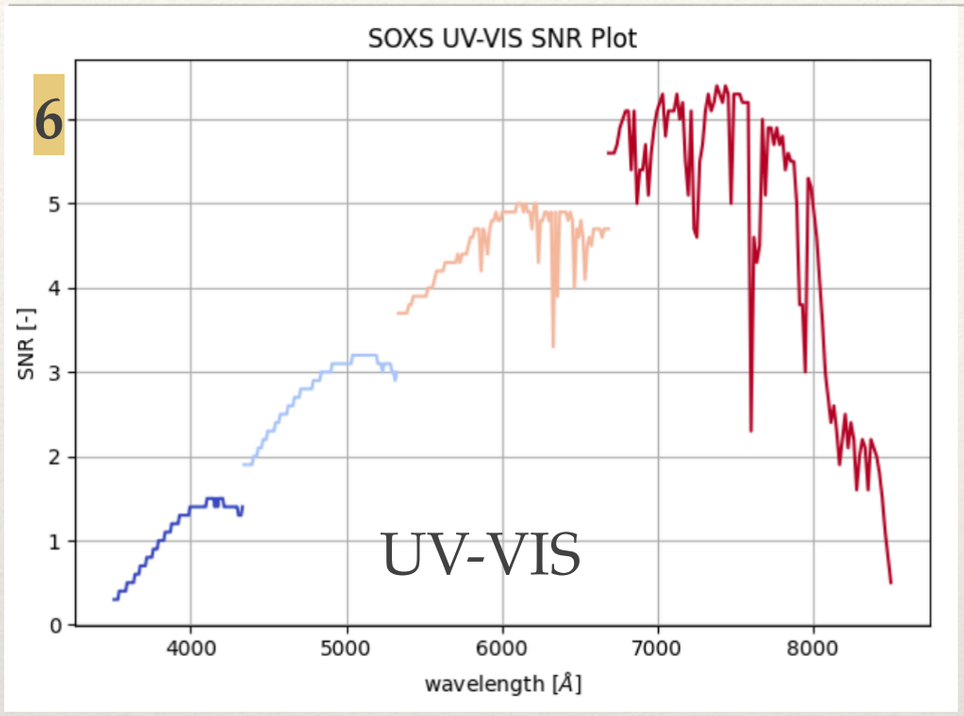
Single exposure 1500s, 0d Moon, 1.2 airmass, 1'' seeing, BB=5600K, mag_AB=24.5

	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

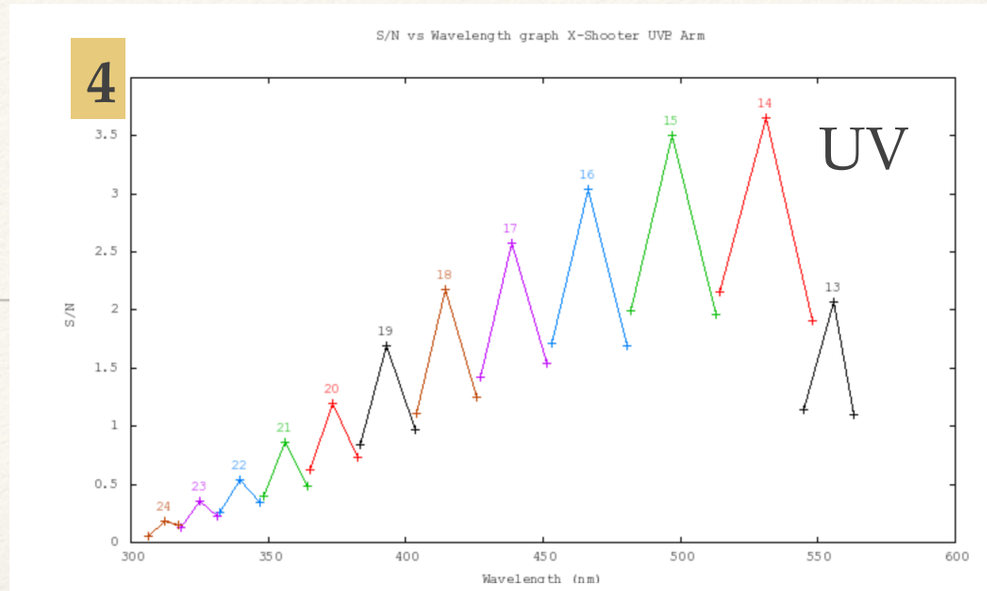
SNR

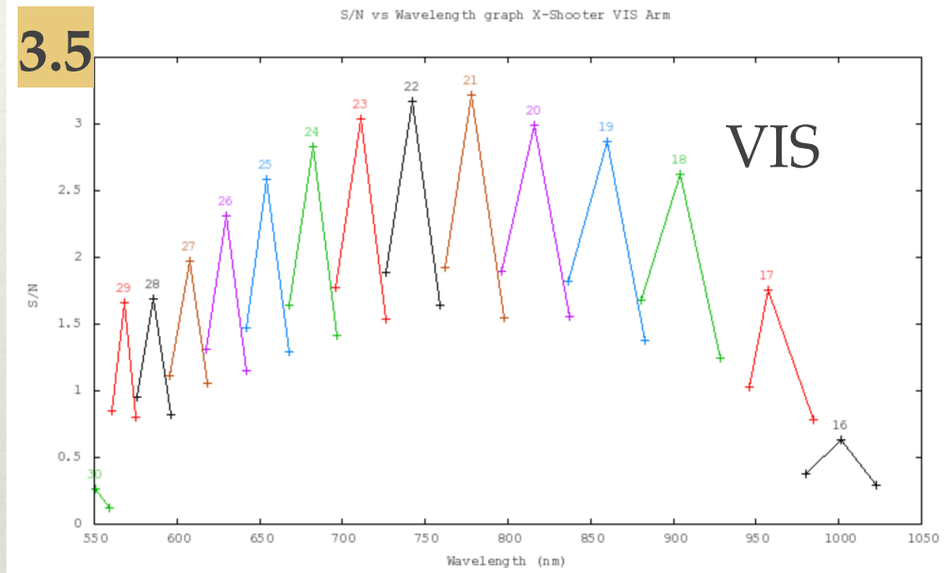
Four 900s exposures, 0d Moon, 1.2 airmass, 1” seeing, PWV=30 BB=5600K, Rmag_AB=21.5

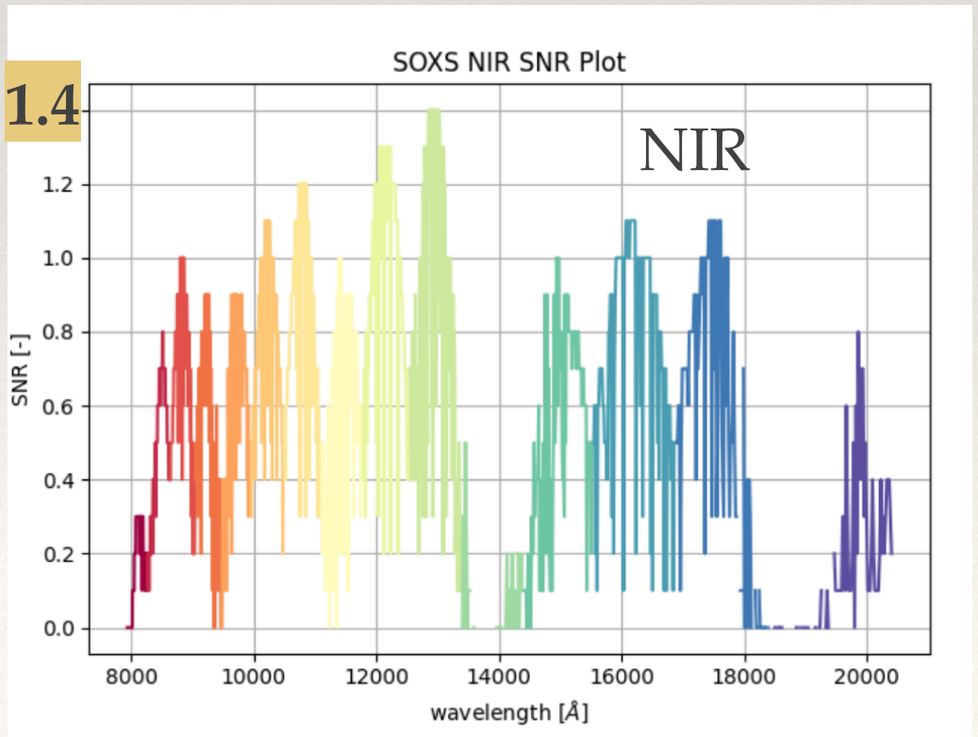
SOXS vs. X-shooter

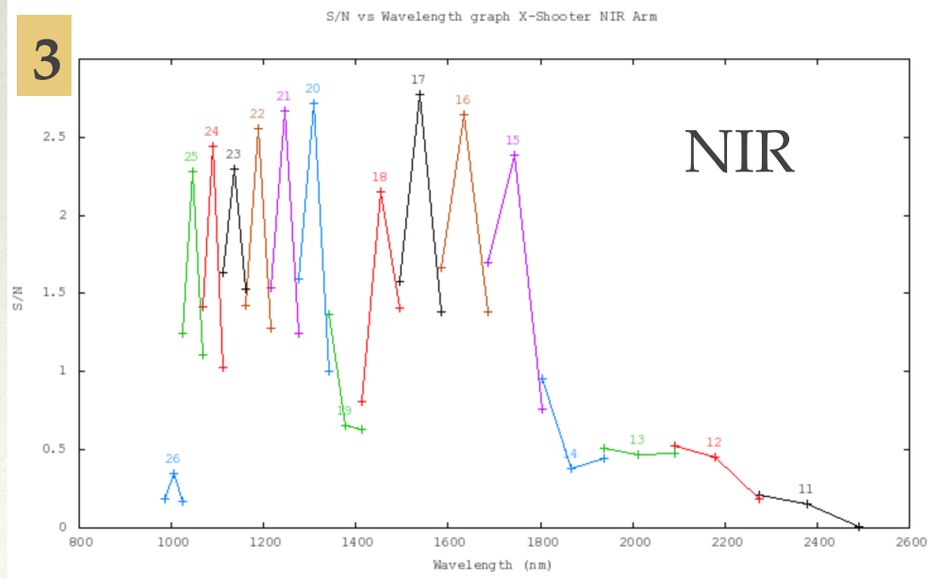


SNR per resolution element

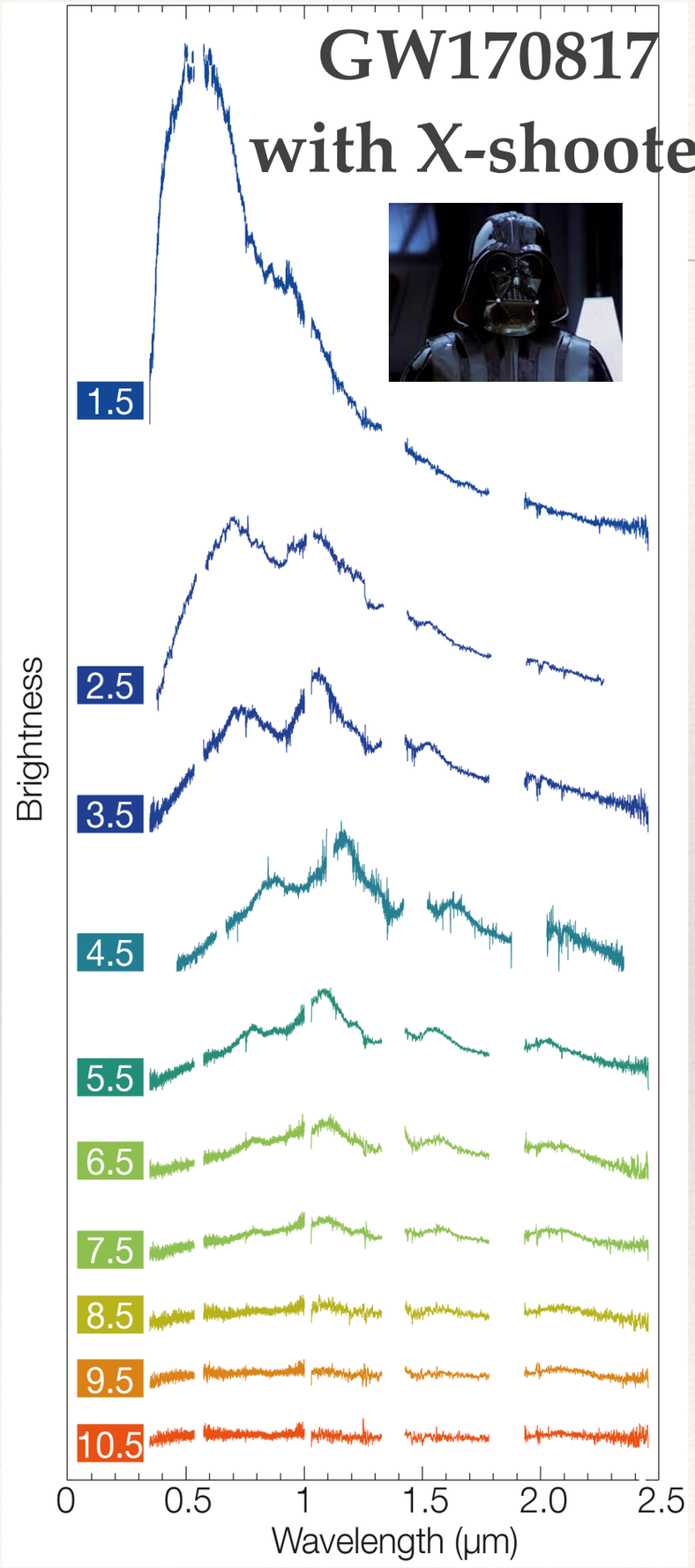


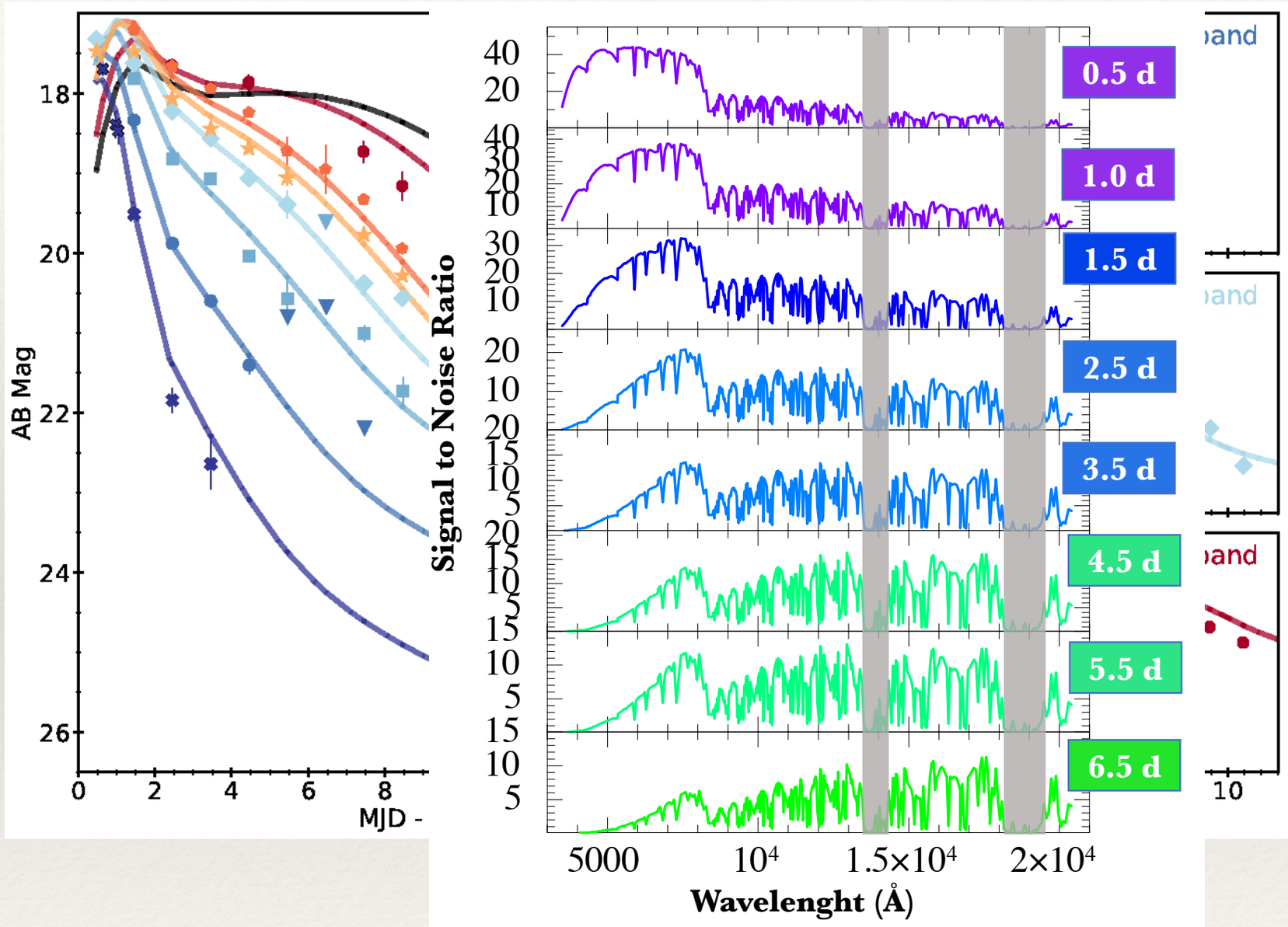






What can SOXS do?





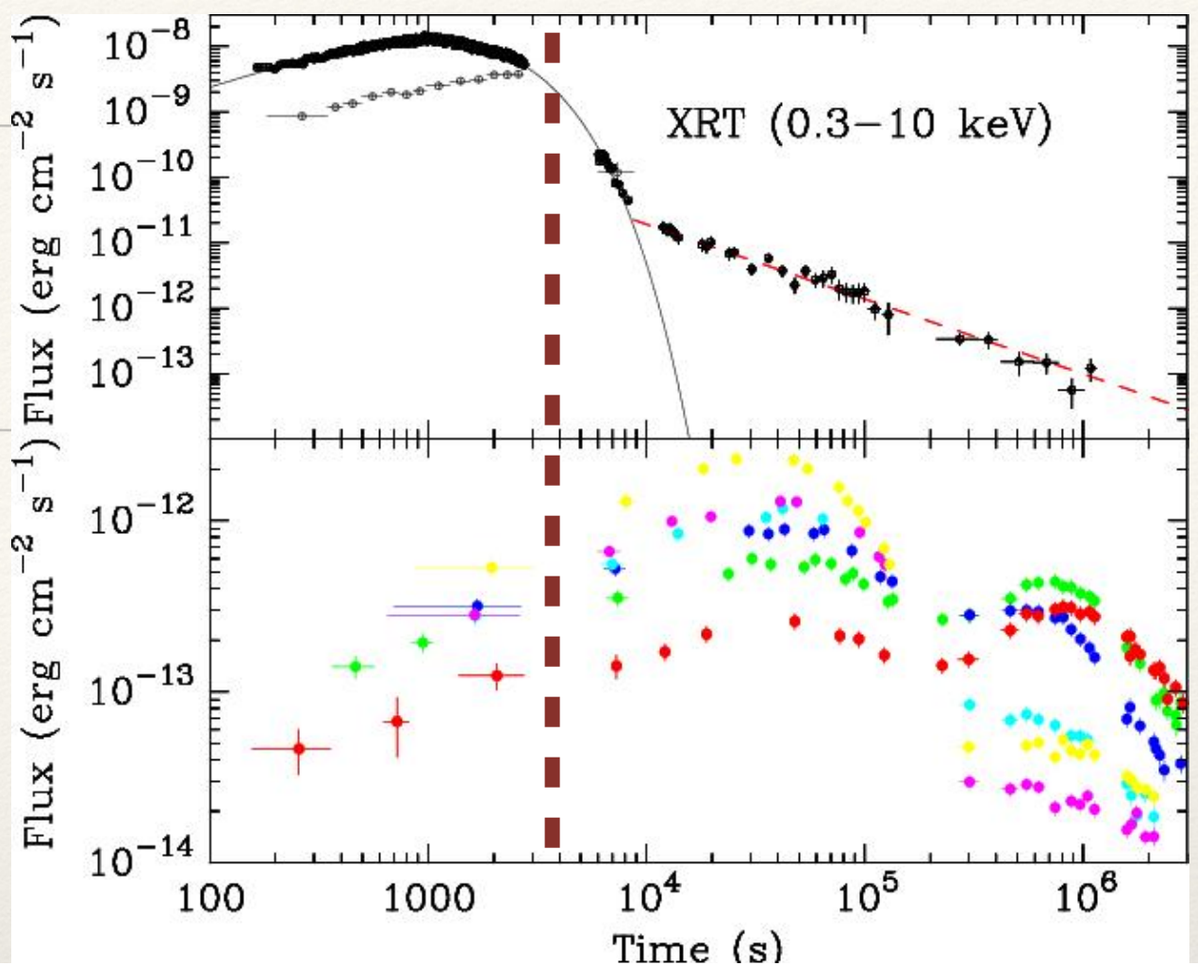
SOXS ETC

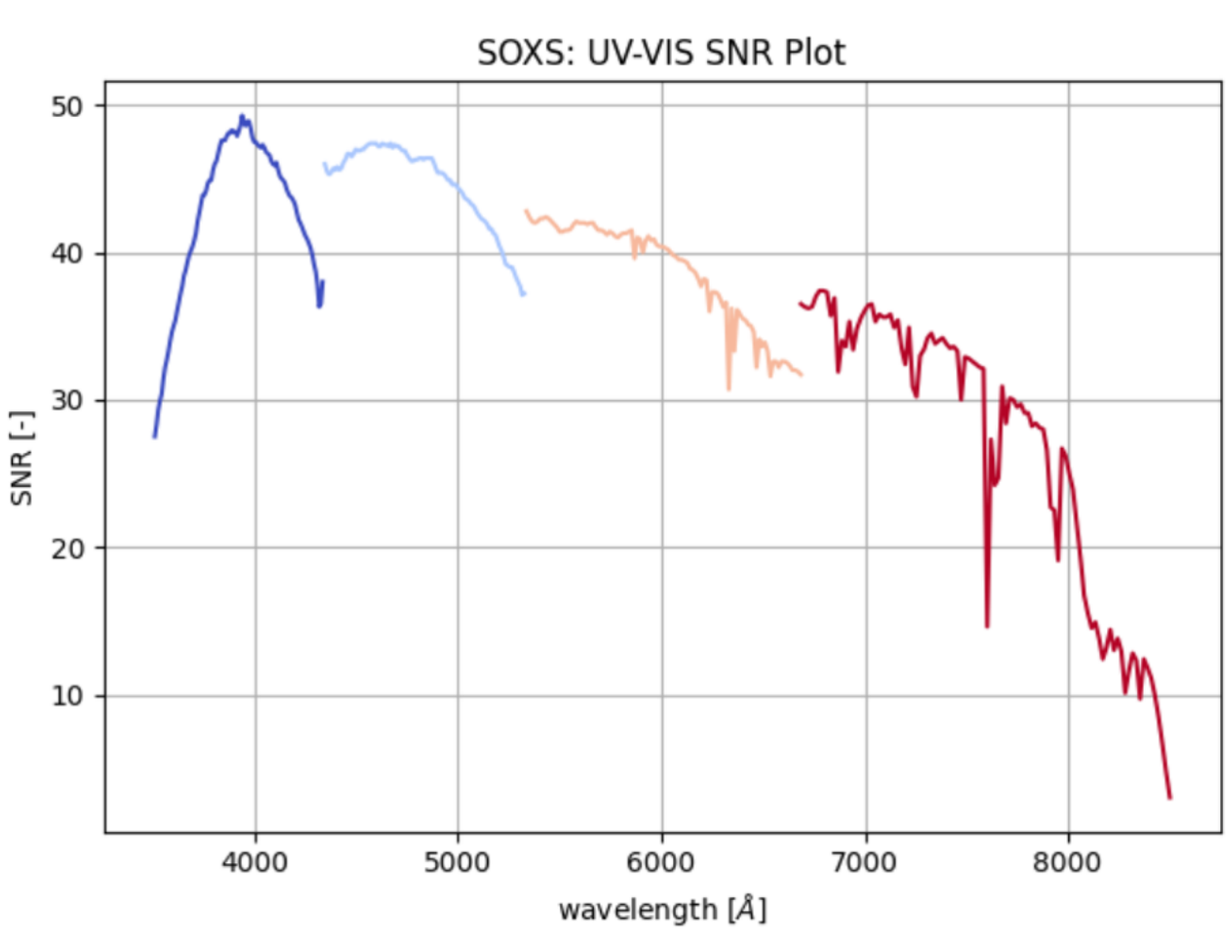
http://192.167.38.34/

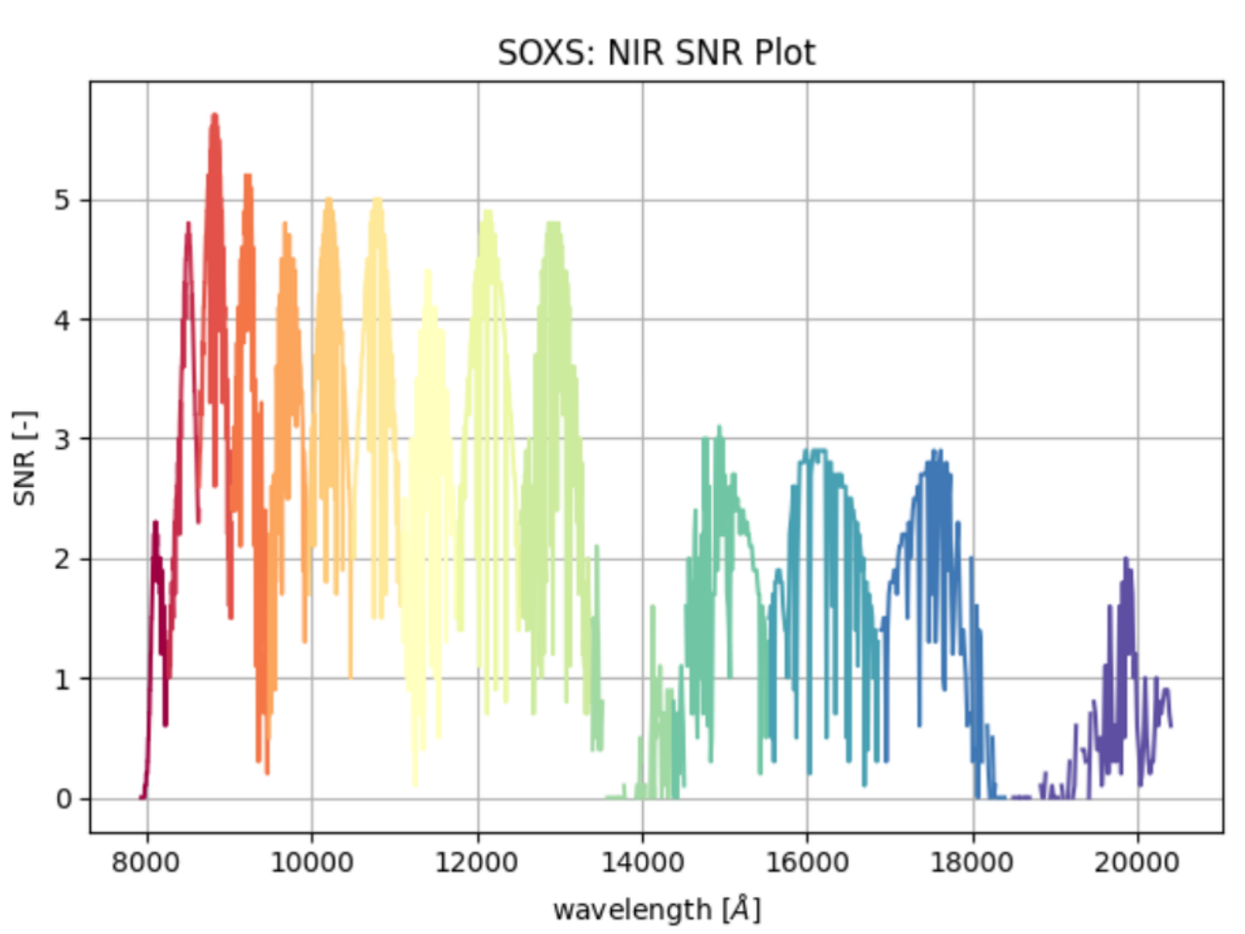
Shock break out

GRB 060218

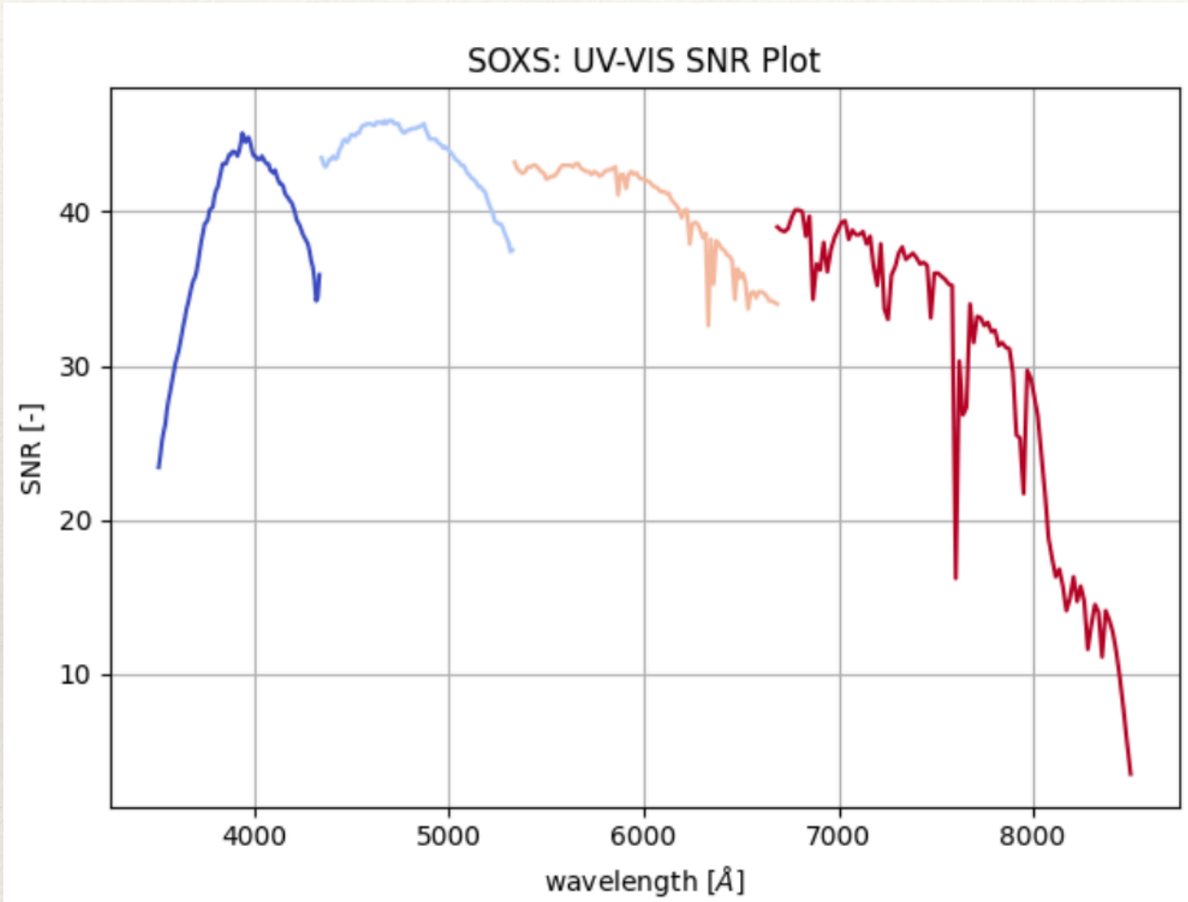
30min exposure – Half Moon 1.2″ seeing
V_{Vega}~18 Hot BB 37,000K

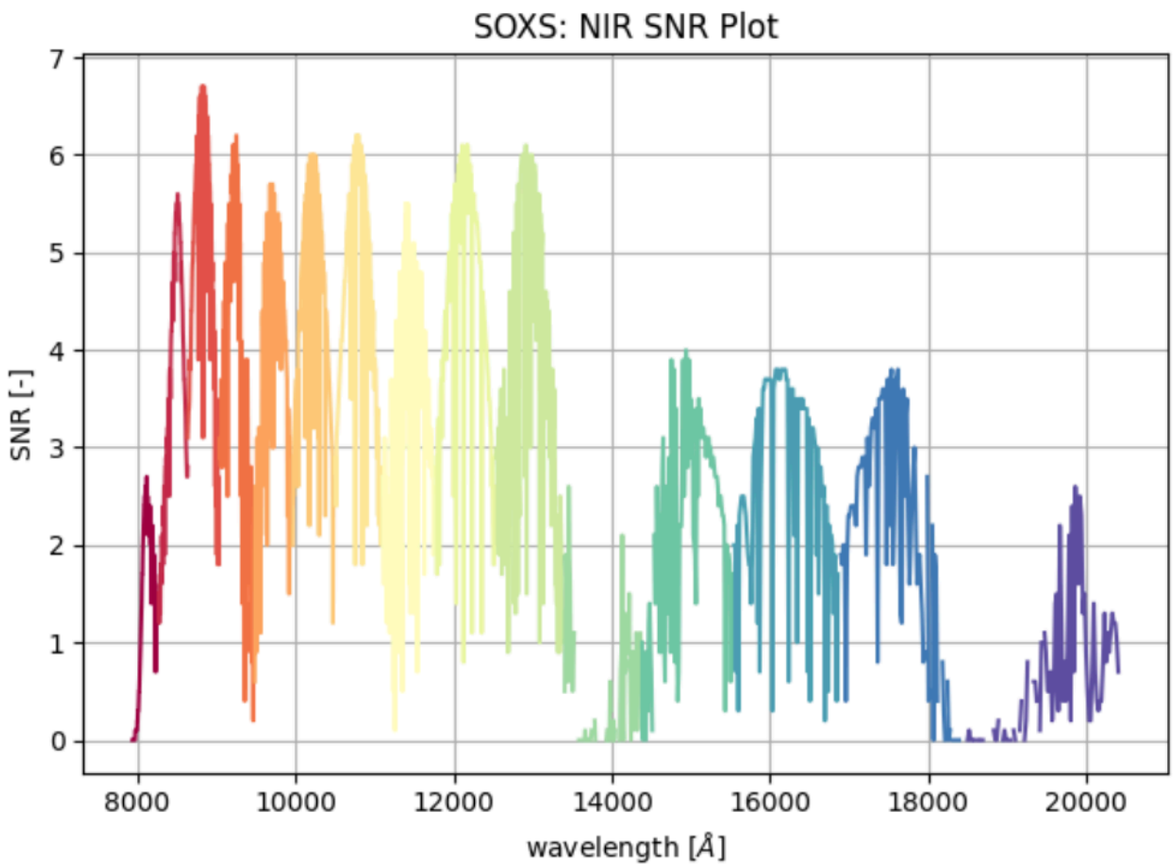






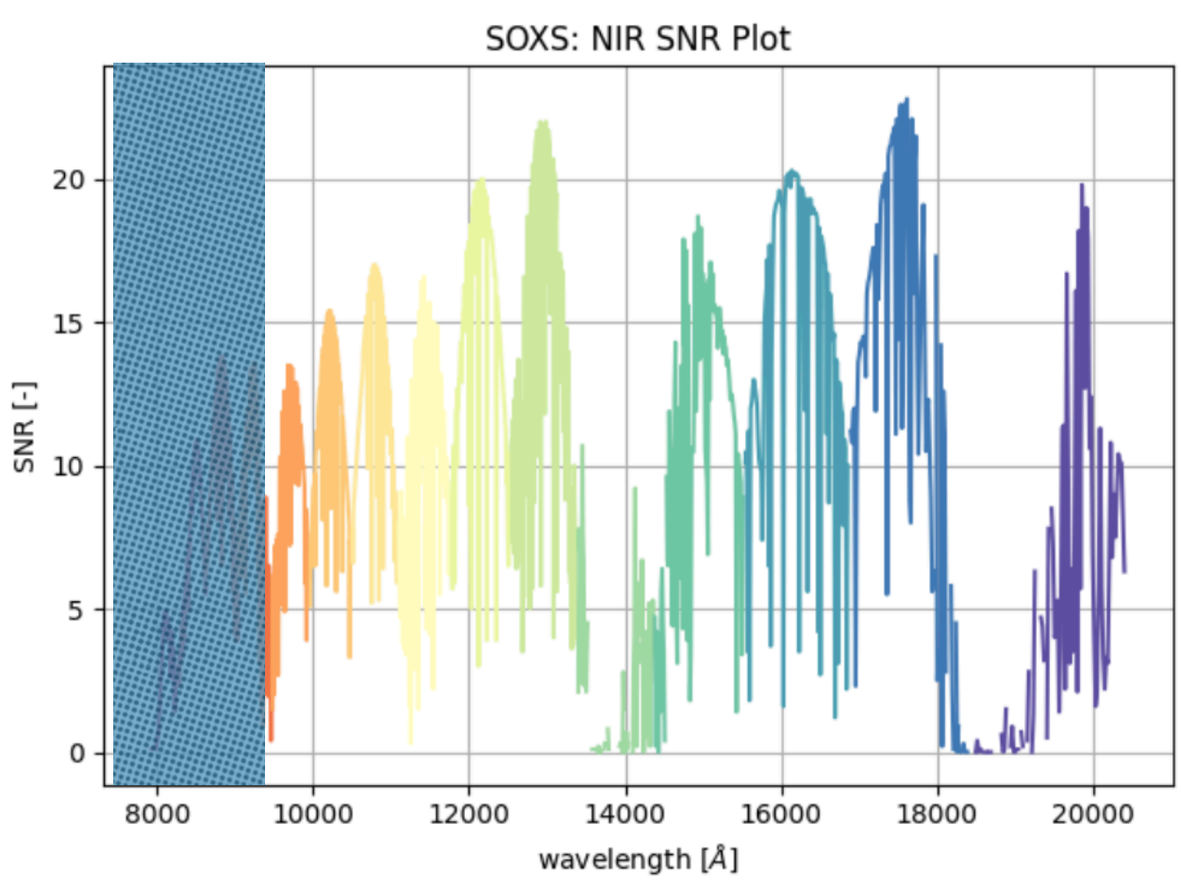
SN Shock ionisation features



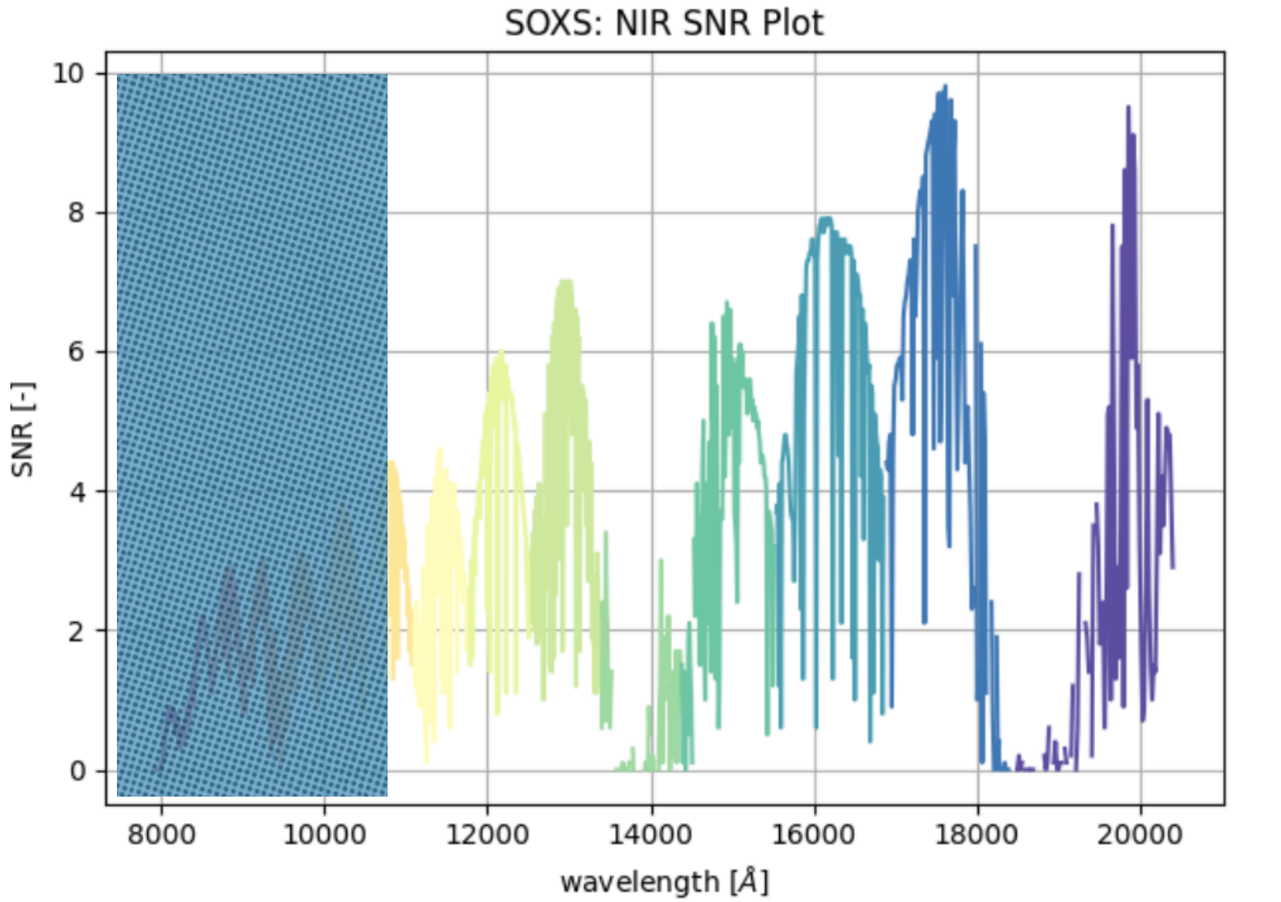


30min exposure - R~18 Hot BB 20,000K

High-redshift GRBs



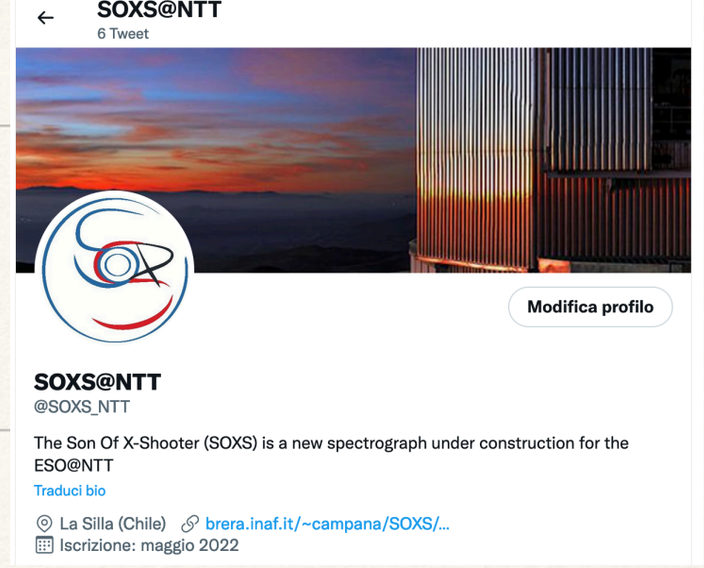
GRB 050904 z=6.3 - 1hr after GRB J(Vega)=18
0.5hr exposure - 7dMoon - airmass 1.2
(monster GRB detected with 25cm telescope)



GRB 090423 z=8.1 - 1hr after GRB K(AB)=19
1hr exposure - 7dMoon - airmass 1.2
(detected with TNG 2hr obs AMICI spectrum)

Take home

News on Twitter



- *SOXS: single-object, broad-band spectrograph (350-2000nm) with imaging capabilities at ESO/NTT*
- *First light in spring 2023, start of GTO October 2023*
- *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*