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

Sergio Campana
INAF - Osservatorio astronomico di Brera

on behalf of the SOXS team

November 9, 2021

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

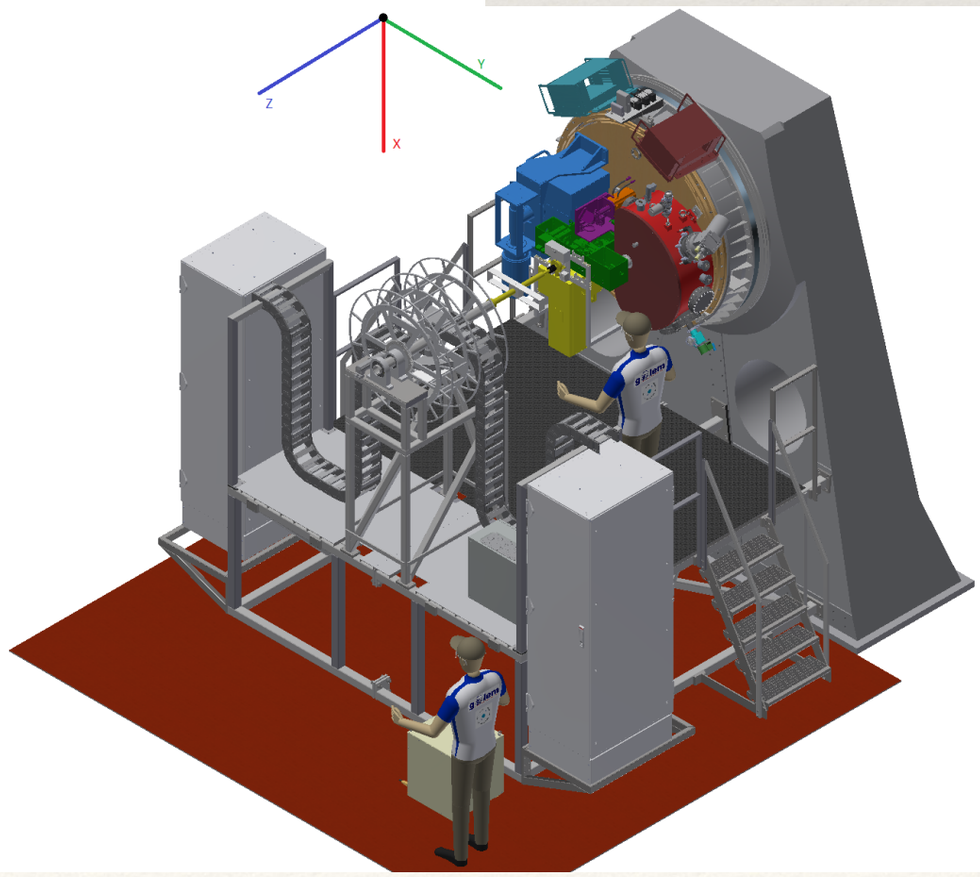
Signed MoU INAF-Partners

Project Phase	Start	End	Duration
Preliminary Design	08/2016	07/2017	12 months
Final Design	08/2017	10/2018	14 months
MAIT	11/2018	05/2022	42 months+COVID
PAE	06/2022	09/2022	3 months
Commissioning & SV & PAC	10/2022	04/2023	6 months
Operations & GTO	2023	2028	

SoXS in a nutshell

Main characteristics

- 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)
- S/N~10 spectrum - 1 hr exposure for R_{AB}~20.5



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% (VIS-CCD, reduction pipeline)

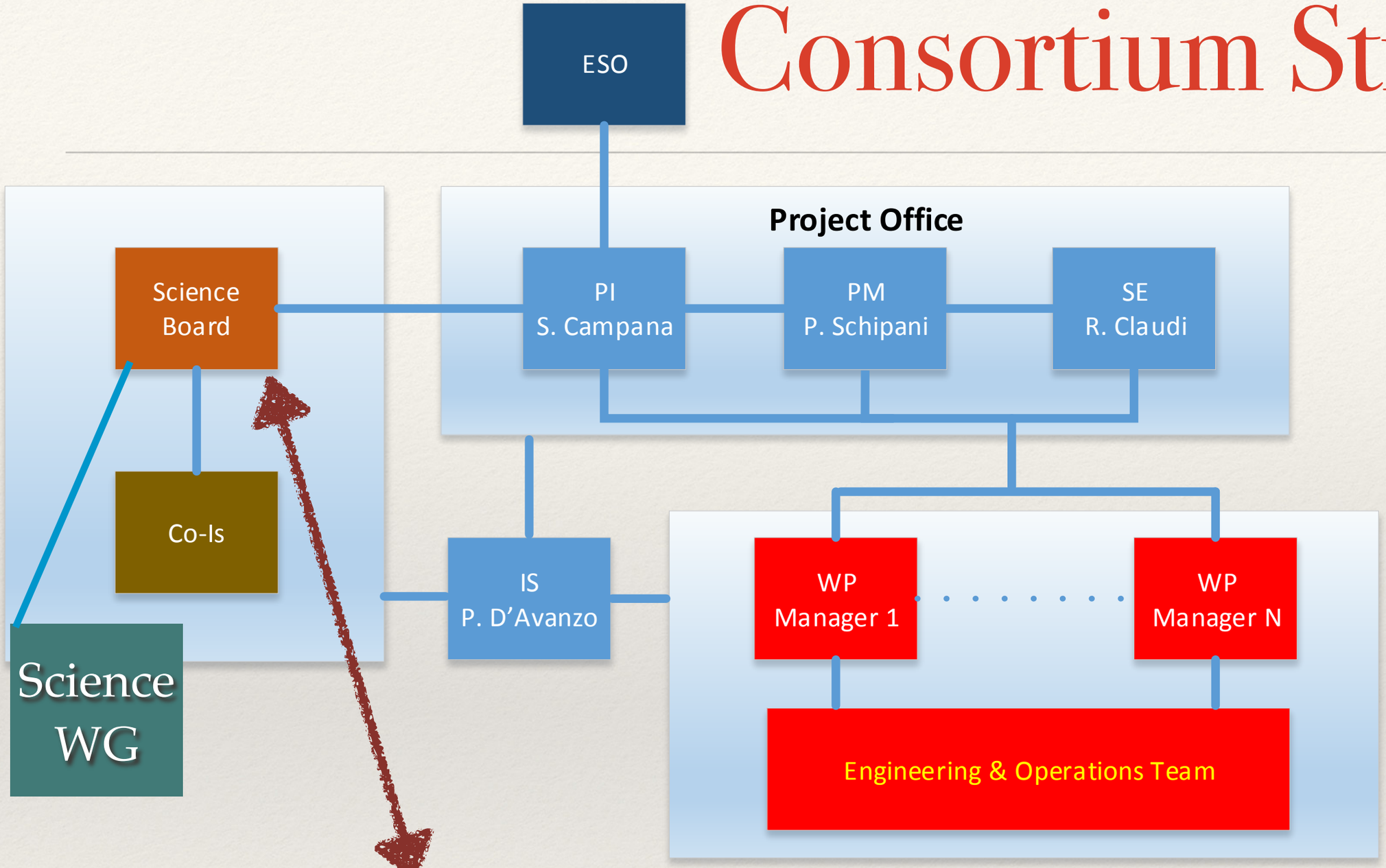
FINCA ~7% (Calibration Unit)

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)

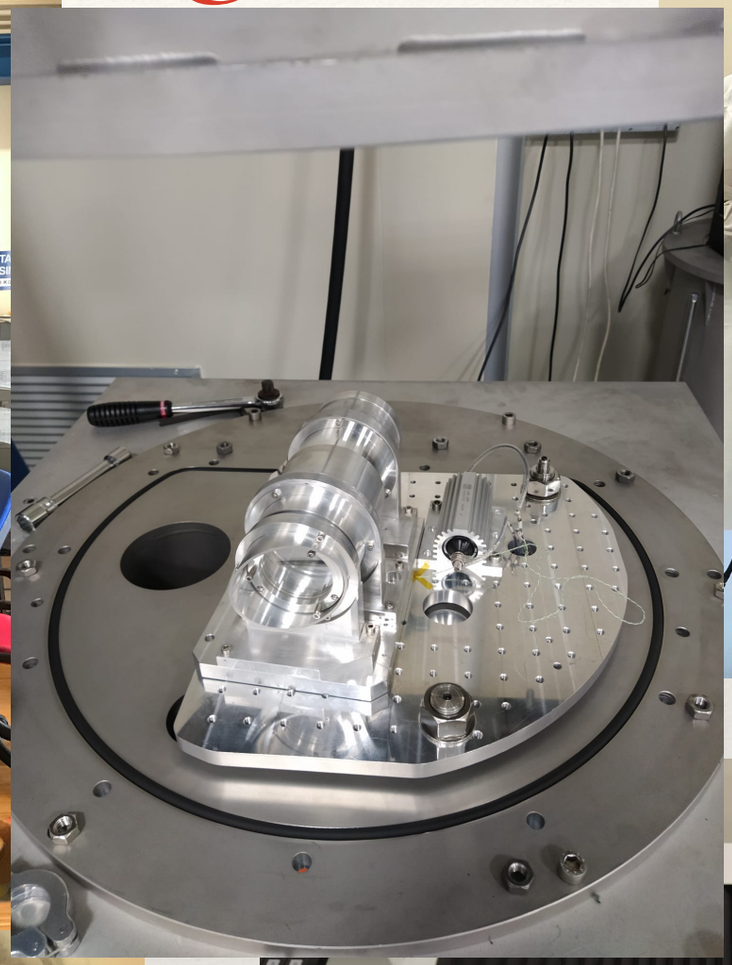
Acquisition Camera WP Manager - Anna Brucalassi (Millenium Institute & INAF)

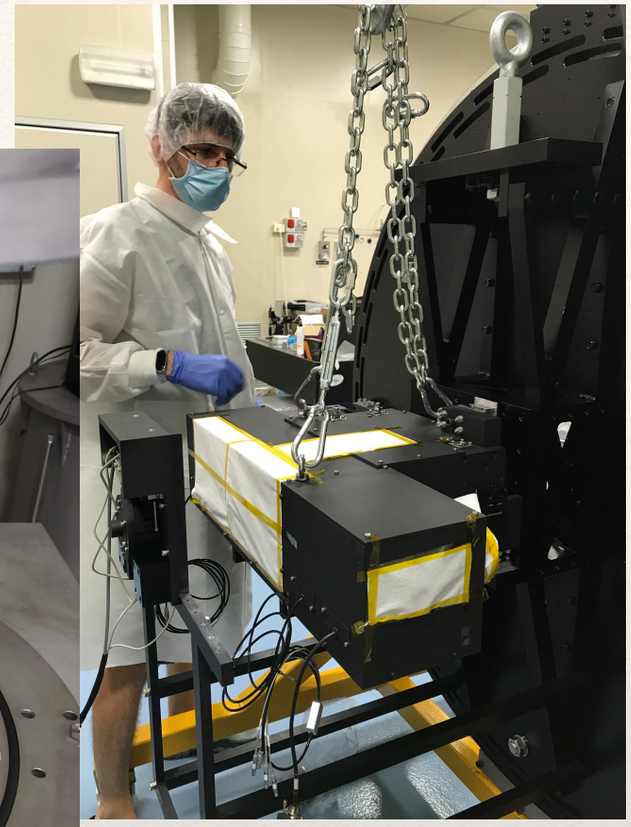
Calibration Unit Optics WP Manager - Haynino Kuncaraycti (Turku University)

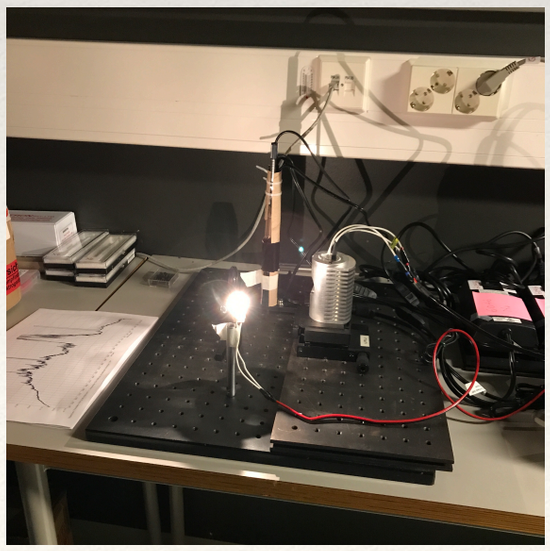
Operations software lead WP Manager - **Marco Landoni** (INAF - Osservatorio astronomico di Brera)

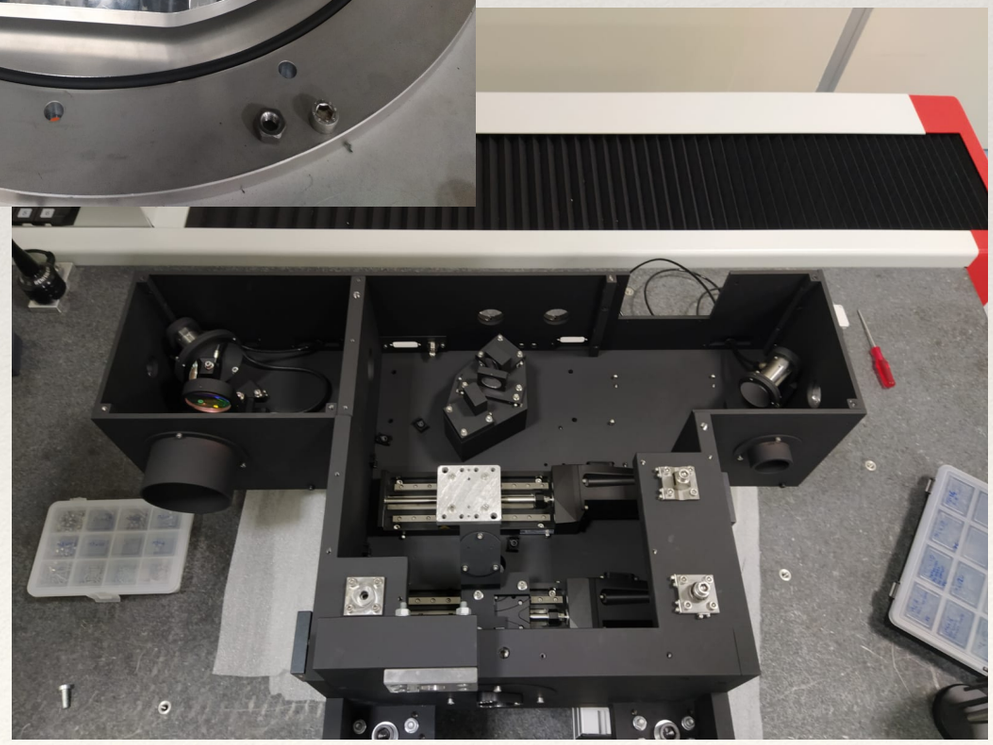
Pipeline WP Manager - David Young (Queens' University Belfast)

Working!









SoXS UV-VIS arm

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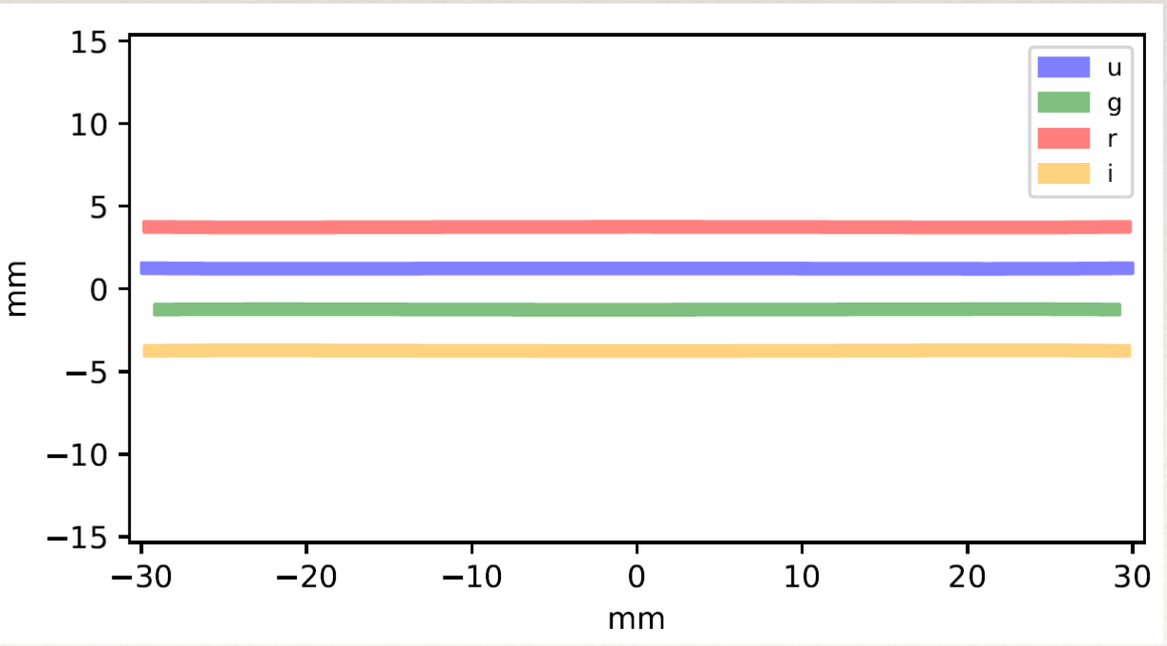
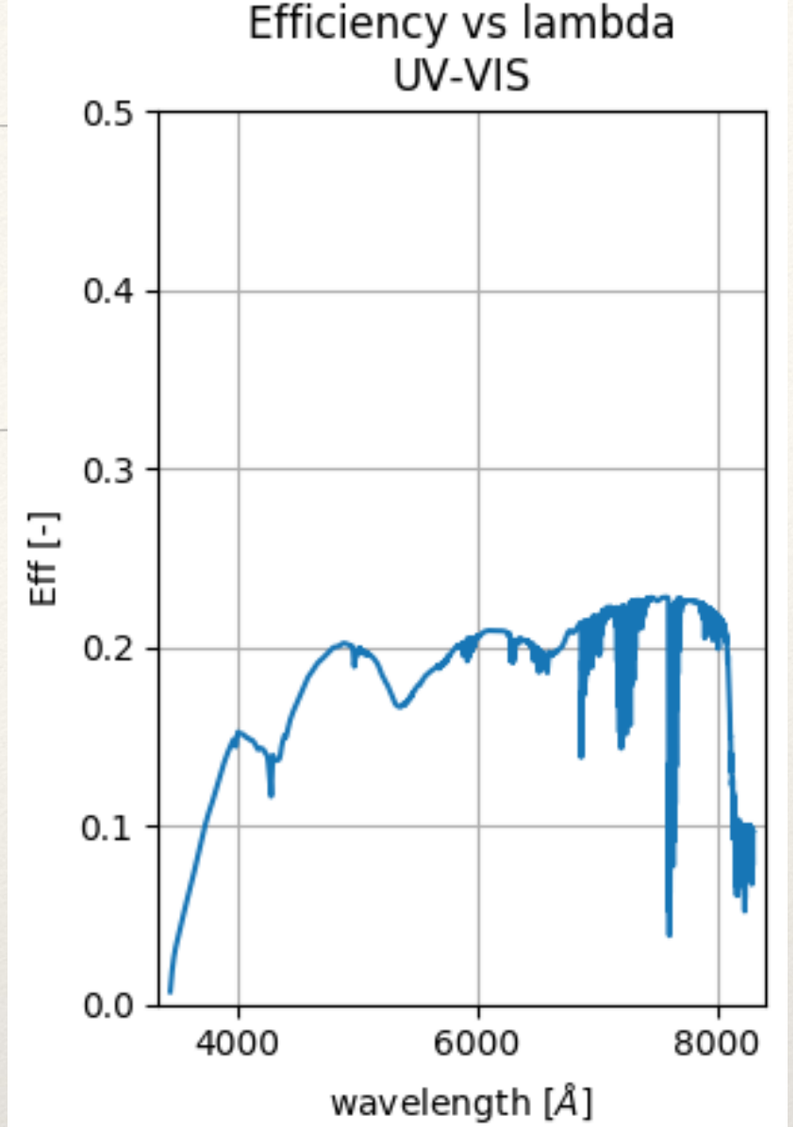
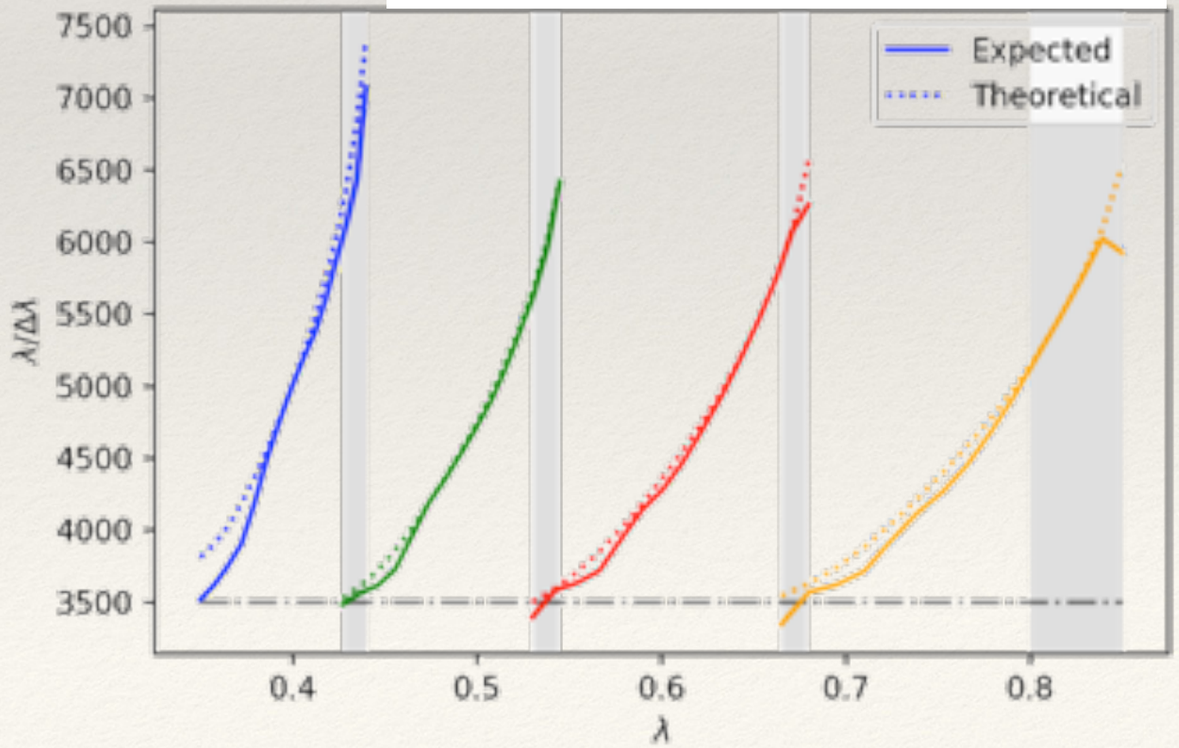
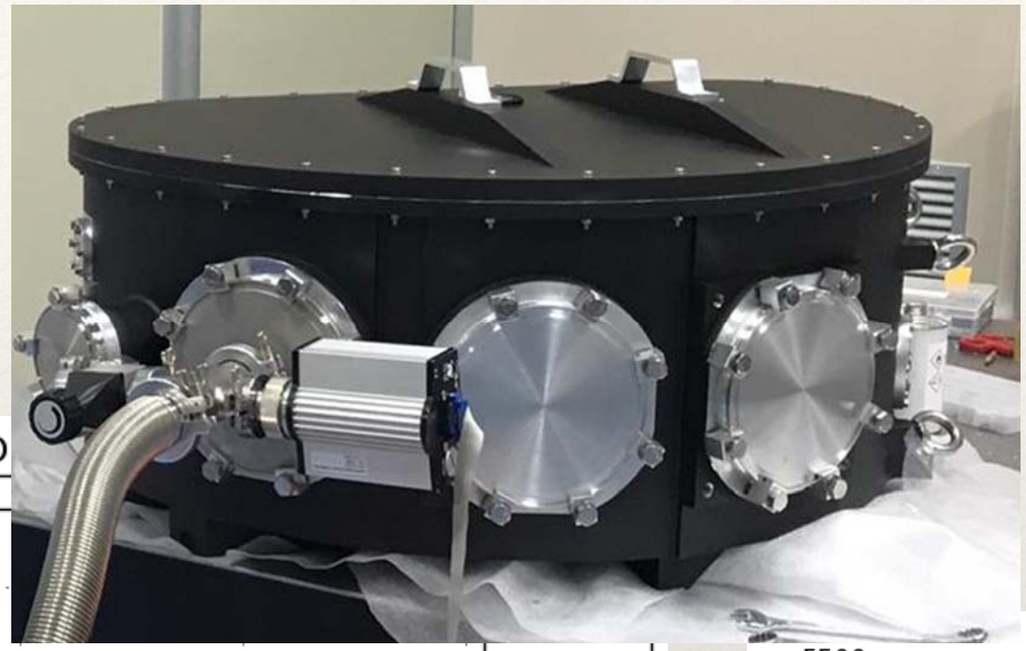
WEIZMANN INSTITUTE OF SCIENCE

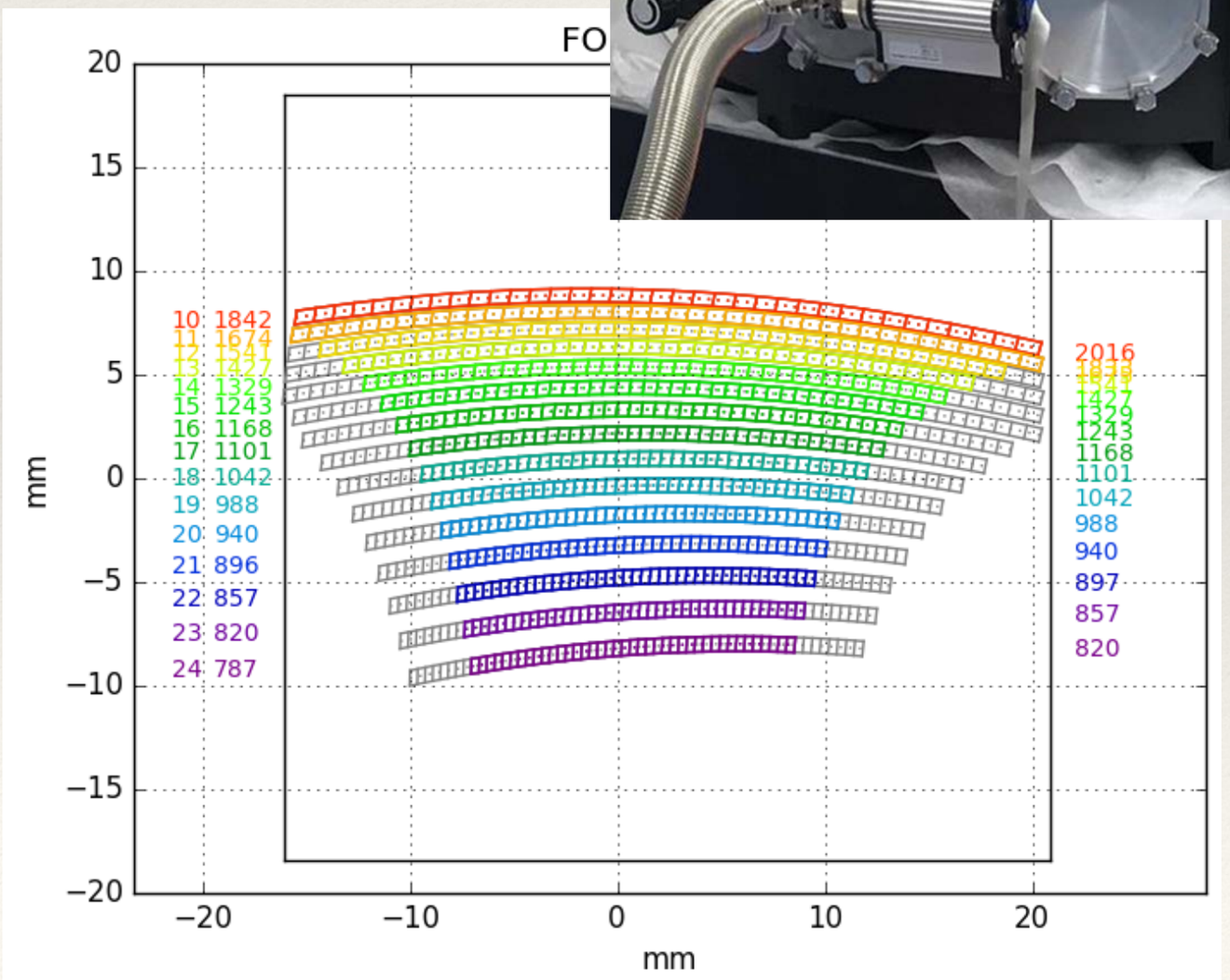






SoXS NIR arm




FO
mm
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
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1674
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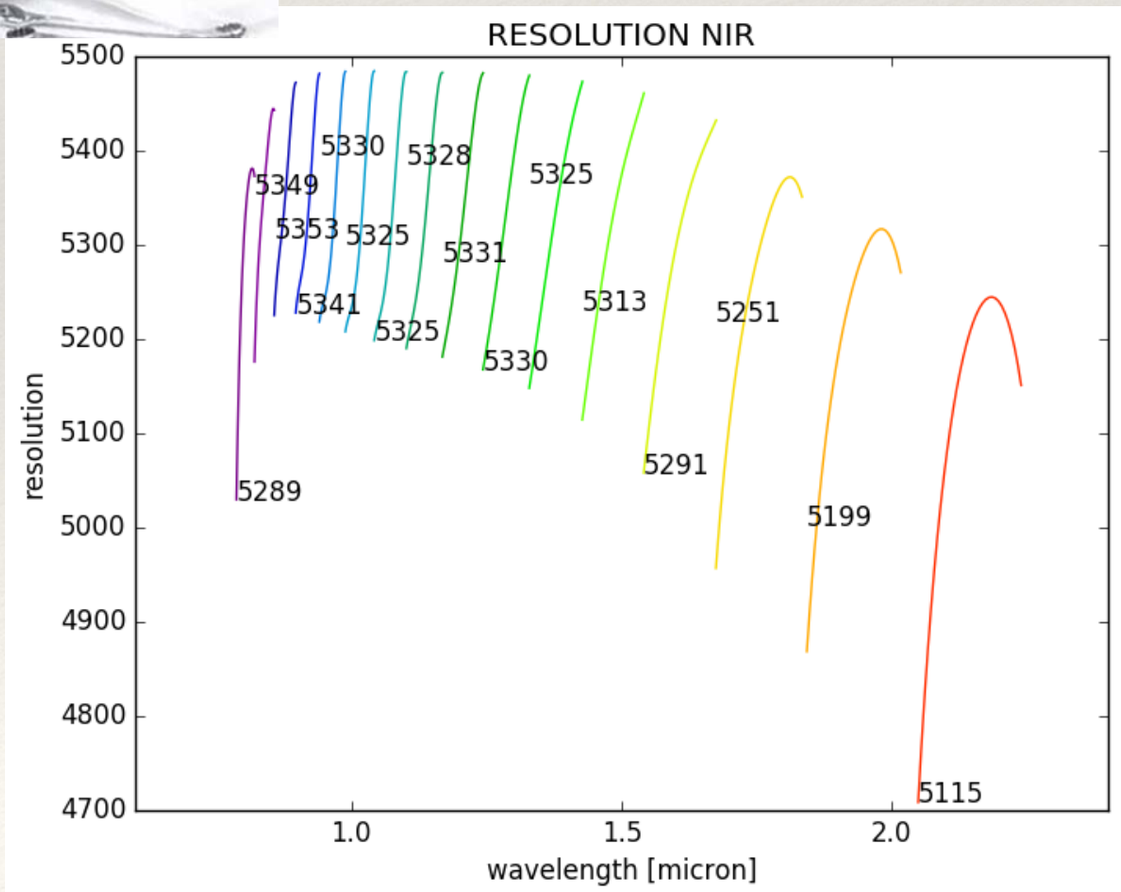
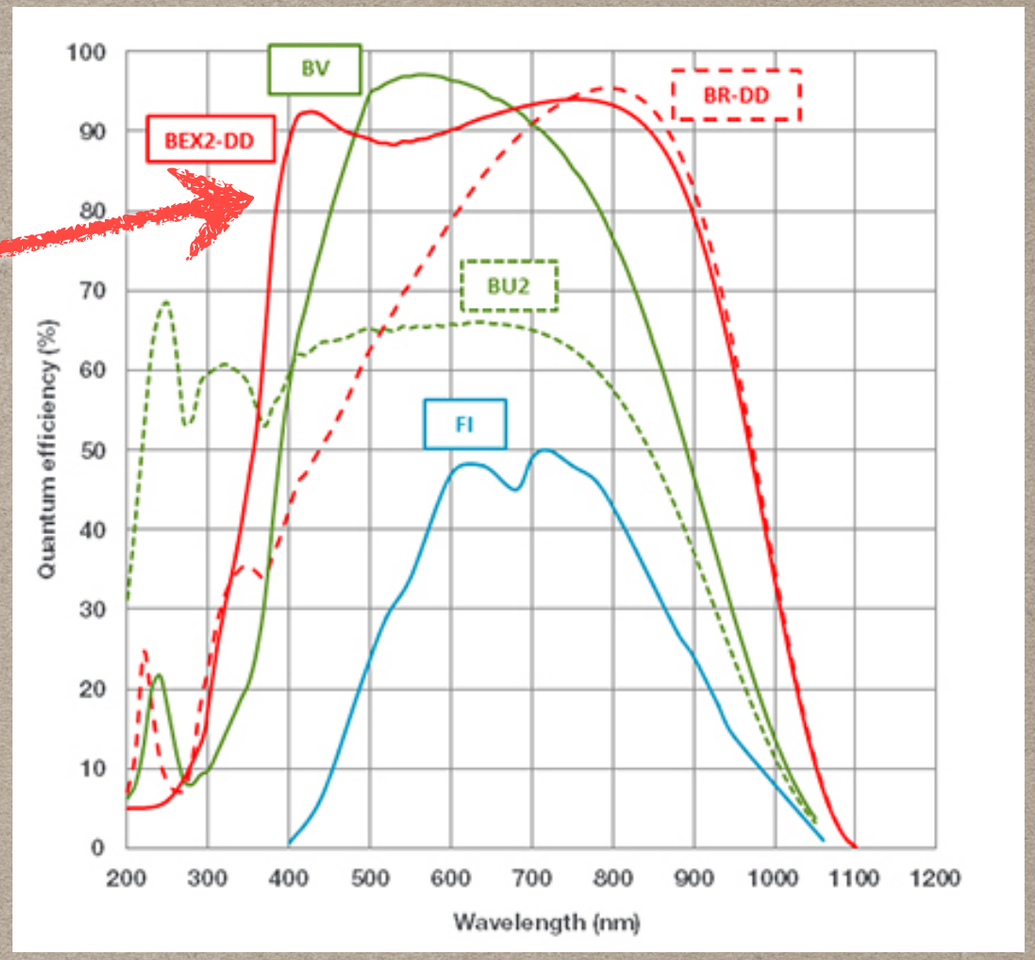
1243
1168
1101
1042
988
940
897
857
820


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

ACQUISITION CAMERA

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



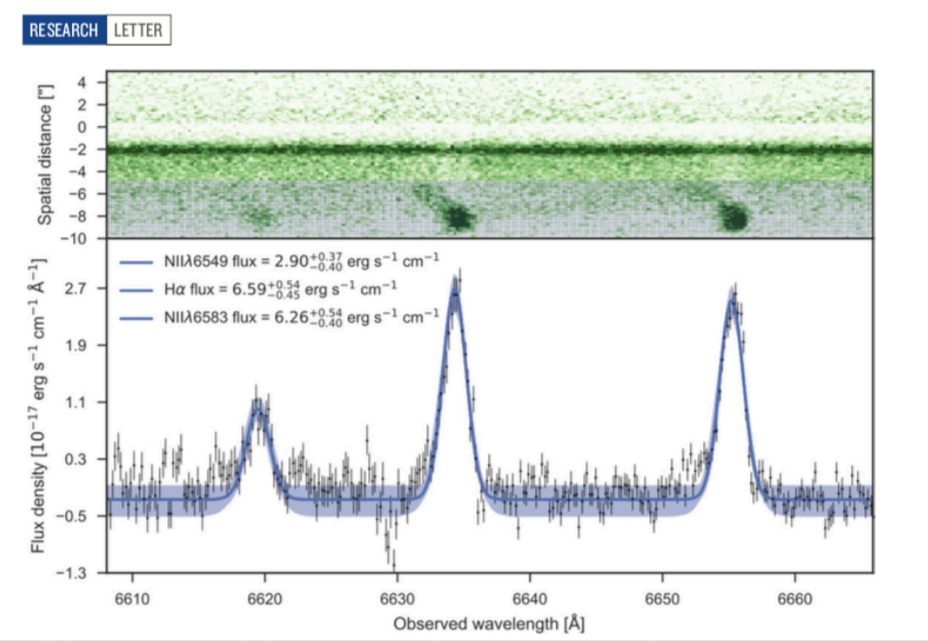
LSST Band (Wav)	1 sec	2 sec	3 sec	5 sec	10 sec	15 sec	20 sec
u' (355.7nm)	15.9	16.7	17.5	17.7	18.4	18.7	19.1
g' (482.5nm)	18.2	18.9	19.4	19.8	20.5	20.8	21.0
r' (626.1nm)	18.0	18.6	19.0	19.5	20.0	20.3	20.4
I' (767.2nm)	16.4	17.1	17.5	17.9	18.4	18.6	18.8
z' (909.7nm)	15.3	15.9	16.2	16.5	16.9	17.2	17.4

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

SoXS 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)



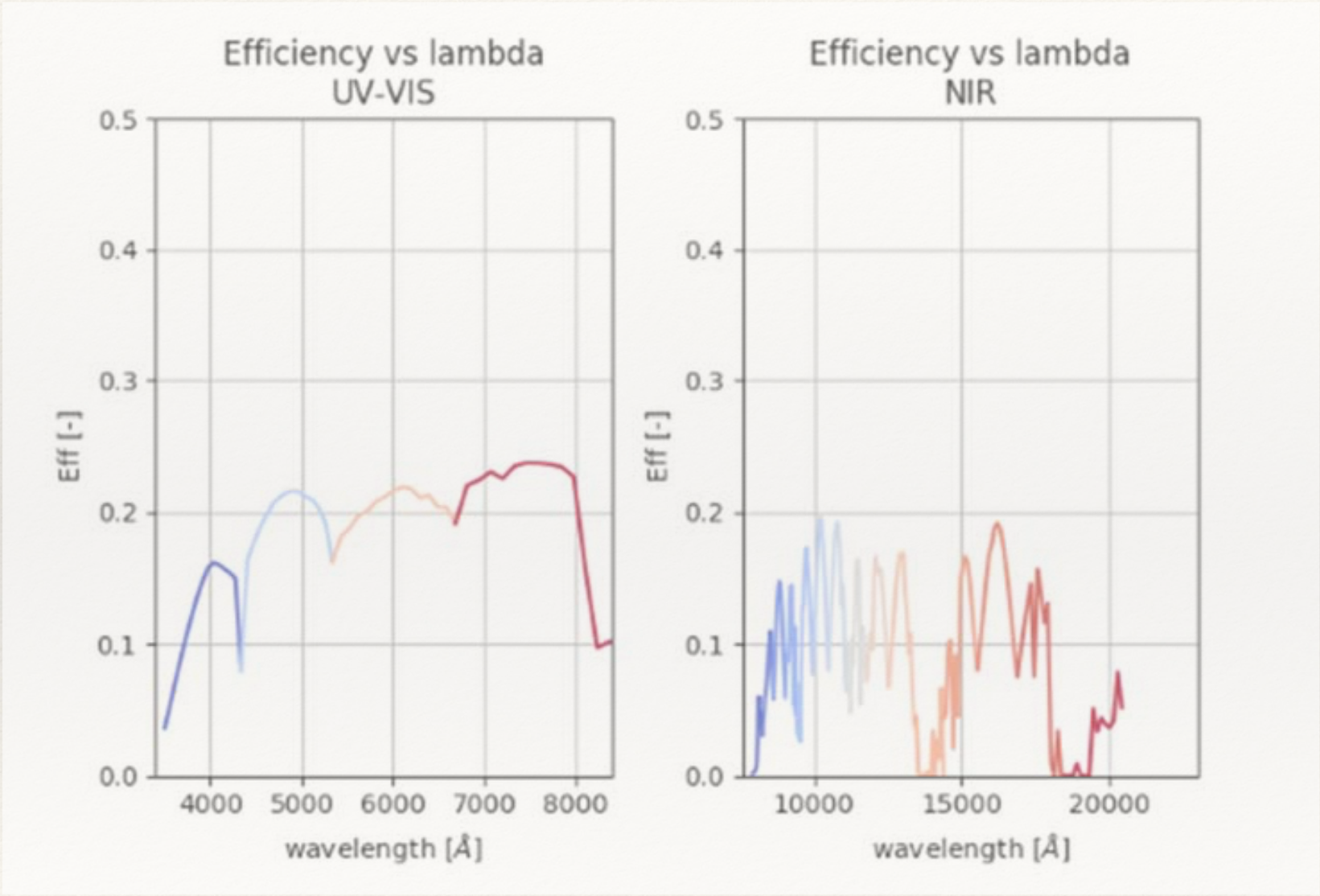
Very quick. Data reduction in near-real time. No need for a quicklook.

- X-shooter like reduction recipes and data products
- But faster production of science ready products

Pipeline also for the acquisition camera data; astrometric and photometric corrections with Pan-STARSS

SoXS pipeline will be public

ETC



http://192.167.38.34/

Kulkarni's comparison

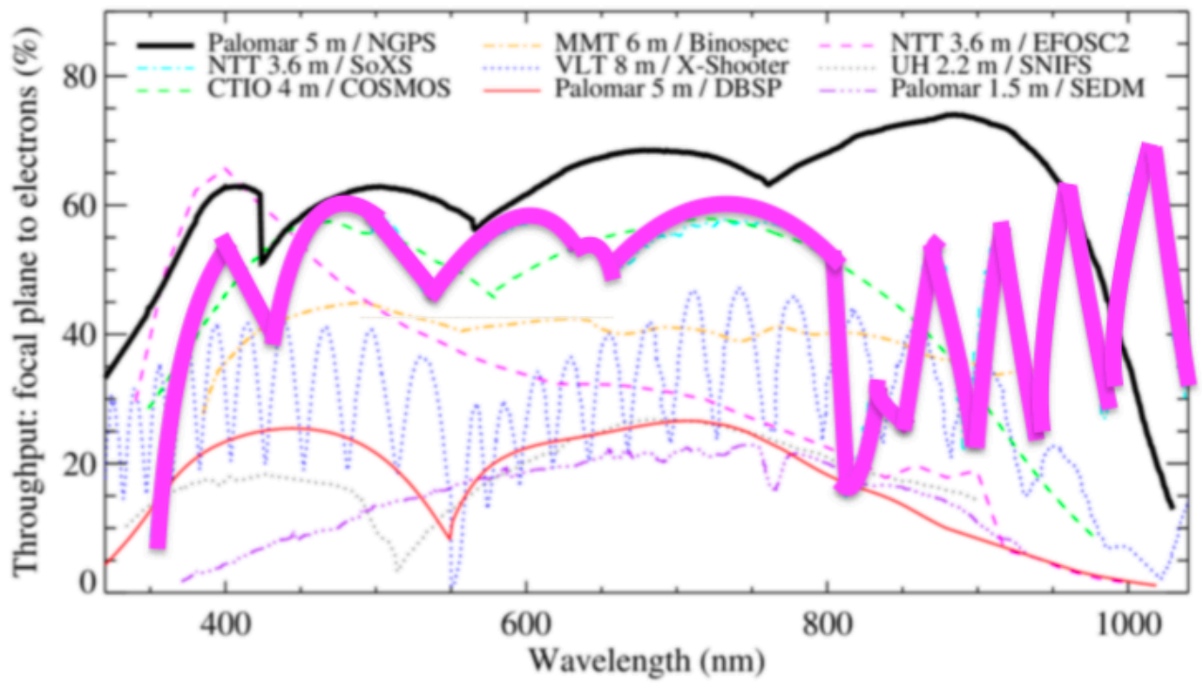


Figure 5. The throughput from the focal plan to photoelectrons of the Next Generation Palomar Spectrograph (NGPS; solid line). The throughput for other spectrographs varies between this measure to "from sky to photoelectrons". References: Son of X-Shooter (SoXS, Claudi et al. 2018, M. Genoni, pers. comm.),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

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).

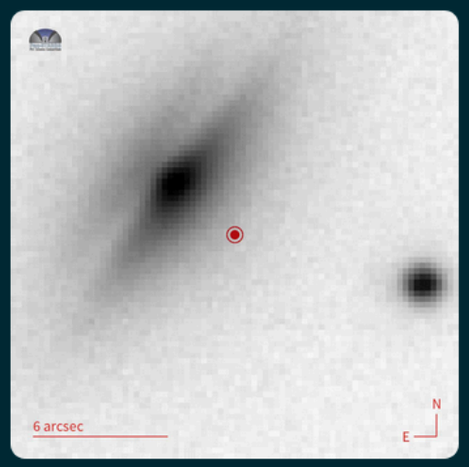
ESO people

- 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

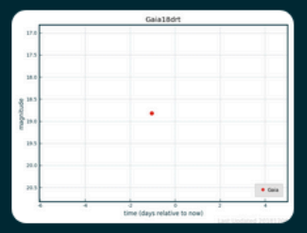
exact sdss location

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

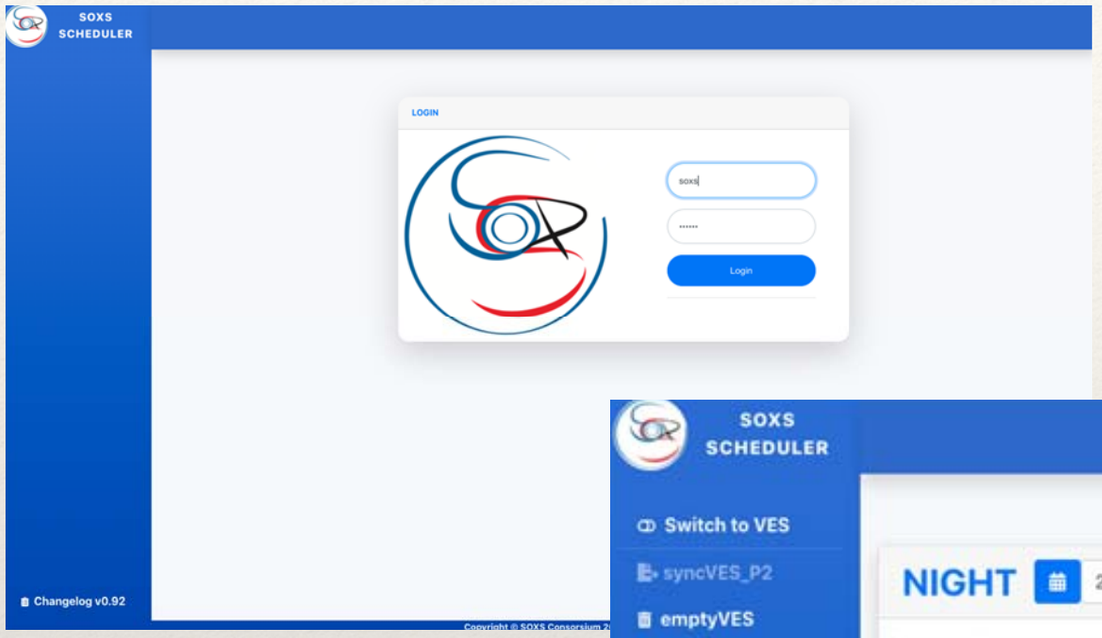
current mag estimate:

18.73

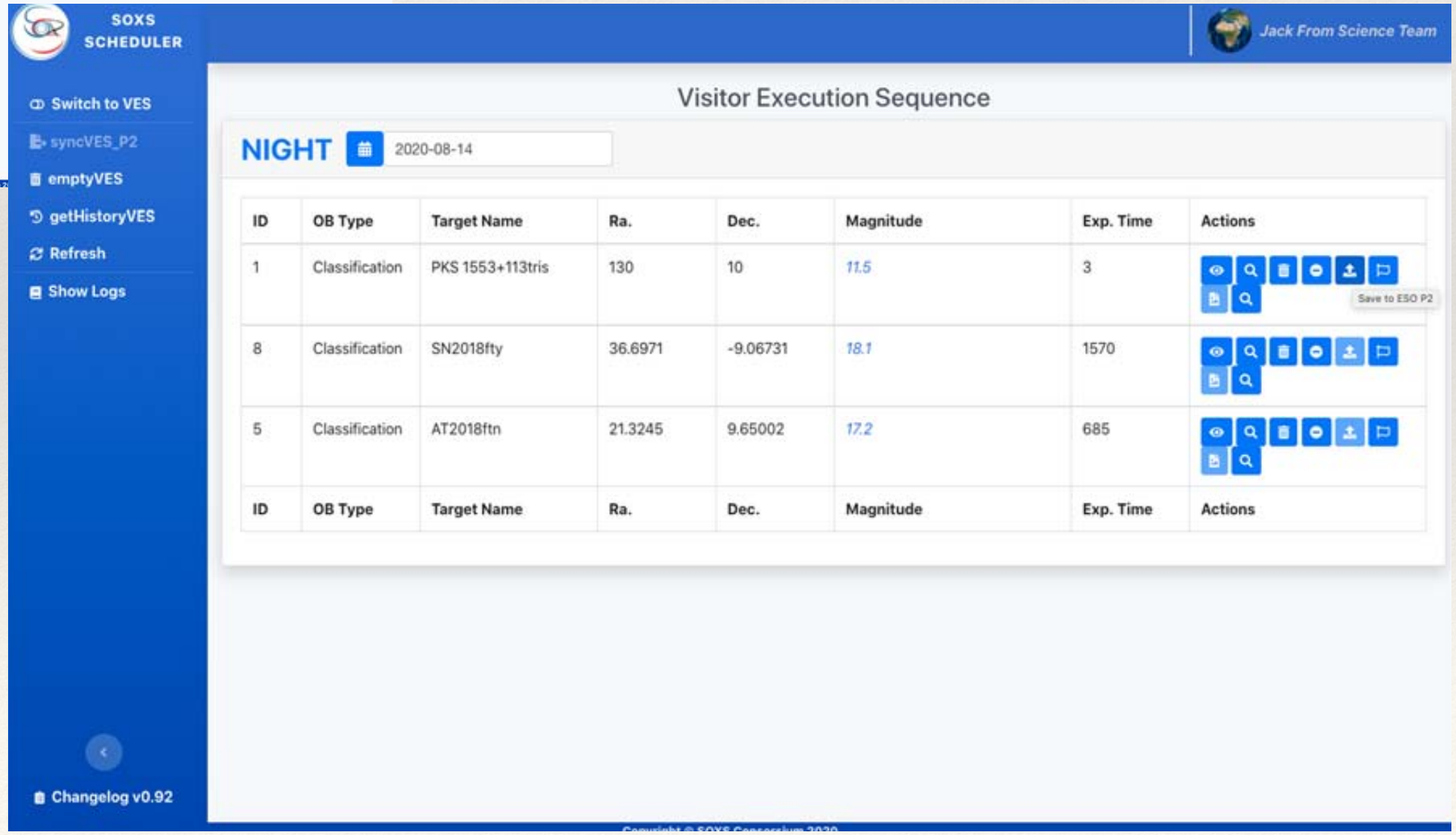
actions

OB

Scheduler



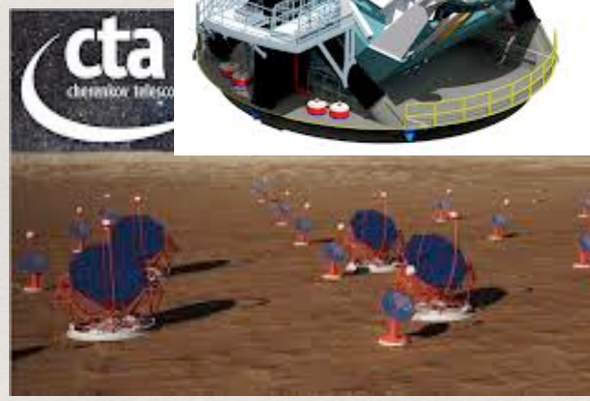
Including Marshall@SOXS

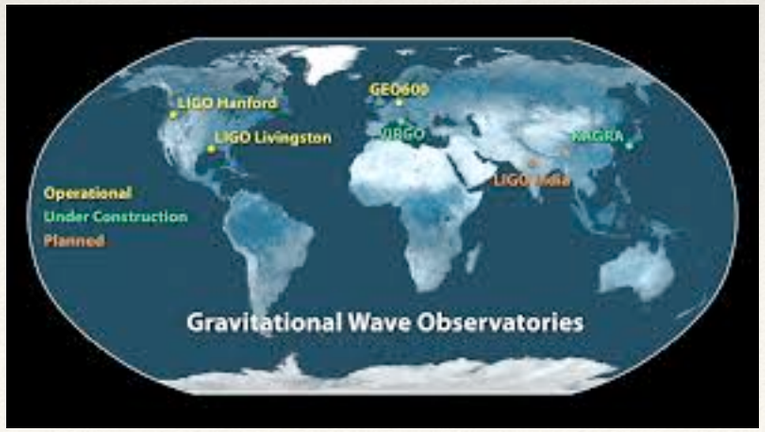


Why do we need SOXS

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

SOXS@NTT will have 180 n/yr (for 5 yr)
~3,000 - 4,000 spectra/yr

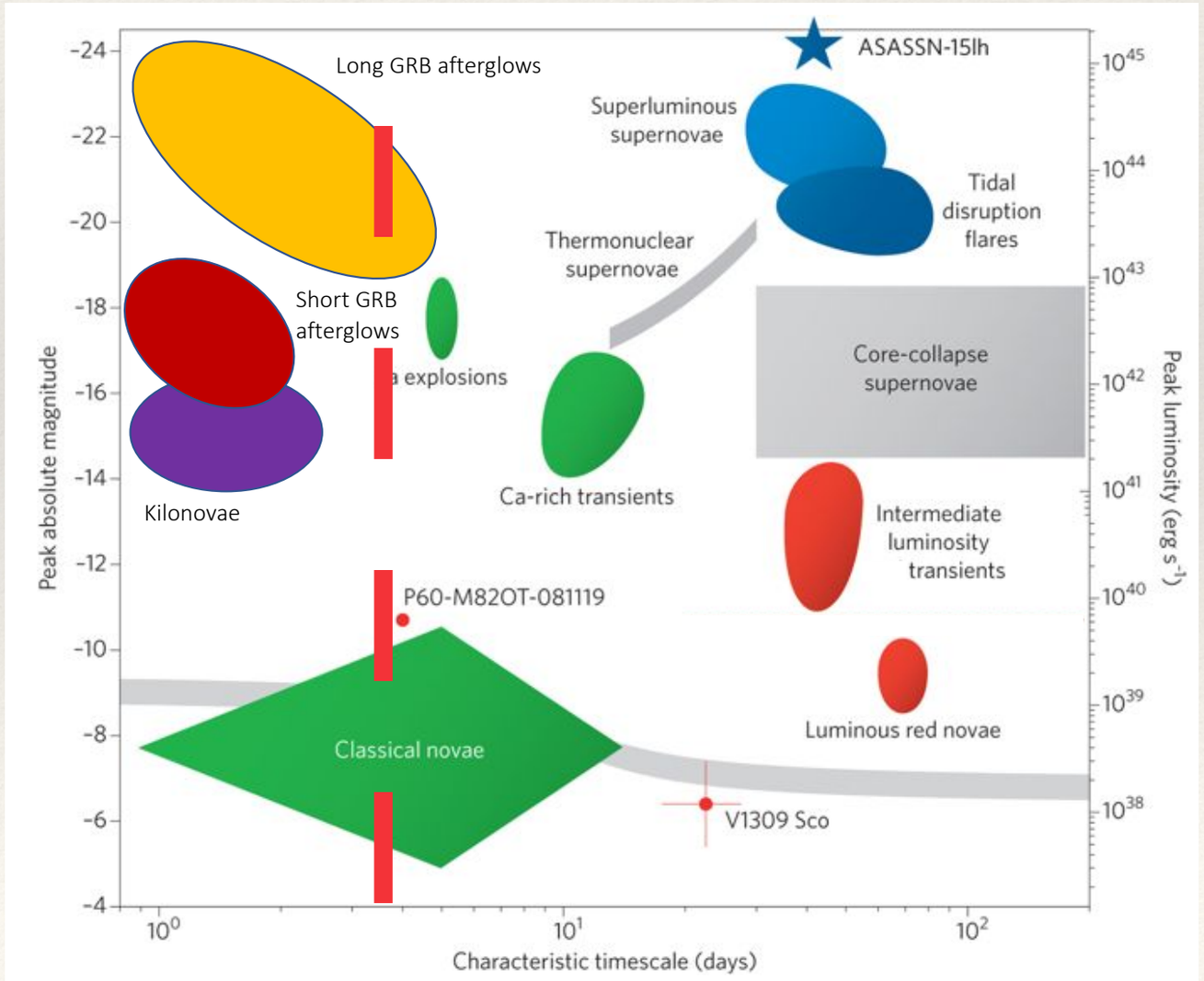




SOXS Science cases

- 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

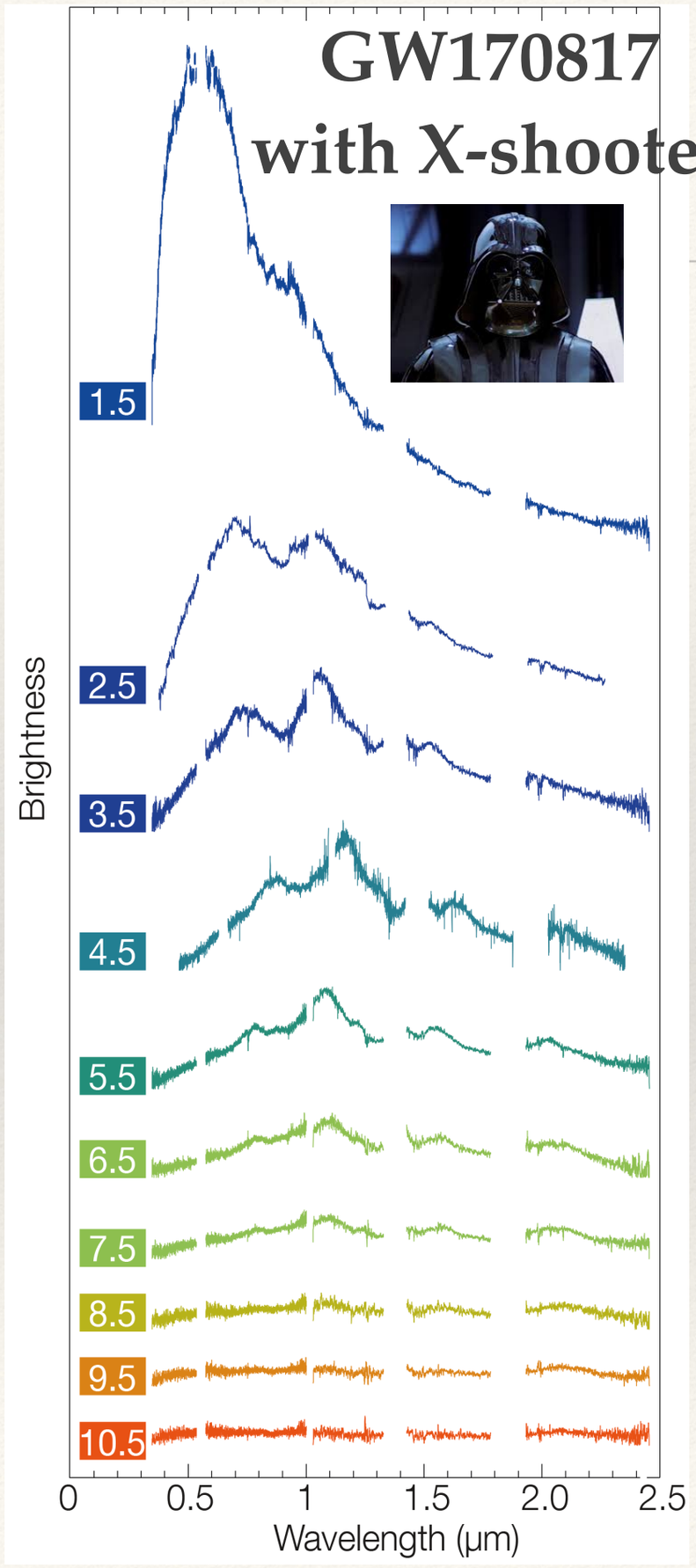
- **Rapid follow-up**
- **Dense monitoring**
- **Always available**

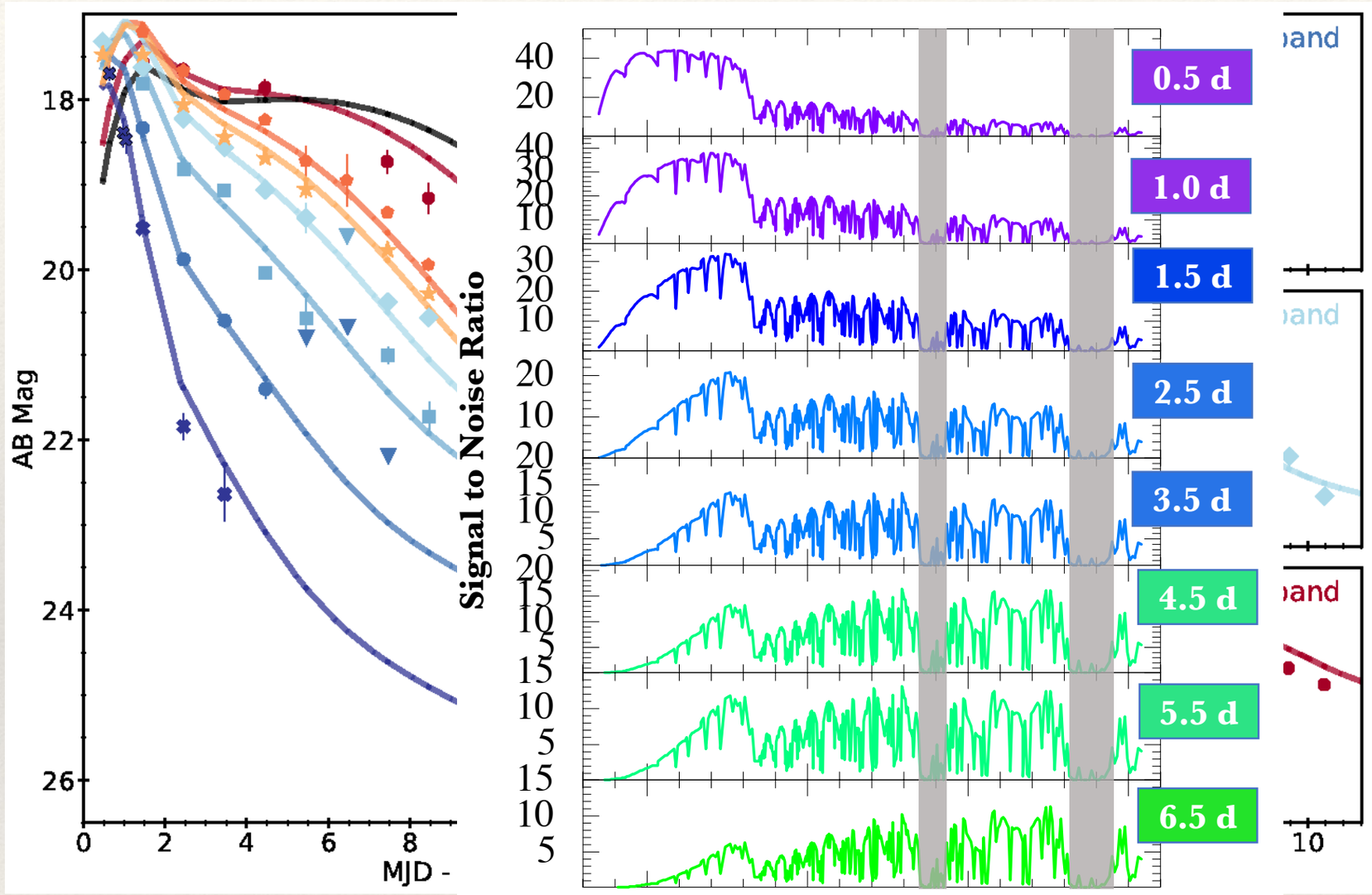


Science Working Groups

WG	WG Topic	WG Leader	WG Deputy	Number of participants
1	Small bodies and comets	Fitzsimmond	**Dotto**	7/11
2	Stellar variability, exoplanets and Young Stellar Objects	**Pagano**	**Alcalà**	19/20
3	Transient X-ray binaries, magnetars, ultra-luminous	**Casella**	Veledina	16/20
4	Cataclysmic variables, novae and white dwarfs	**Della Valle**	Ben-Ami	5/9
5	Supernovae Ia and thermonuclear transients	Stritzinger	Kotak	4/15
6	Fast and extreme transients (including SLSNe)	Arcavi	Mattila	6/18
7	Intermediate luminosity transients	Kotak	**Pastorello**	9/20
8	Core Collapse Supernovae	Gal-Yam	Pignata	10/23
9	AGN and blazars	**Landoni**	—	11/19
10	Tidal Disruption and Nuclear Events	Mattila	Arcavi	3/10
11	Gamma Ray bursts & Fast radio bursts	**D'Avanzo**	Fynbo	8/10
12	Gravitational wave and neutrino counterparts	**Campana**	Smartt	16/29
13	Classification	**Benetti**	**Botticella**	14/27

What can SOXS do?





Preliminary SoXS ETC

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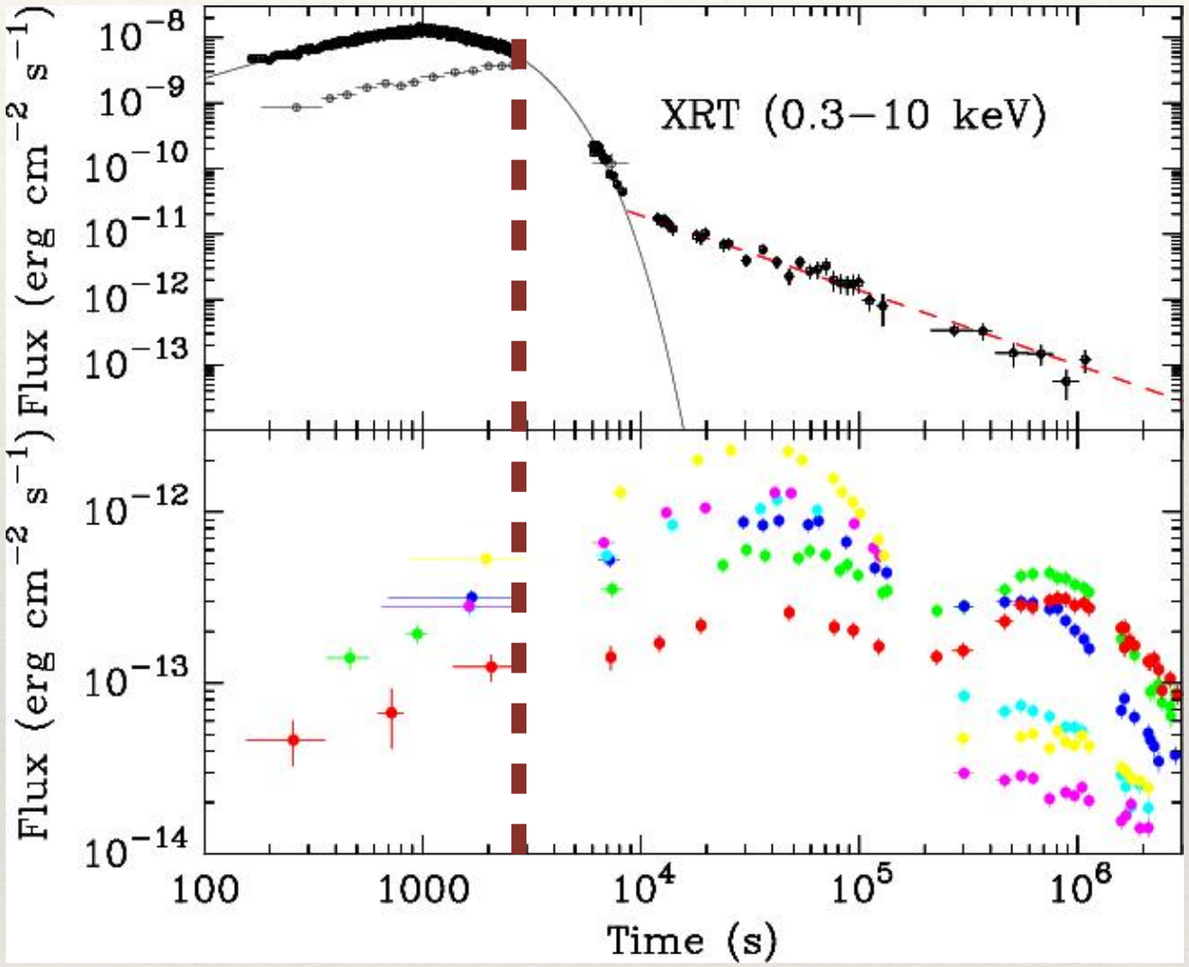
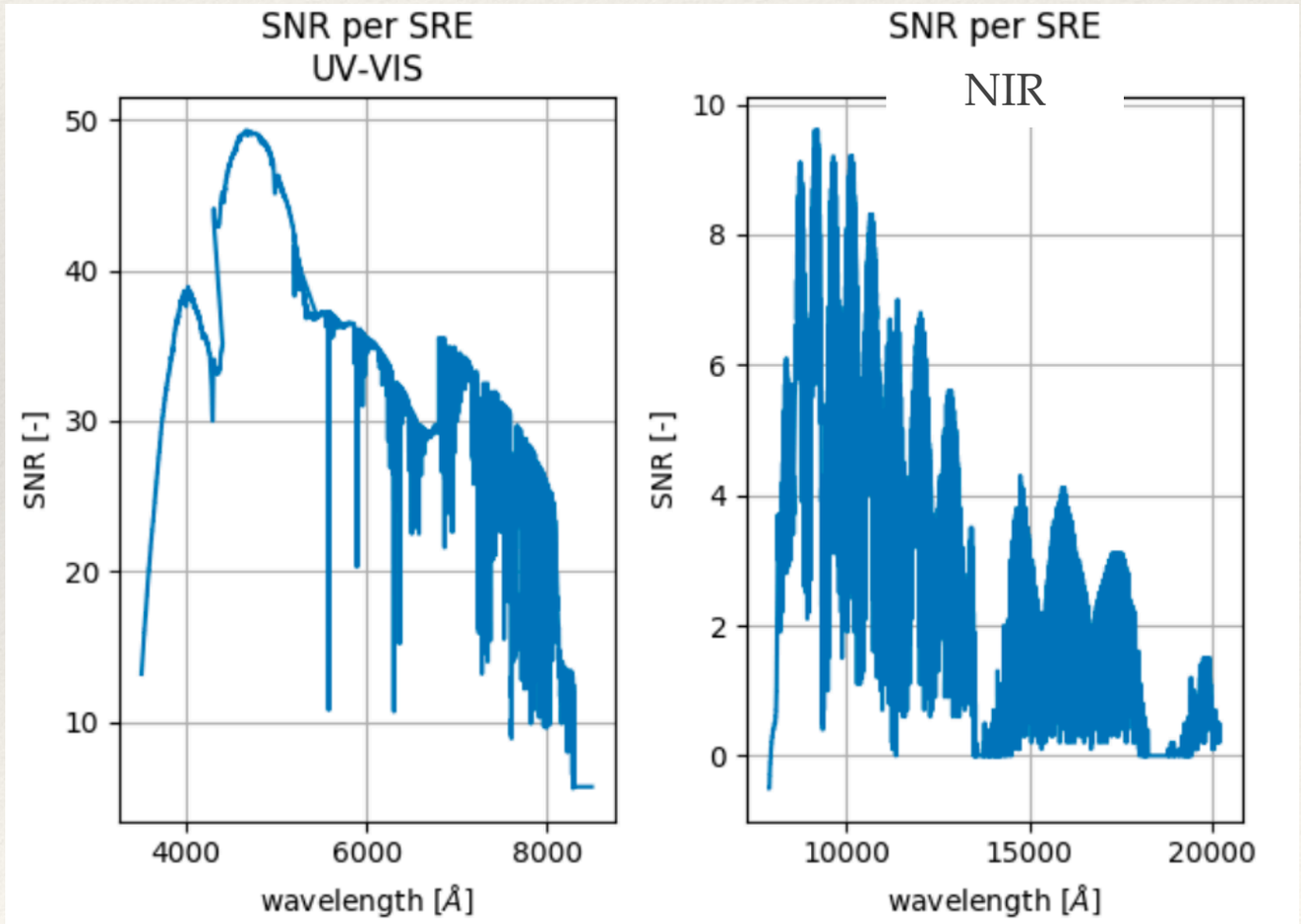
Shock break out



GRB 060218



and

SOXS will observe spectroscopically **all** GRBs visible from La Silla discovered by SVOM, promptly, if directly accessible, or when the night comes if there is an afterglow detection. If none has observed before, SOXS will search for the afterglow.
This will occur for the entire SOXS GTO (5 yr).

Agreement at the PI level has been signed.
SOXS-WG has been involved in the discussion and agreed on the terms.

High-energy data will remain with the SVOM consortium, optical-nIR images and spectra will remain within the SOXS consortium.
Agreements will be searched for on a GRB-by-GRB basis.
Collaboration and exchange of authors is welcome.
Possible collaborations on transients will be explored in the future.

One SVOM person will help with the SOXS operations for one week every months for the first year.

Conclusions

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

- *International project: 49% Italy - Italy leads*

- *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).*

- *Active collaboration with SVOM for GRB follow-up. We are all happy and eager to start!*

Thanks