Roma, July 24, 2018

III ePESSTO meeting

SON OF X-SHOOTER

SOXS

SERGIO CAMPANA
OSSERVATORIO ASTRONOMICO DI BRERA

ON BEHALF OF THE SOXS CONSORTIUM

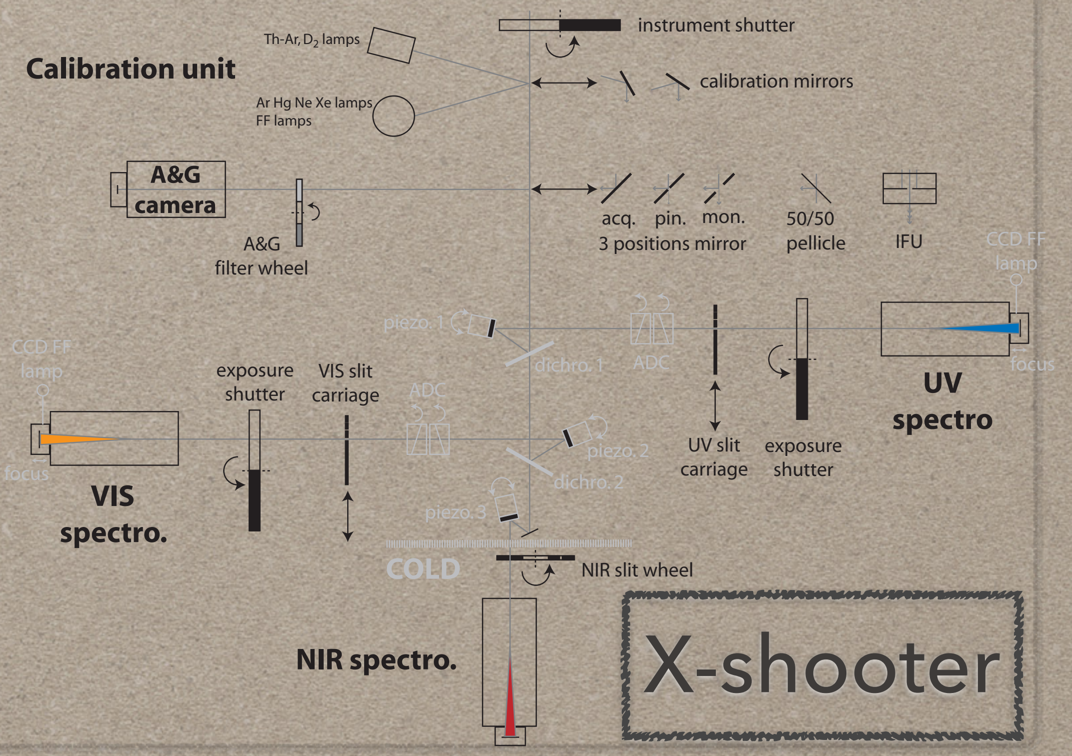
HISTORY

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

Proposal submission (02/2015)

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

Similar to X-shooter
.. but also different, only two arms
with overlap around 850 nm
to cross-calibrate spectra



SOXS@NTT IN A NUTSHELL

- *Broad band spectrograph 350-2000 nm*
- *R~4,500 (3,500-6,000)*
- *Two arms (UV-VIS + NIR)*
- *S/N~10 spectrum - 1 hr exposure for R~20*
- *Acquisition camera to perform photometry ugrizY (3.5'x3'.5)*

Consortium

Institutes from 6 Countries

- Common Path, NIR Spectrograph, Control Software & Electronics, Vacuum and Cryogenics, Detectors control (INAF)
- UV/VIS Spectrograph (Weizmann)
- Acquisition Camera (Millennium Institute of Astrophysics - MAS)
- Calibration Unit (Turku University)
- Data Reduction (Queen’s Un. Belfast)
- Tel Aviv University
- Neils Bohr Institute

MOU

MoU between INAF & ESO agreed in all details.
Signed by ESO. To be signed soon (July 30) by INAF.

Single MoUs among partners.

INAF-NBI ✓

INAF-Tel Aviv University ✓

INAF-Turku University (Lett. Endors. - Mou Within 2018) ✓

INAF-Weizmann Institute working

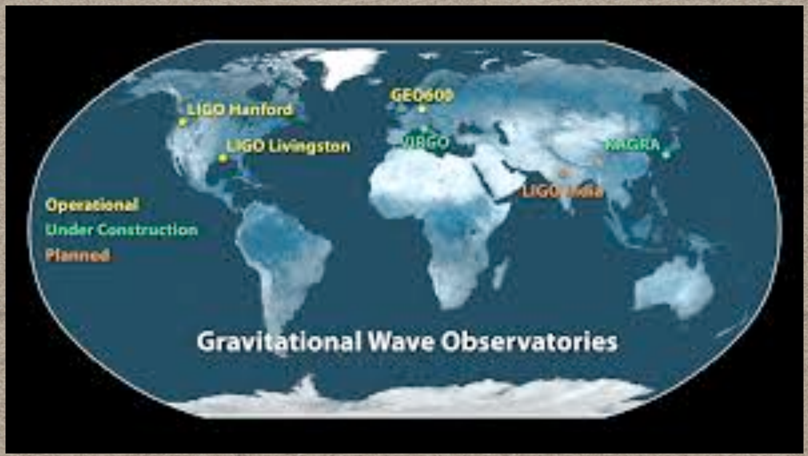
INAF-Millenium Institute working

INAF-Queen's University Belfast working

WHY SOXS?

New deeper survey: PanSTARSS, DES, ZTF, LSST, ...
Space optical missions: Gaia, EUCLID, ...
Space high-energy missions: Swift, Fermi, SVOM, ...
Radio new facilities: MeerKAT, SKA, ...
VHE: CTA
Messengers: aLIGO-Virgo, KM3Net, ANTARES, ...

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



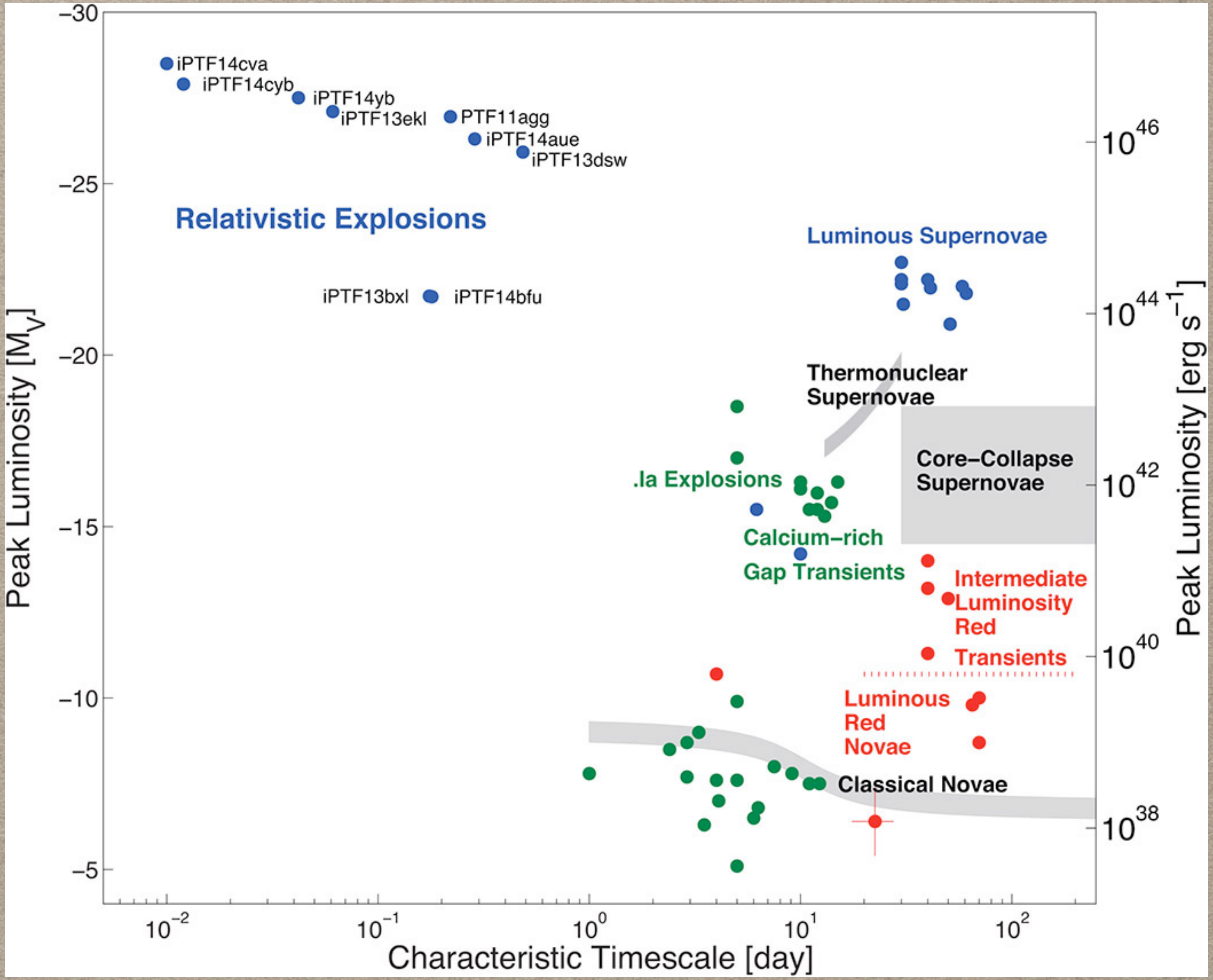
SPECTROSCOPIC BOTTLENECK

- New transients need to be classified (& redshift) and studied over time in details

- PESSTO/ePESSTO (Large ESO program 90n/yr):
  - initially focussed on SN, now open to more science cases
  - service classification activity
  - ~80 papers in 5 years and ~600 ATel

SOXS SCIENCE CASES

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

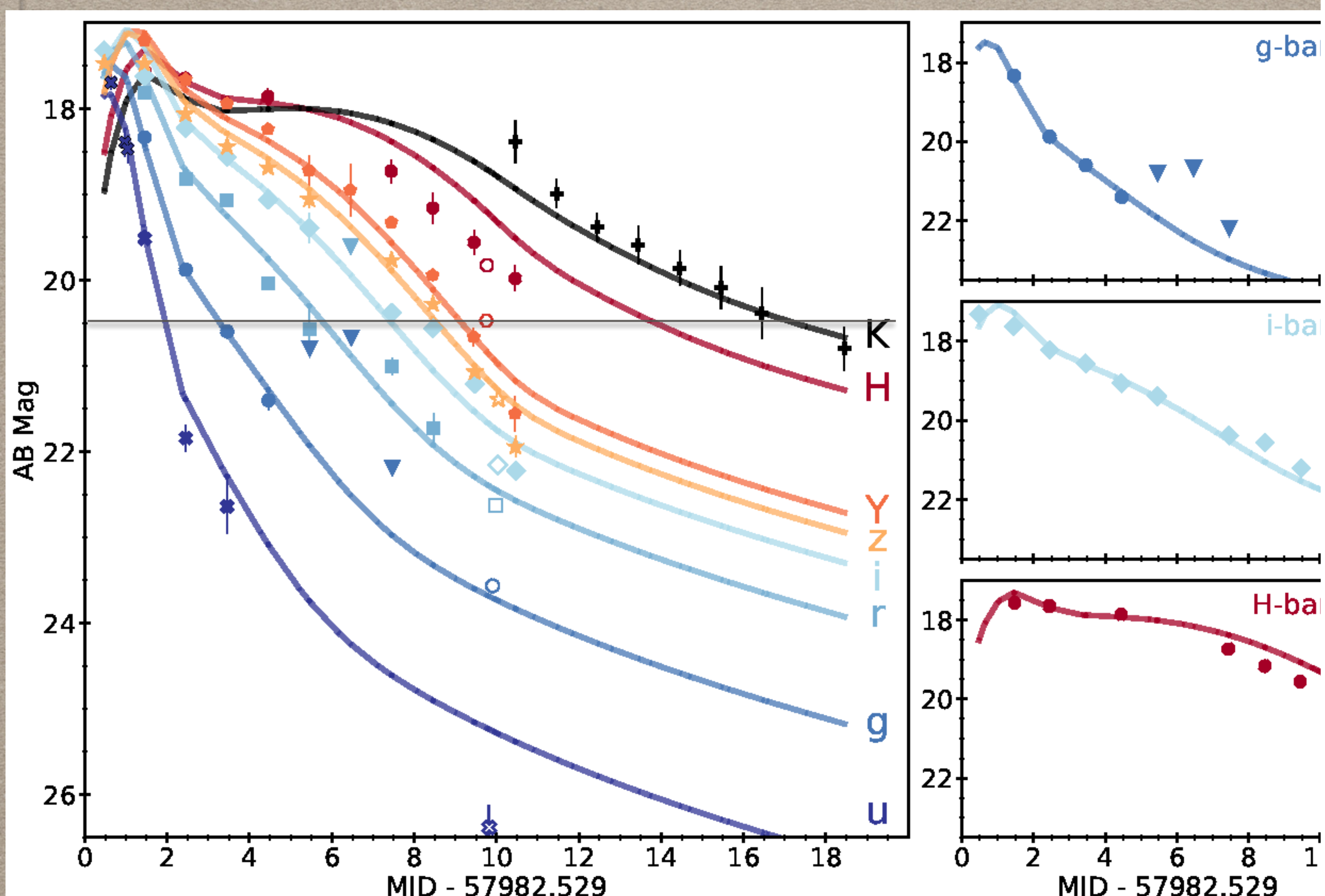


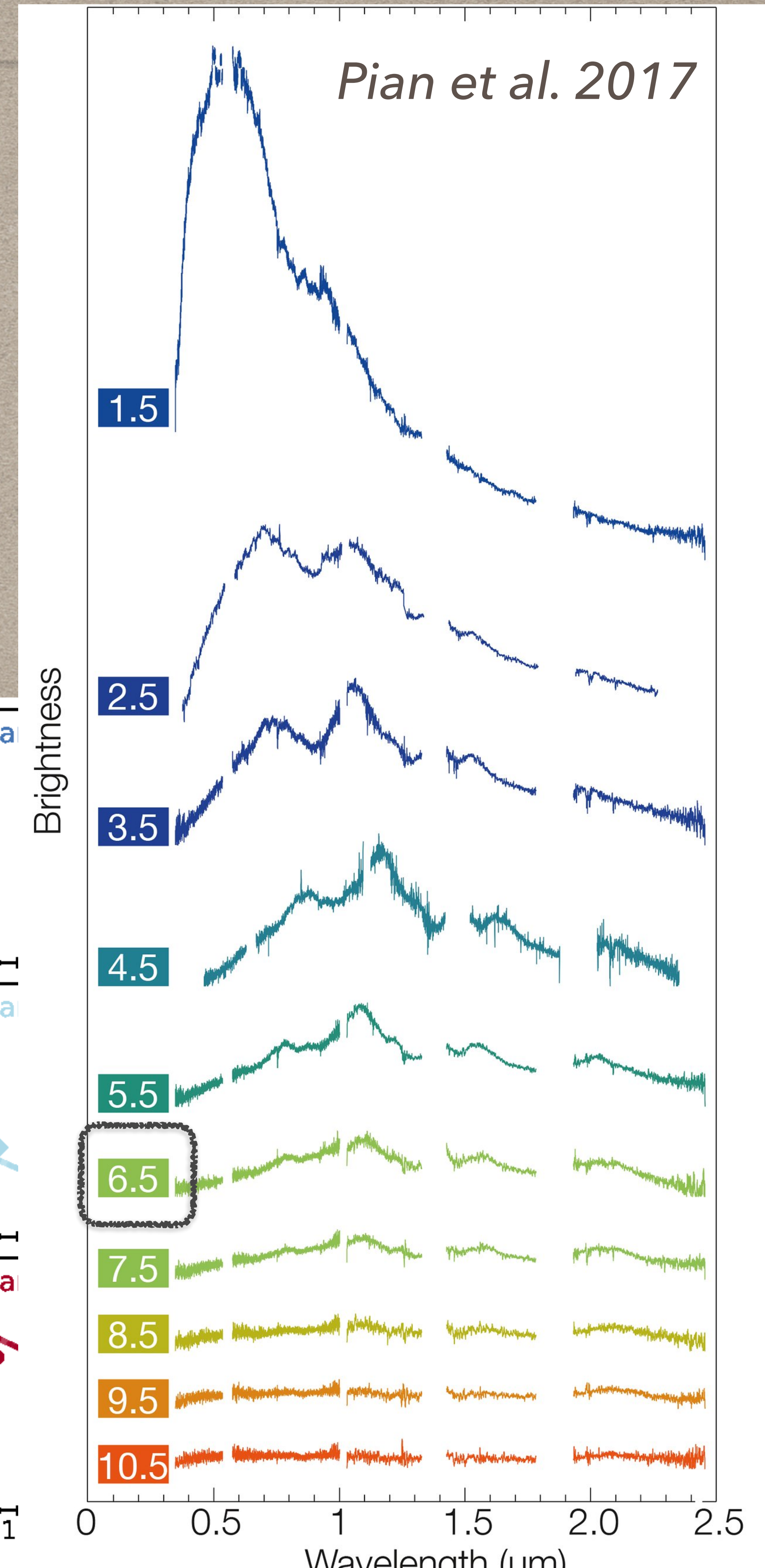
SOXS FOR GW

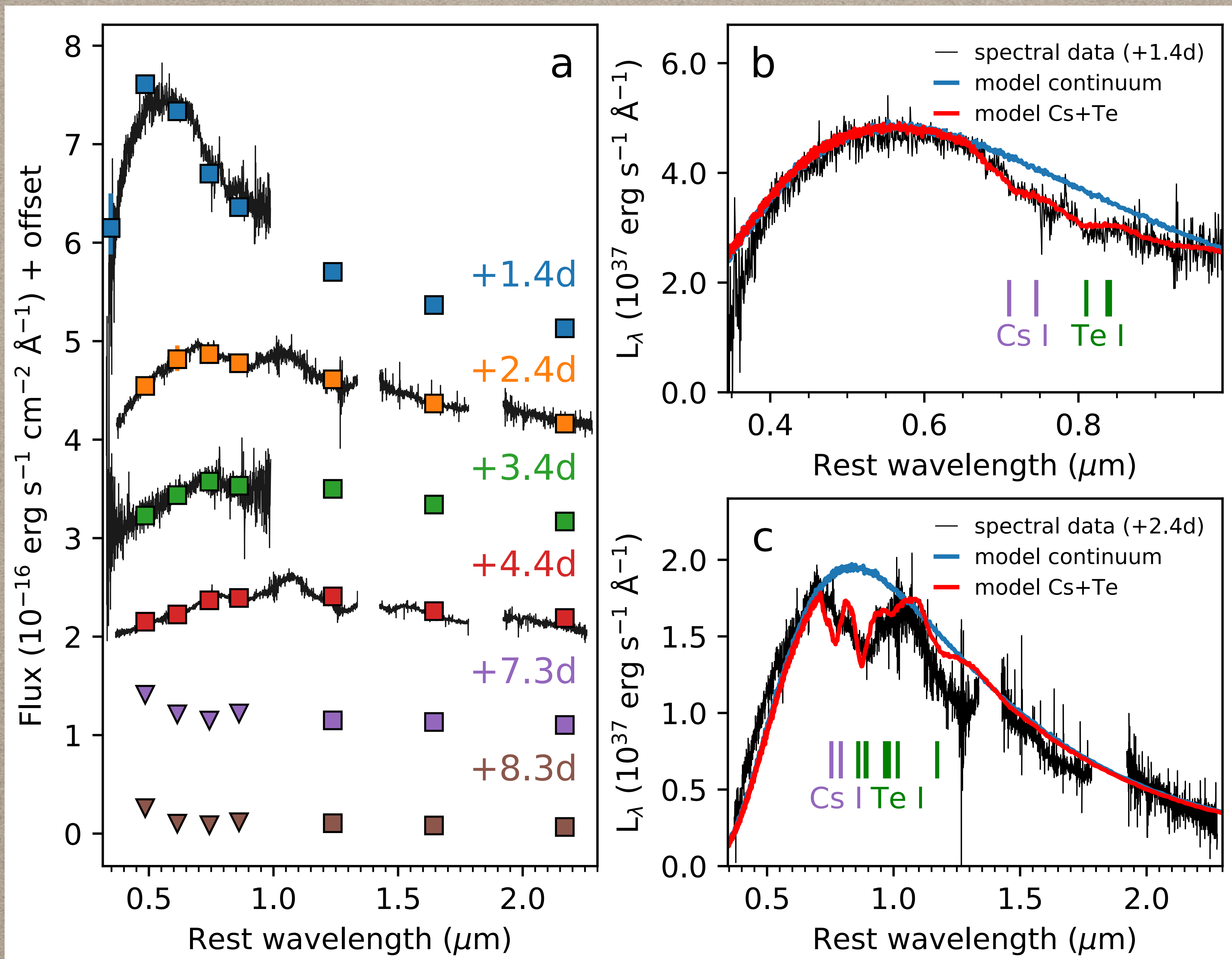
High priority targets

Spectroscopic study of GW candidates

Deep follow-up of GW counterparts

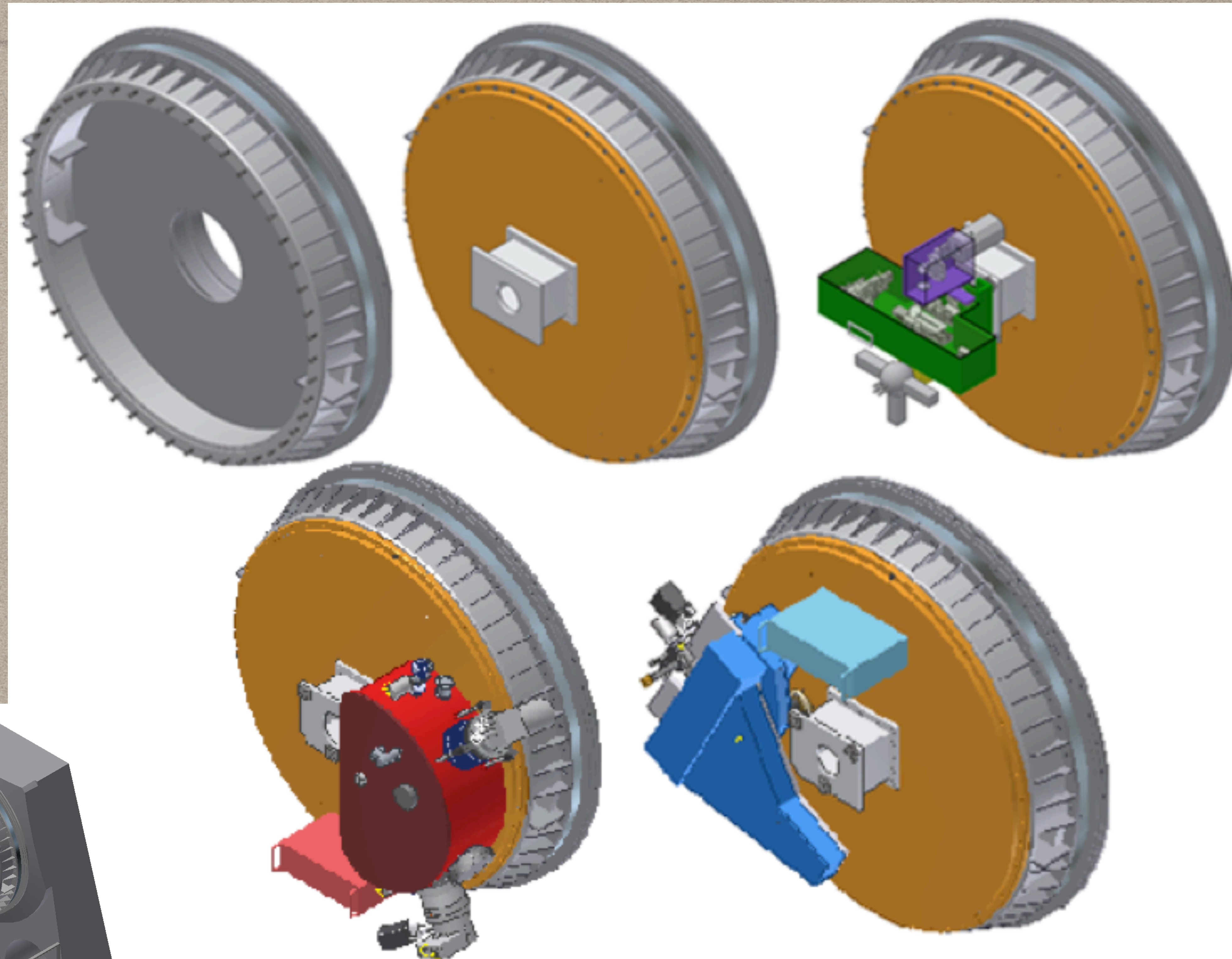


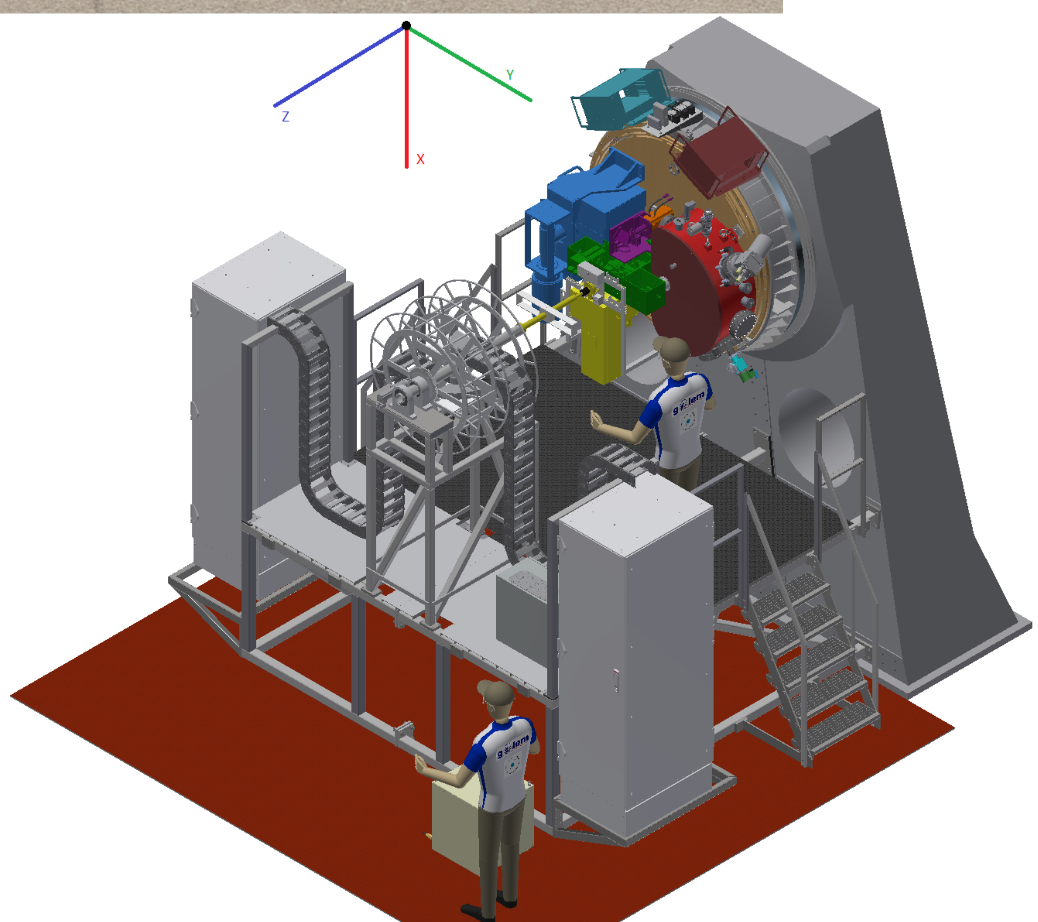




Smartt et al. 2017

SOXS

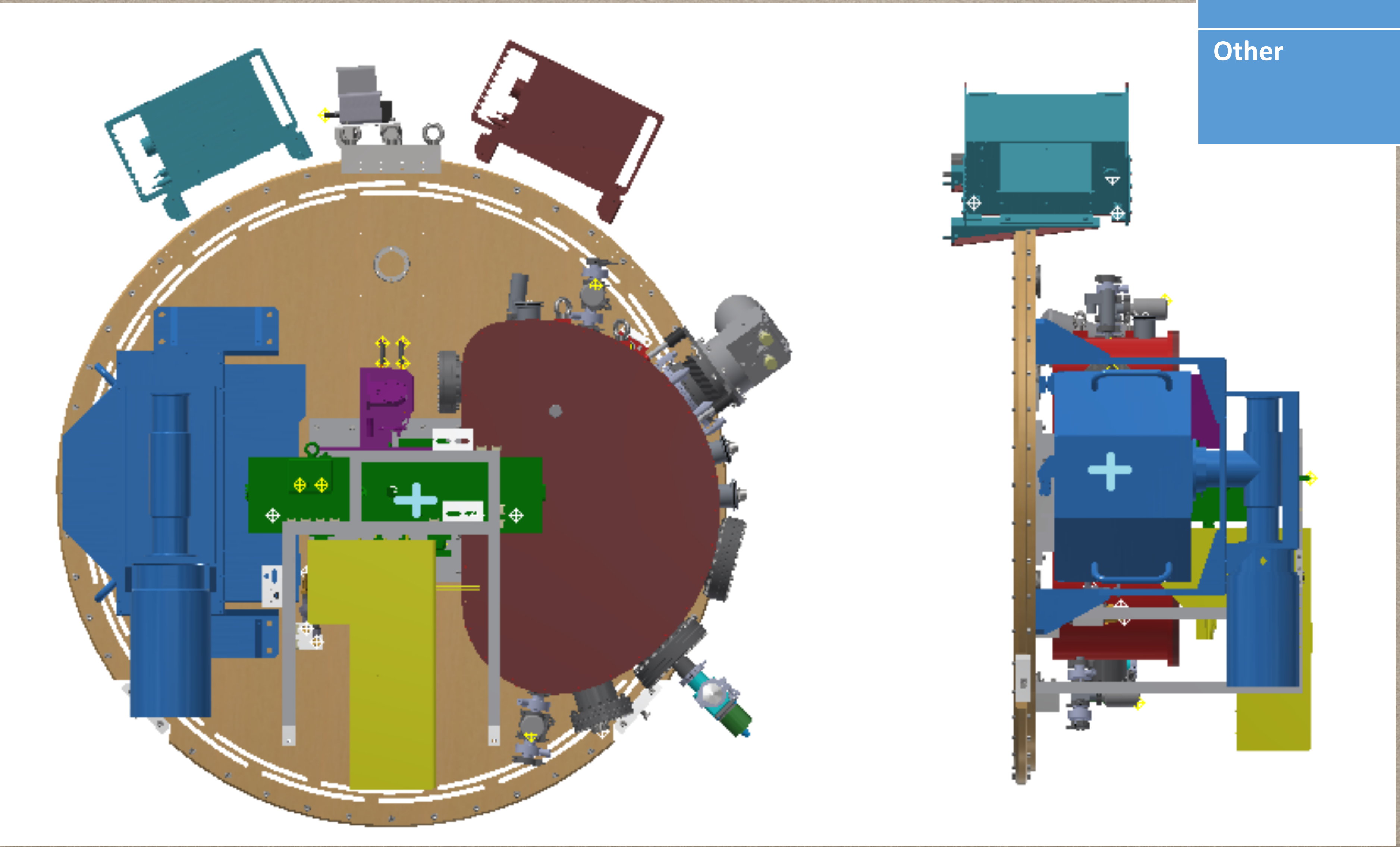




MASS BUDGET

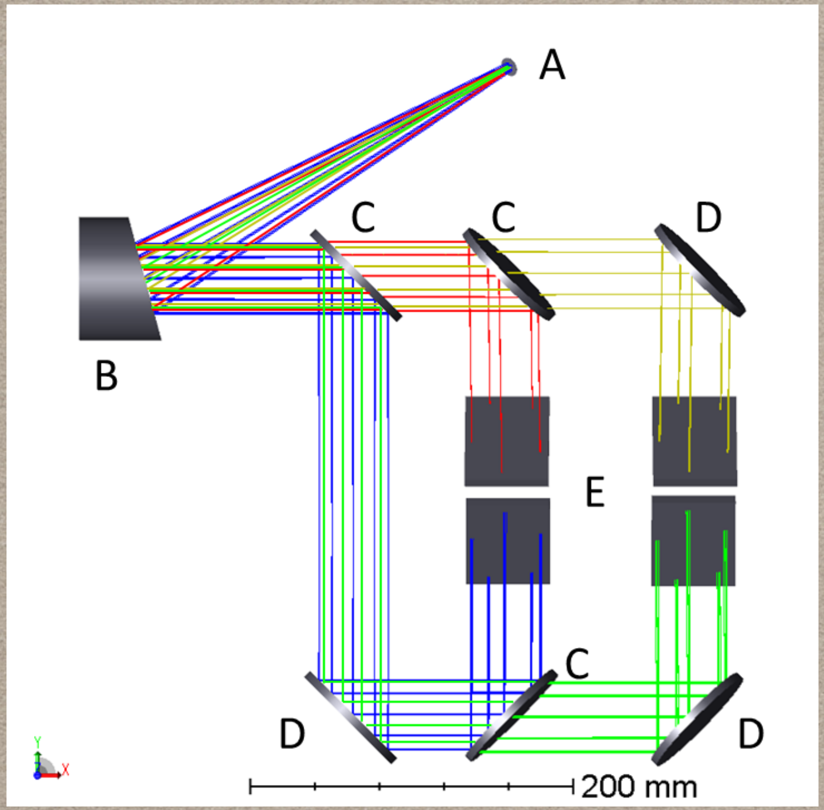
Torque = 28% allowable budget

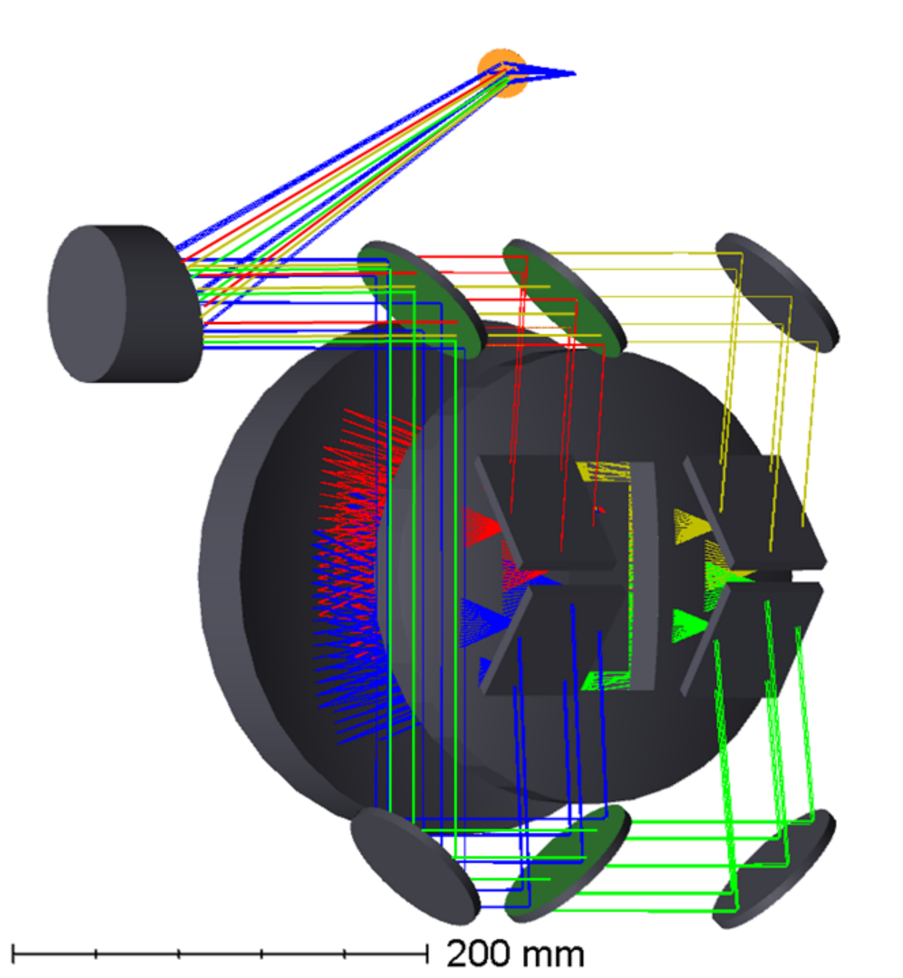
	Mass [kg]
IF flange	332
CP	45
NIR	220
UV-VIS	132
Other	46



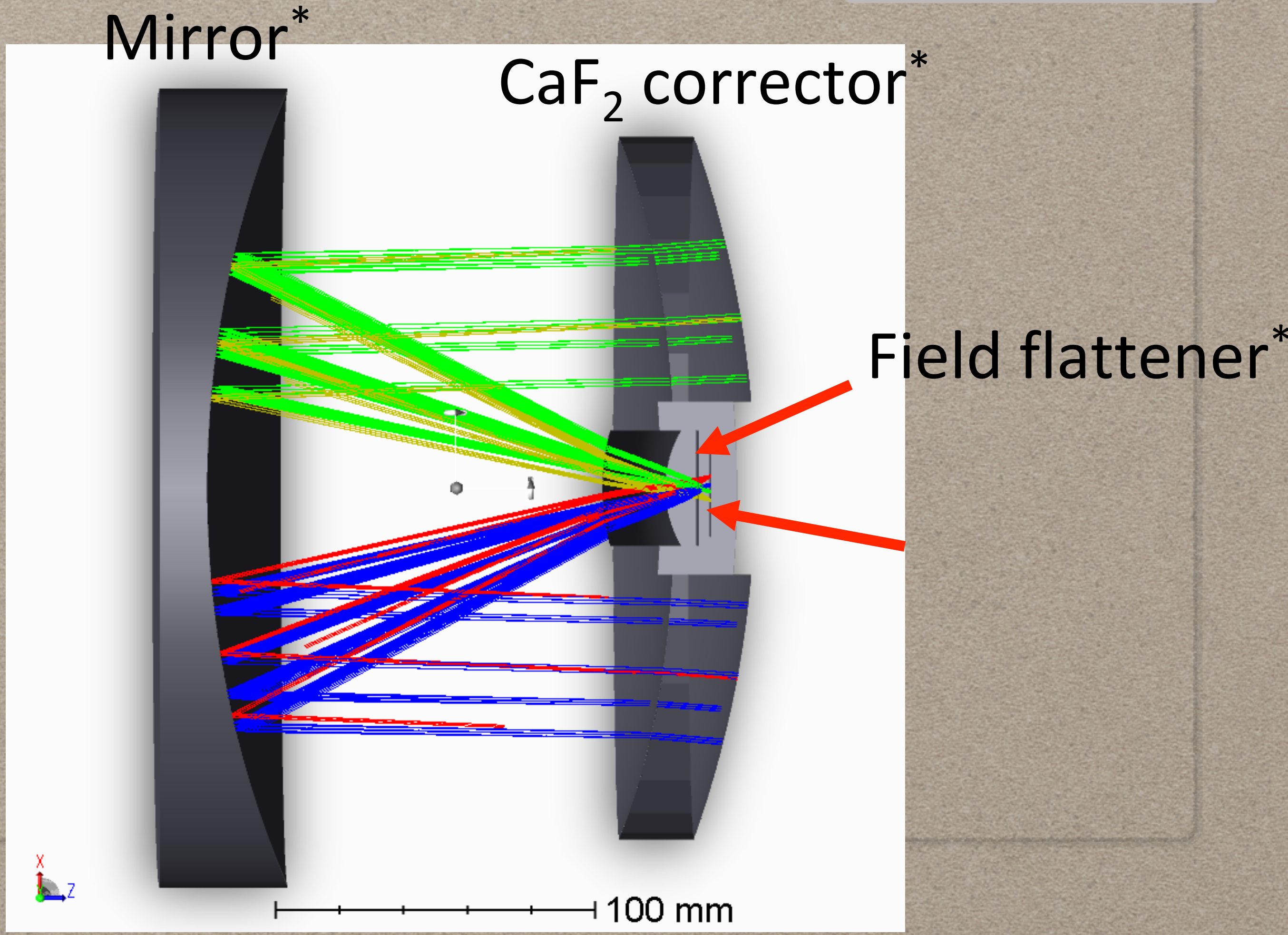
UV-VIS ARM

מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE



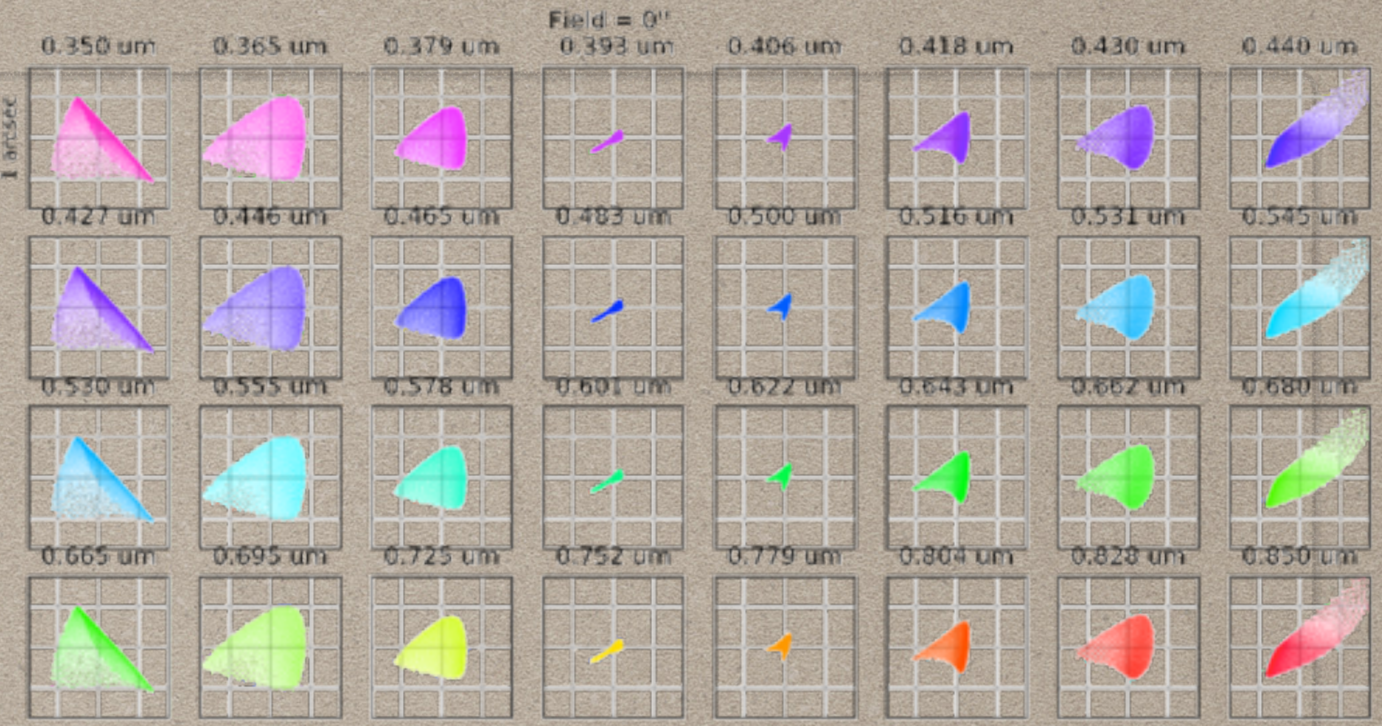


*Aspheric



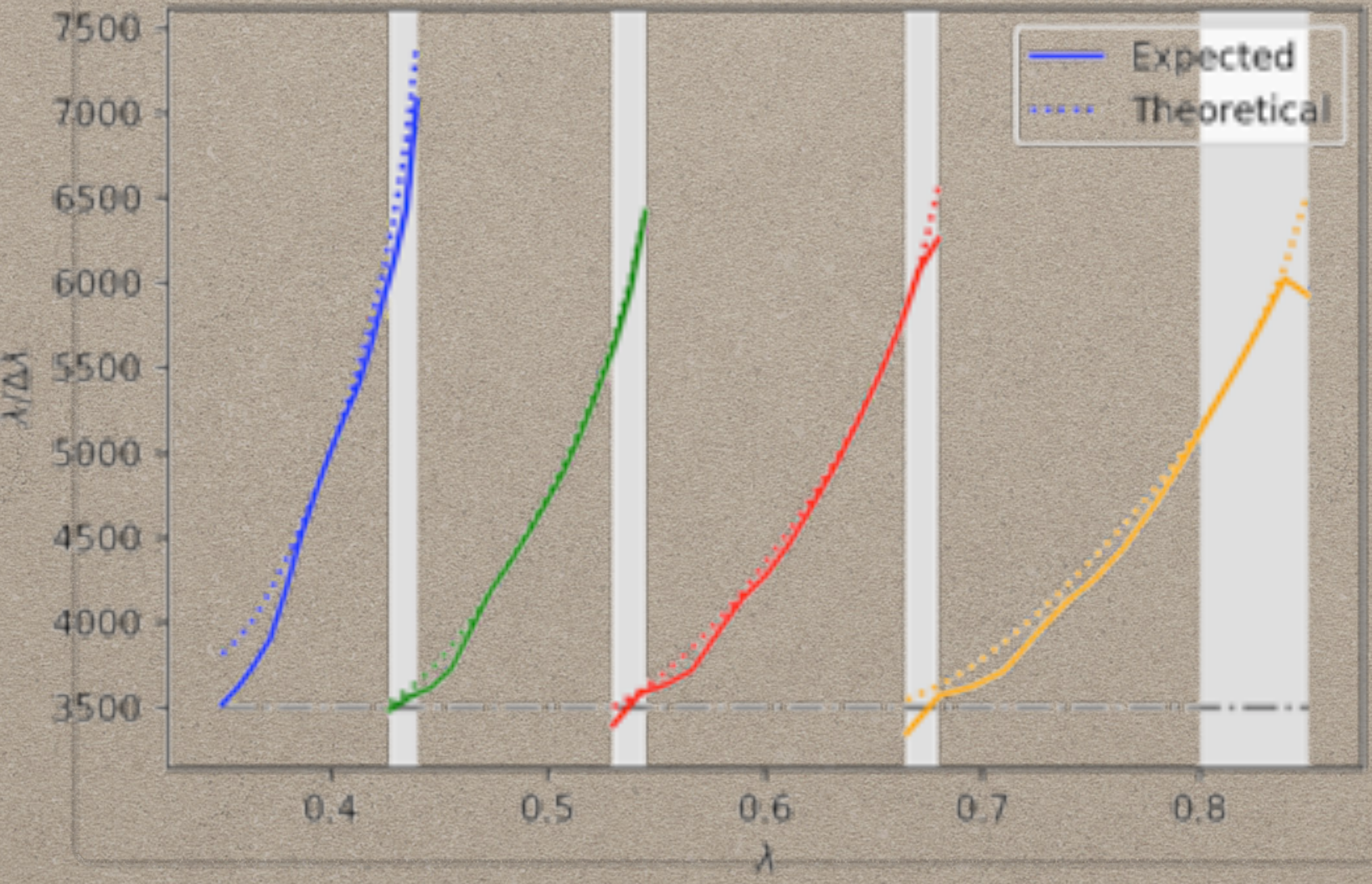
Quasi-Order	Wavelength Range [nm]
u	350 - 440
g	427 - 545
r	522 - 680
i	656 - 850

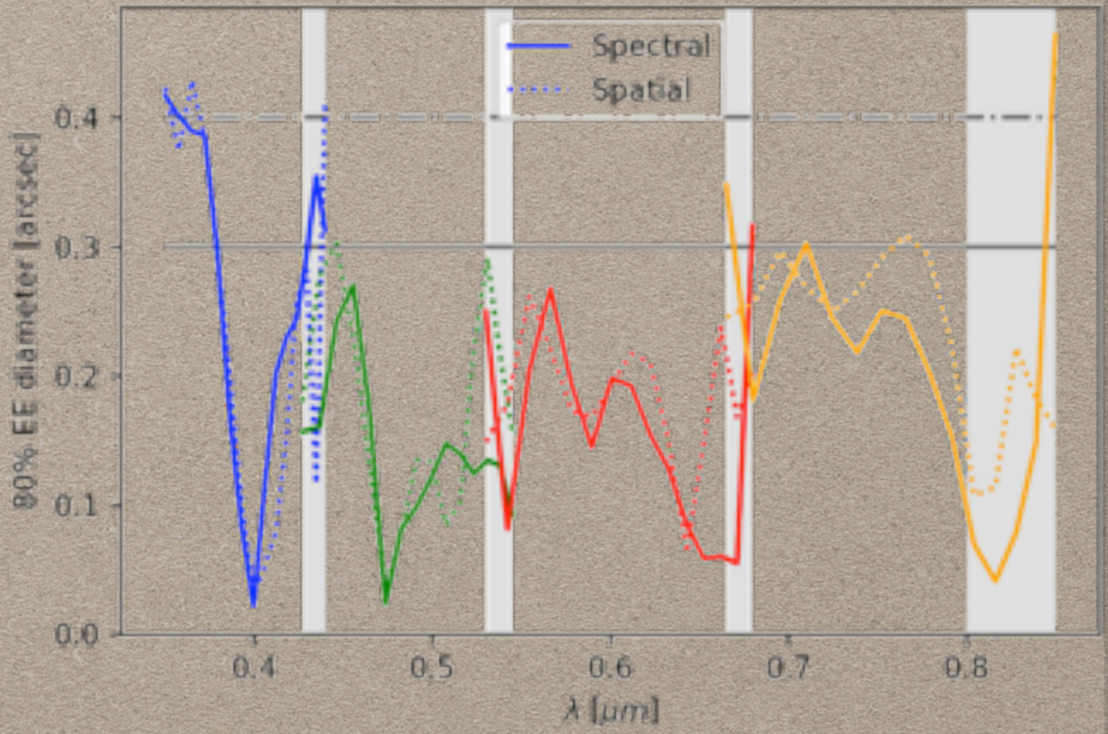
UV-VIS ARM



We use 80% enslitted energy diameter as our figure of merit.

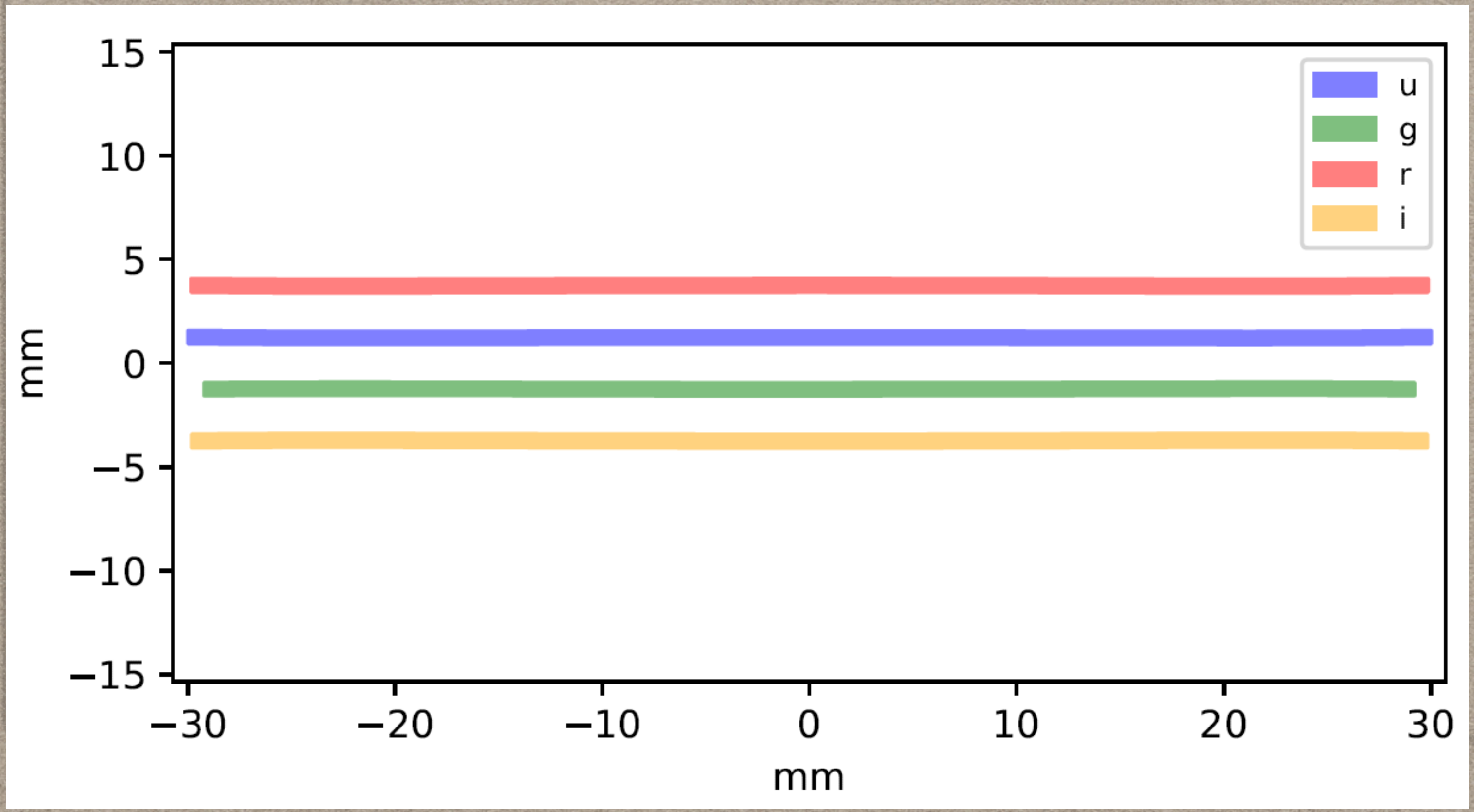
- 80% EE $\leq 0.3''$ for 90% of band on axis
- 80% EE $\leq 0.43''$ for 90% of band slit edge

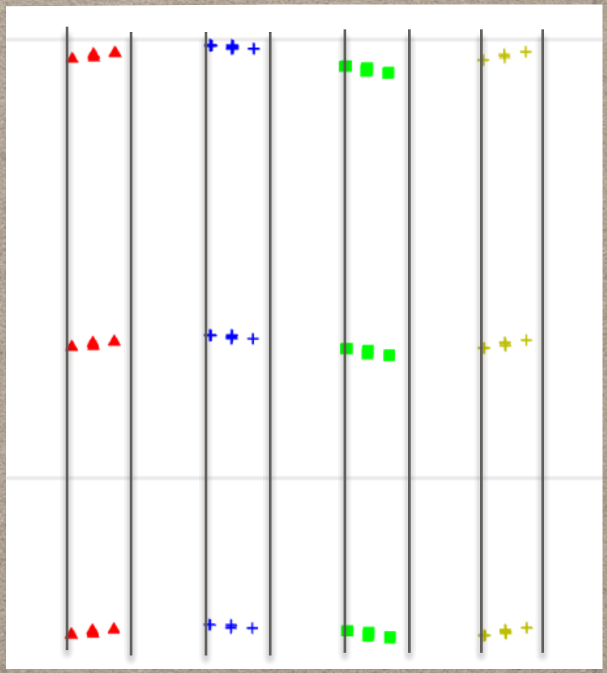




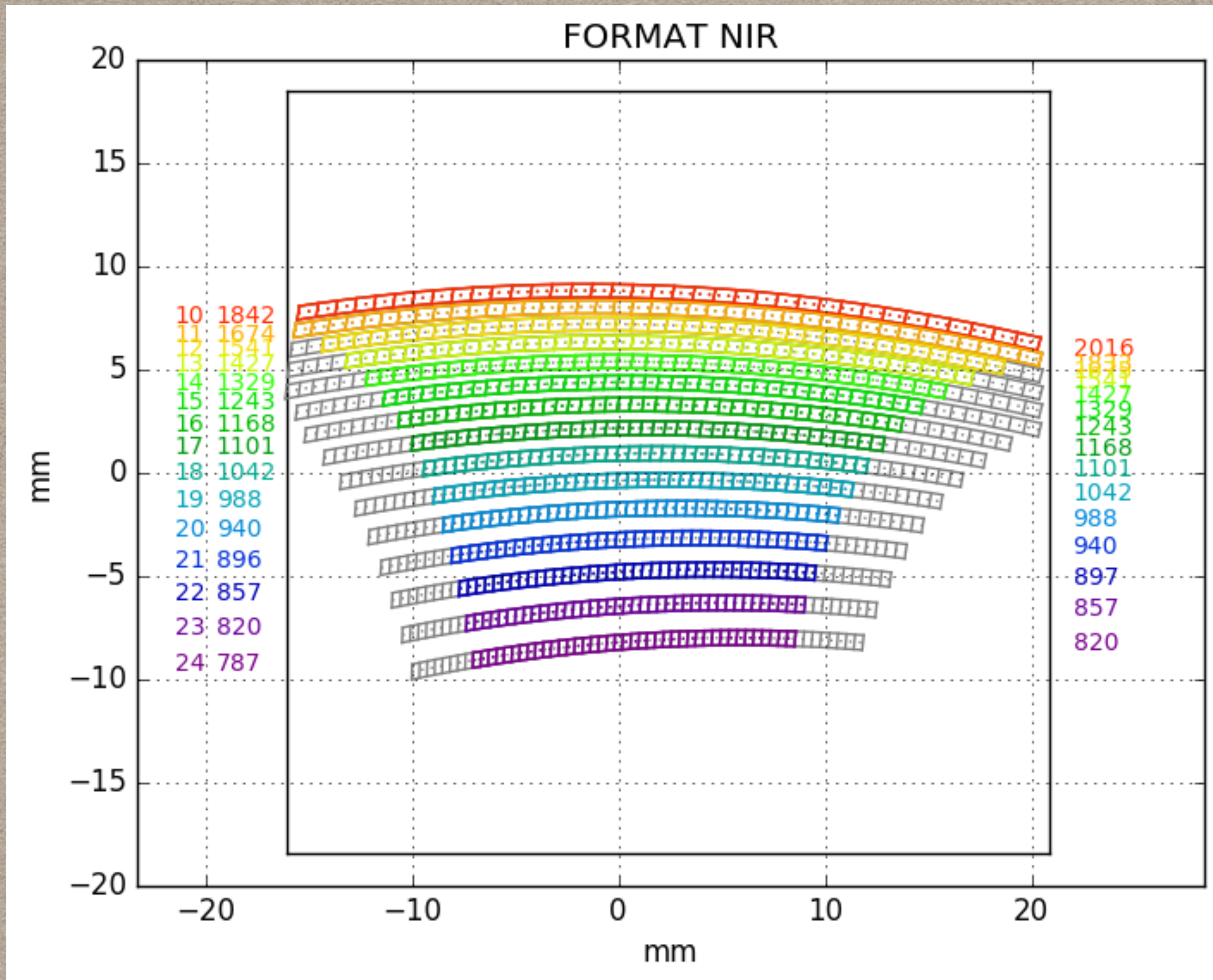
UV-VIS ARM

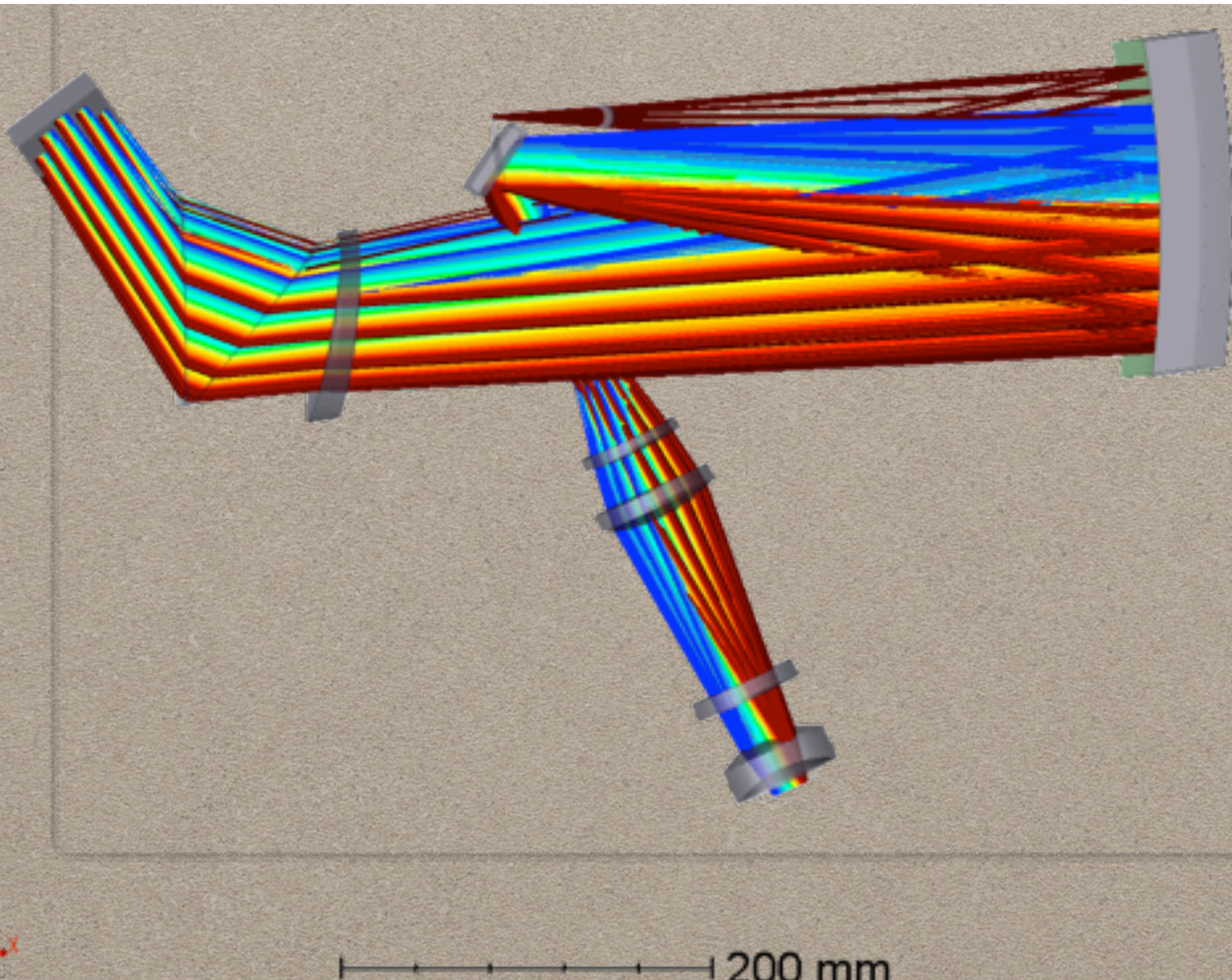
		u	*g*	*r*	*i*
Camera		0.920	0.920	0.920	0.920
UV-VIS Spectrograph		**0.656**	**0.668**	**0.655**	**0.652**
No Contingency		**0.756**	**0.770**	**0.755**	**0.751**
Common Path		0.820	0.820	0.820	0.820
Telescope		0.510	0.510	0.510	0.510
Overall		0.274	0.279	0.274	0.272
	No Contingency	0.316	0.322	0.316	0.314





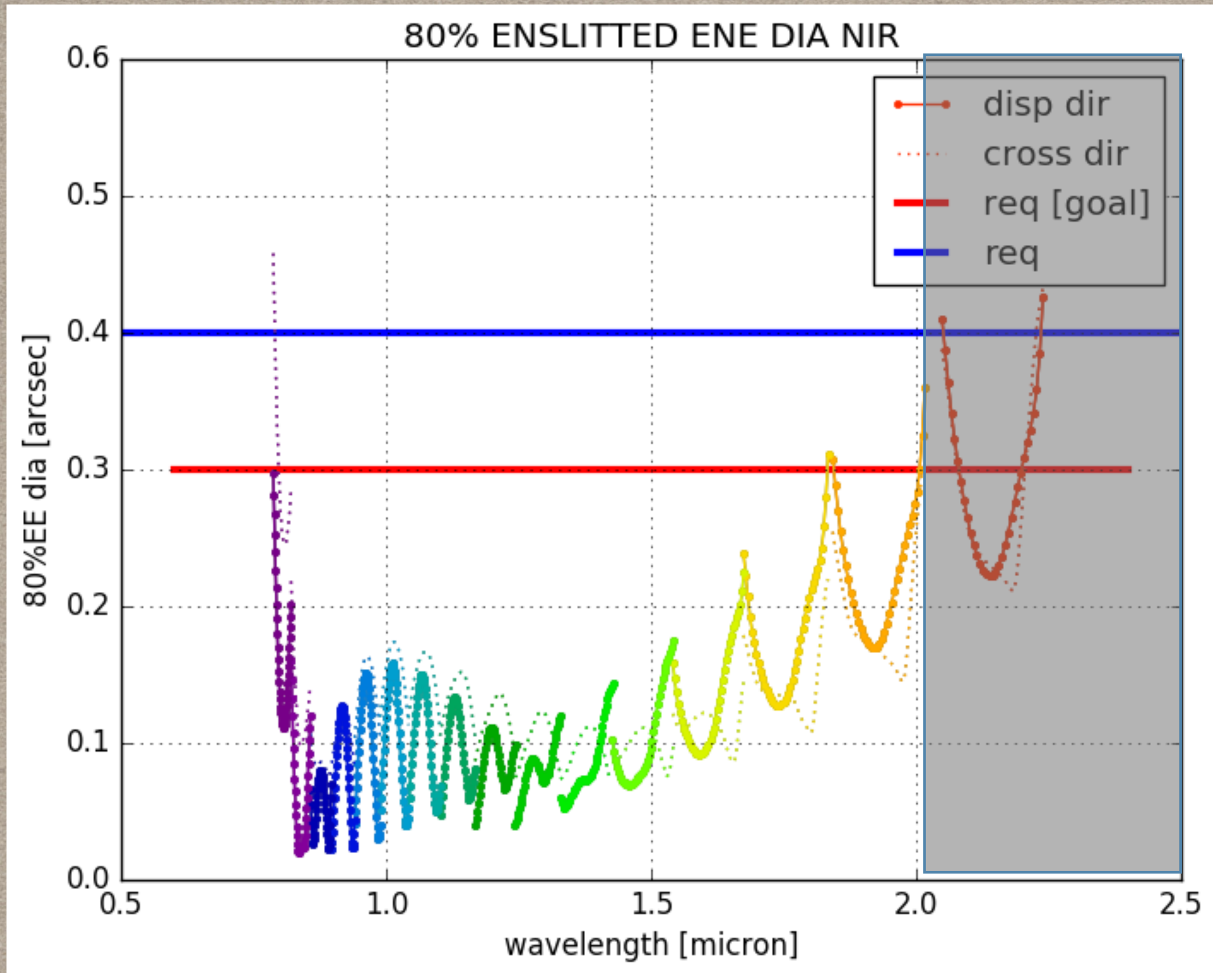
NIR ARM

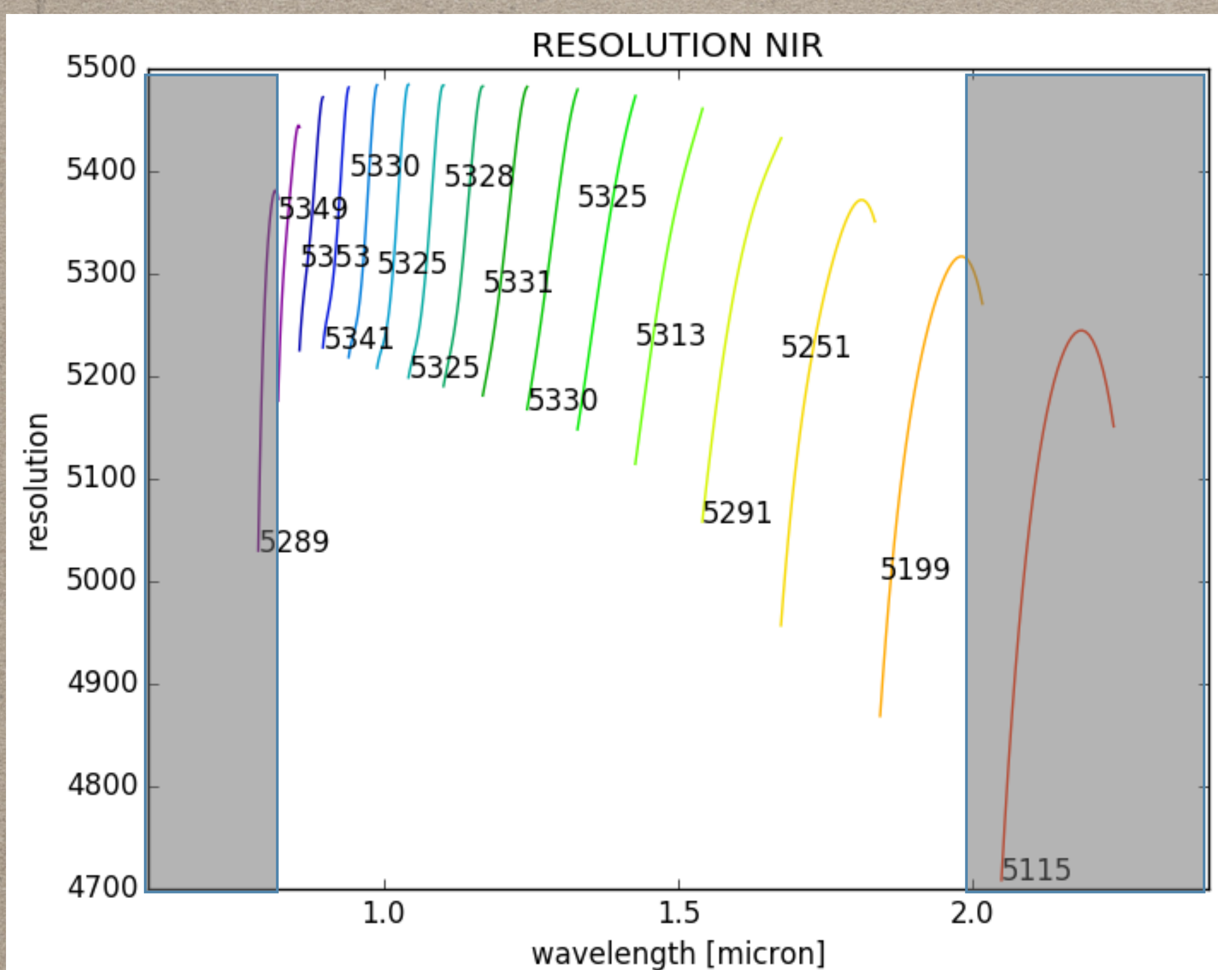


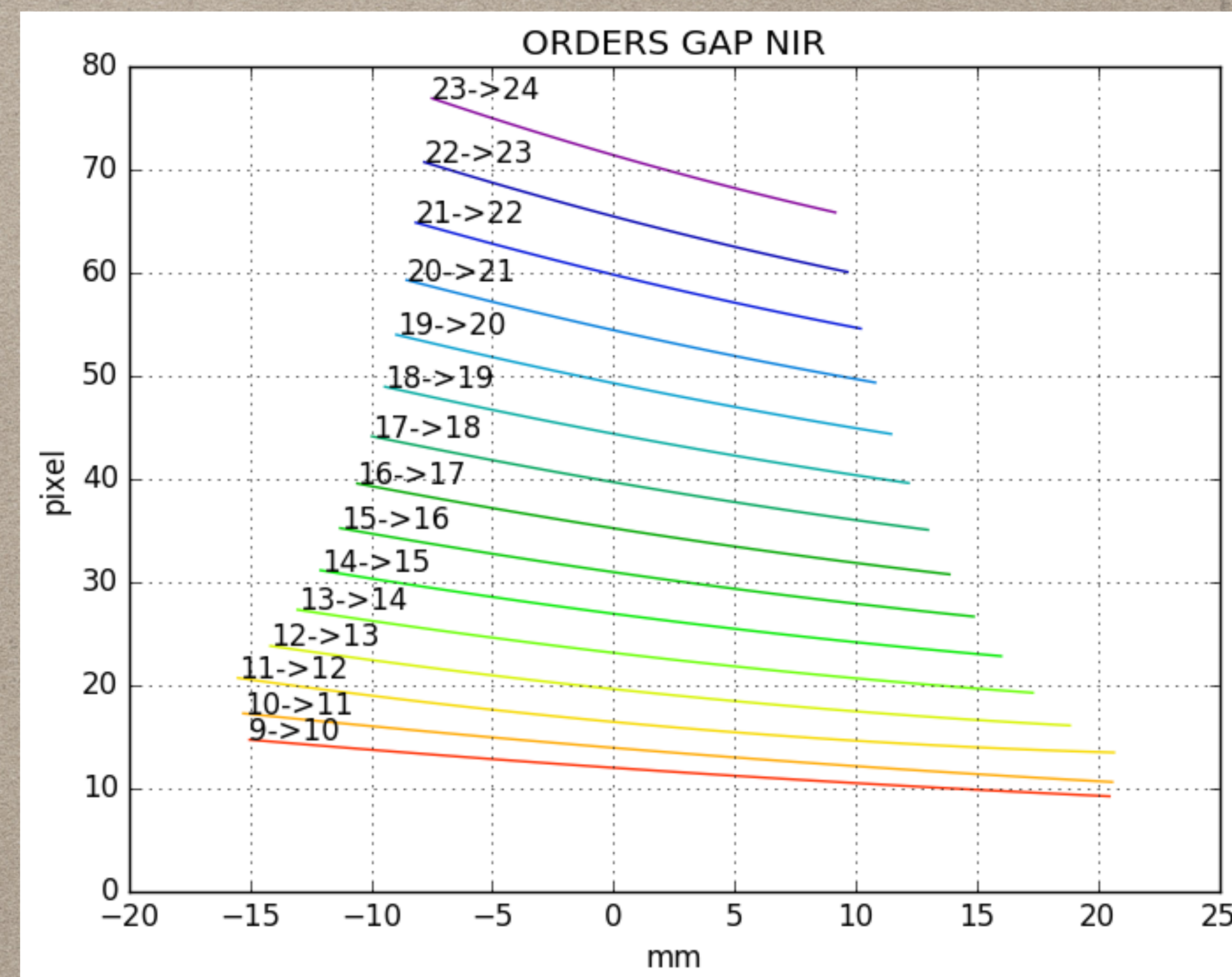


Collimator Focal Ratio	6.5
Collimator Beam diameter	50mm
Spectral range	800-2000 nm
Resolution (1 arcsec slit)	5000
Foreseen slits	0.5 - 1.0 - 1.5 - 5 arcsec
Silt height	12 arcsec
Camera Output Focal Ratio	~3.7
Detector	2K x2K , 18 μm side pixel
Detector Scale	1arcsec/4pixel
Main Disperser	Grating 44° blaze angle, 4° off-plane
Cross Disperser	3 Cleartran Prisms of apex angle 20°, 20°, 26°
Total Volume (optical surfaces)	~700 x450 x200 mm
Working temperature	150K. 40K for the last two elements of the camera and detector

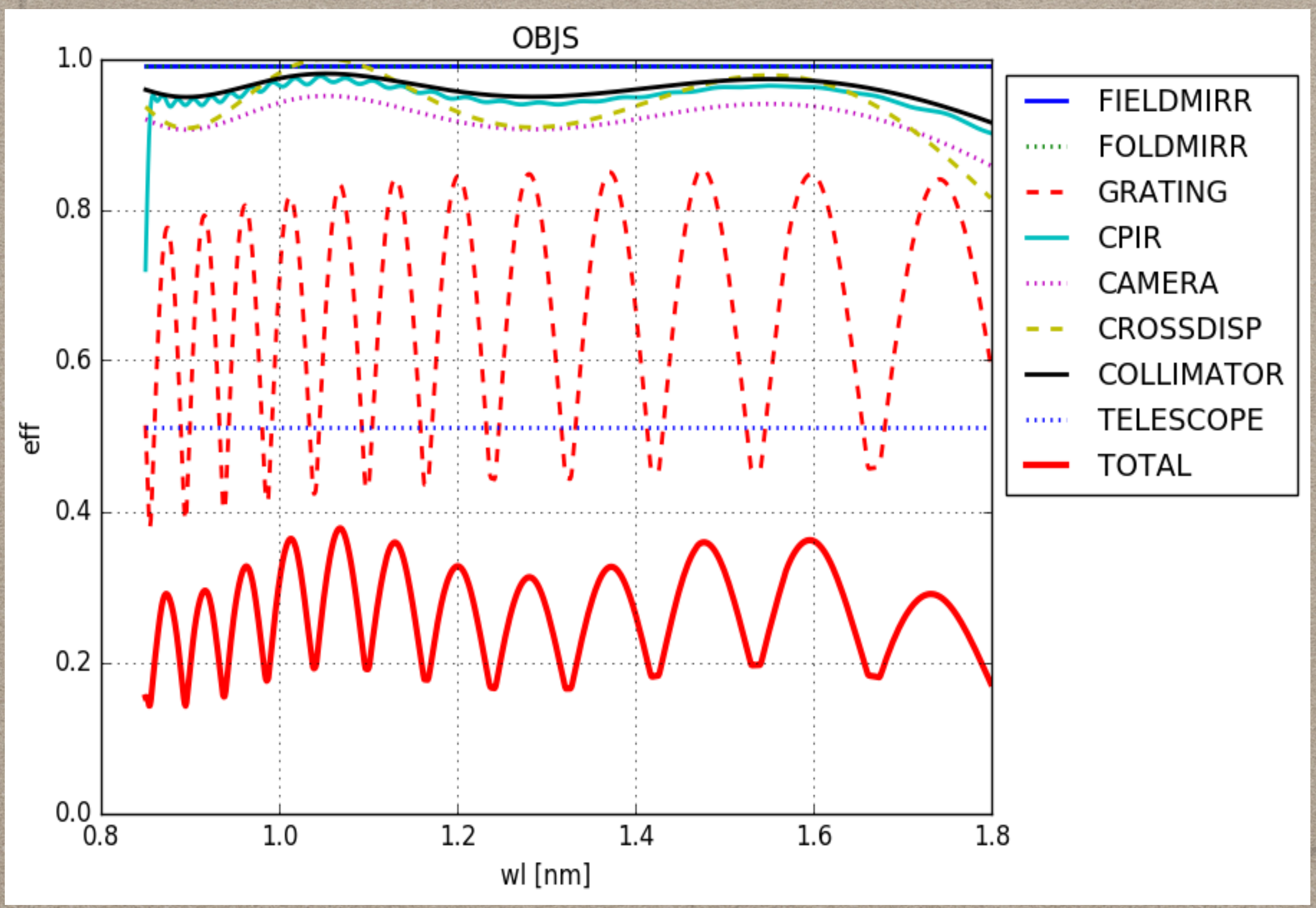
NIR ARM IMAGE QUALITY







NIR ARM EFFICIENCY



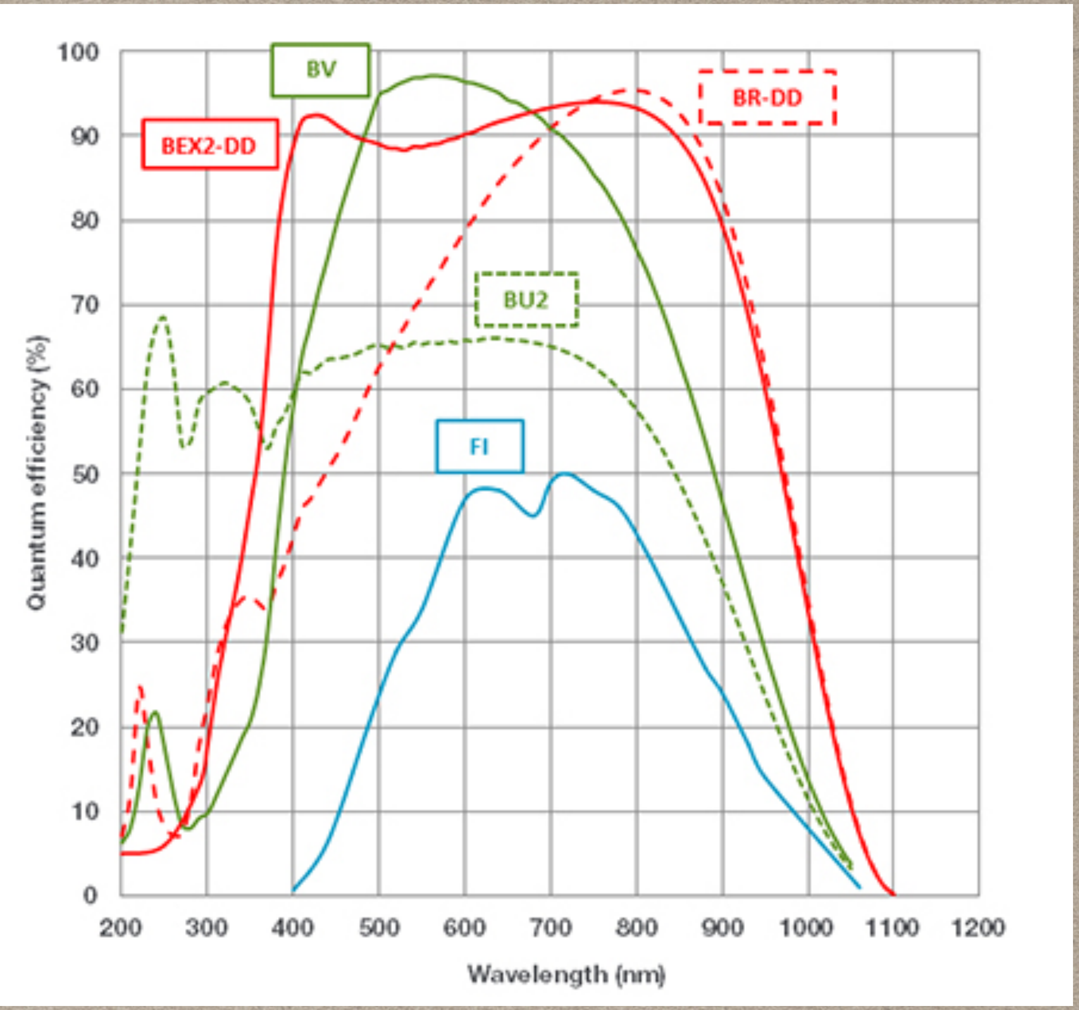
	Tave	Tmax	Tmin	C
Spectrograph				
Folding mirror	0.99	0.99	0.99	0.98
Collimator double pass	0.96	0.98	0.91	0.96
Prisms double pass	0.94	1.00	0.82	0.96
Grating	0.67	0.85	0.37	0.90
Field Mirror	0.99	0.99	0.99	0.98
Camera with filter	0.92	0.95	0.86	0.98
Total Spectrograph	**0.55**	**0.78**	**0.23**	0.78
Total Spectrograph with contingency	0.43	0.61	0.18	
Common Path	0.95	0.98	0.72	0.90
Telescope	0.51	0.51	0.51	1.00
Total Overall	**0.26**	**0.39**	**0.09**	**0.70**
Total Overall with contingency	**0.19**	**0.27**	**0.06**	

ACQUISITION CAMERA

	Value
Field of View (FOV)	3.5 arcmin x 3.5 arcmin
Detector wavelength range	Up to 1.0-1.1micron, with QE>20%
Filters	u, g, r, i, z, y (LSST) and V (Johnson)
Image quality	Scale < 1 arcsec/pixel
Detector format	1k x 1k optimized for NIR QE
Pixel size	13 micron
Frame Rate	High Frame rate (up to 5MHz)
Readout noise	Low read out noise (3.0e-)
Volume	600mm x 340mm x 393 mm
Back focal plane	500mm
Position	Close to the Nasmyth flange/ at least 110mm from the optical axis
Design	*Based on Xshooter A&G*

ACQUISITION CAMERA

- Andor iKon M-934
- CCD sensor BEX2-DD (Broad band coverage and higher NIR-QE)

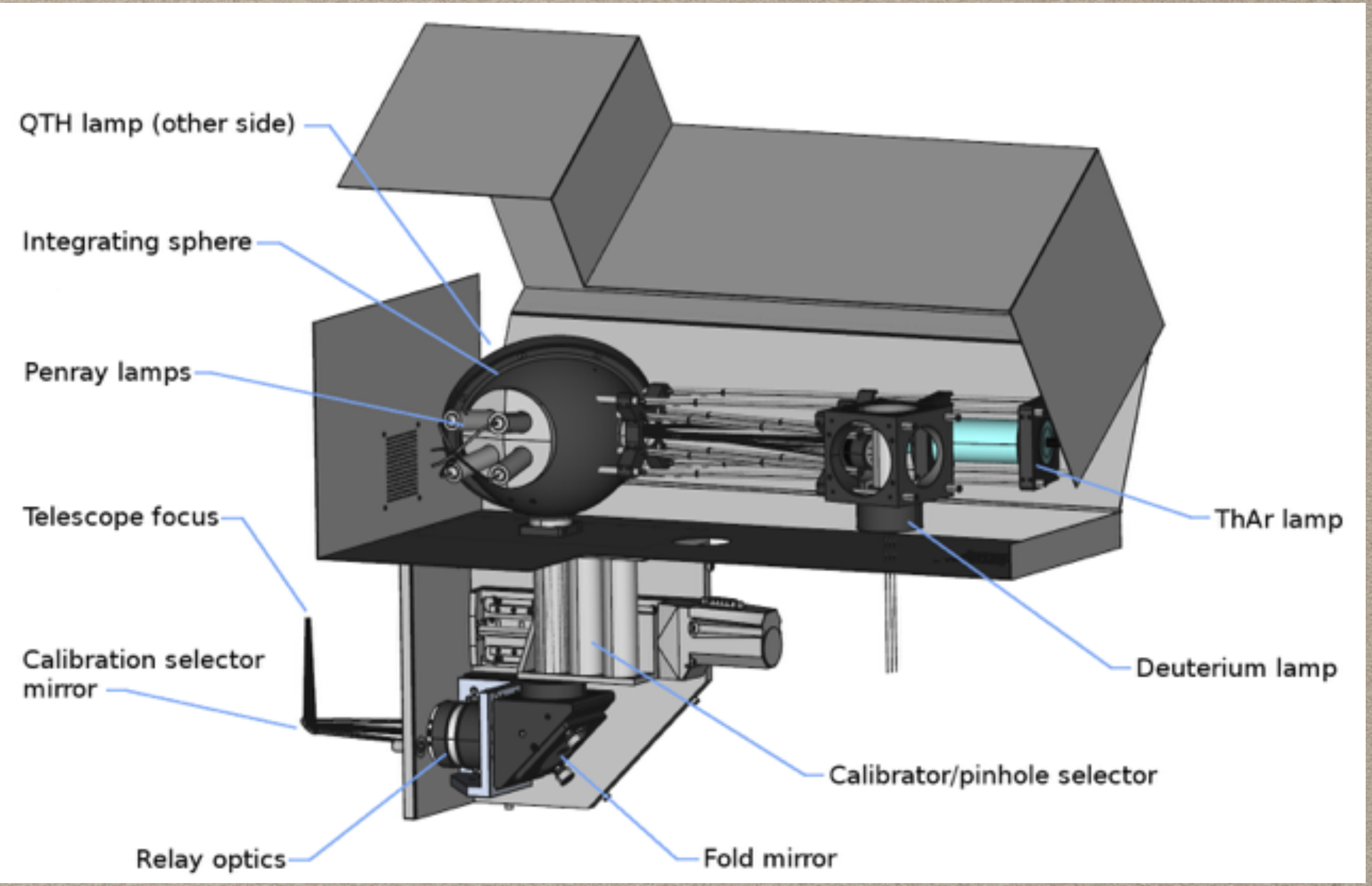


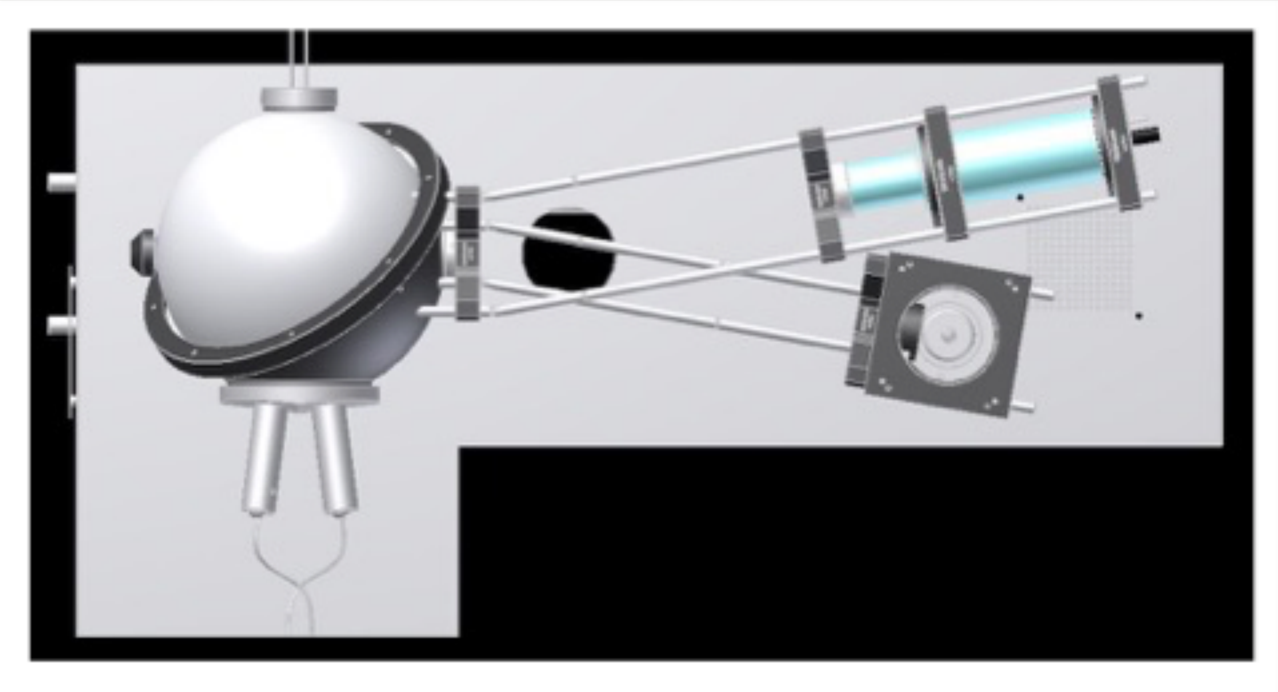
LSST Band (Wav)	1 sec	2 sec	3 sec	5 sec	10 sec	15 sec	20 sec
u' (355.7nm)	15.9	16.7	17.5	17.7	18.4	18.7	19.1
g' (482.5nm)	18.2	18.9	19.4	19.8	20.5	20.8	21.0
r' (626.1nm)	18.0	18.6	19.0	19.5	20.0	20.3	20.4
I' (767.2nm)	16.4	17.1	17.5	17.9	18.4	18.6	18.8
z' (909.7nm)	15.3	15.9	16.2	16.5	16.9	17.2	17.4

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

CALIBRATION UNIT

Turun yliopisto
University of Turku





- QTH, penrays, each uses 1 port
- D2 + ThAr occupy 1 port
- —> COTS 4-port sphere (Labsphere)
- cable feedthrough at bottom side, ventilation grills
- cover + hinge for easy lamp access, with interlock

END OF FIRST HALF

TIME FOR ADVERTISEMENT

ASTRONOMY & ASTROPHYSICS TURNS 50

A&A is the European Journal of astronomy under the legal umbrella of ESO.

Birthday celebration at the IAU General Assembly in Vienna this August.

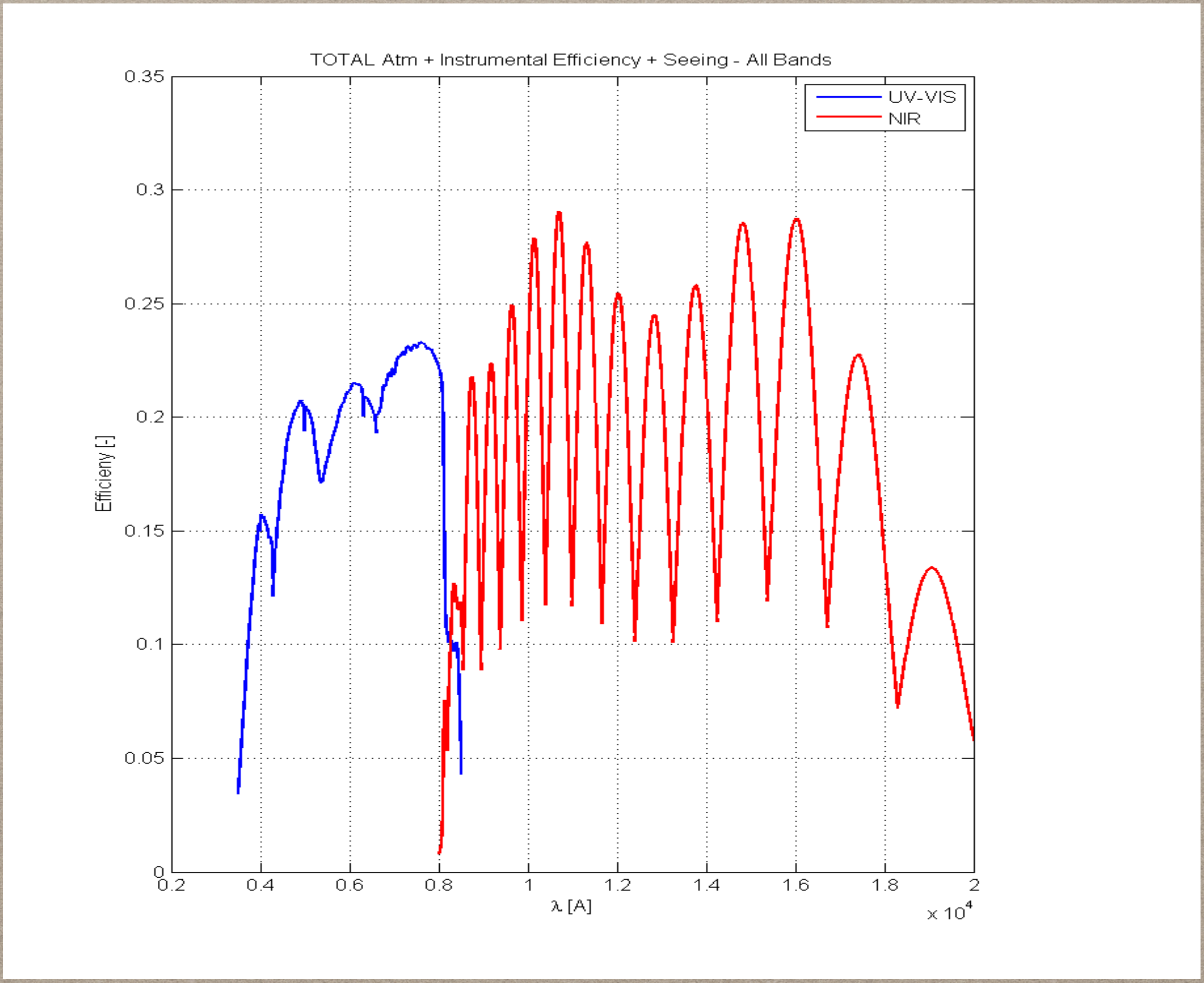
A&A Letter has recently changed its policy becoming a high-impact, fast publication, no page limits on supplementary material, and free of charge to the world

Impact Factor 2018
A&A 5.57
ApJ 5.55
MNRAS 5.19

END OF ADVERTISEMENT

SECOND HALF

EXPOSURE TIME CALCULATOR



1 arctic slit - after atmosphere convolution @ zenith

ETC

Give input:

Blackbody Temperature [K]

5600

Power Law Index

0

Magnitude

20

Redshift

0

Lambda

5000

FWHM

1

Flux [erg/cm^2/s]

1

Airmass

1

Seeing

1

Exposure time

3600

nframe

1

Target Input Flux Distribution

- Black body
- power-law
- Template Spectrum
- User define
- Single emission line

Template Spectrum: O5

Band m: R

Magsystem: Vega

Moon: +-0

Slit: 1.0

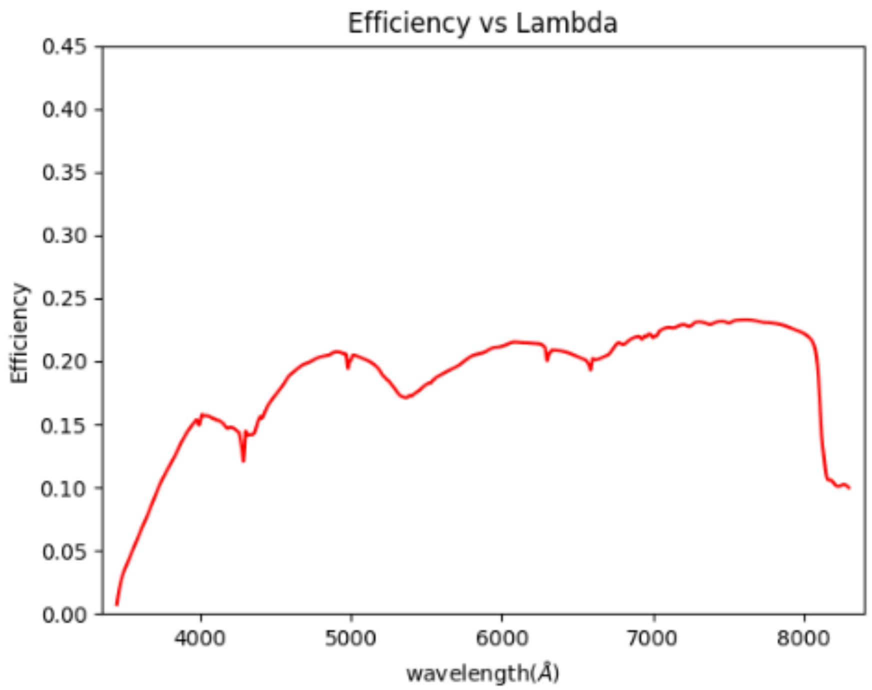
Binning x: 1

Binning y: 1

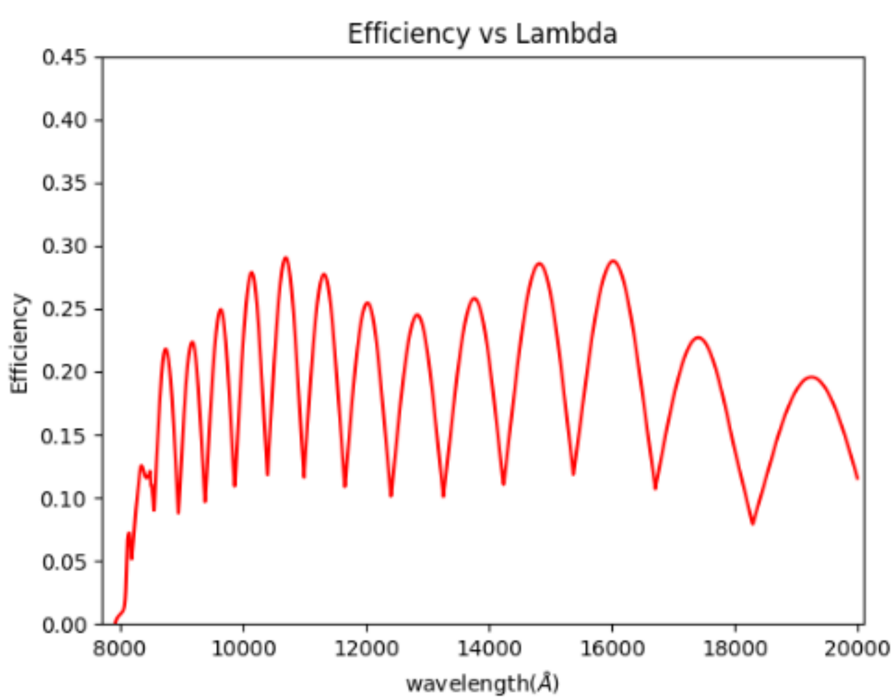
CALCULATE

ETC

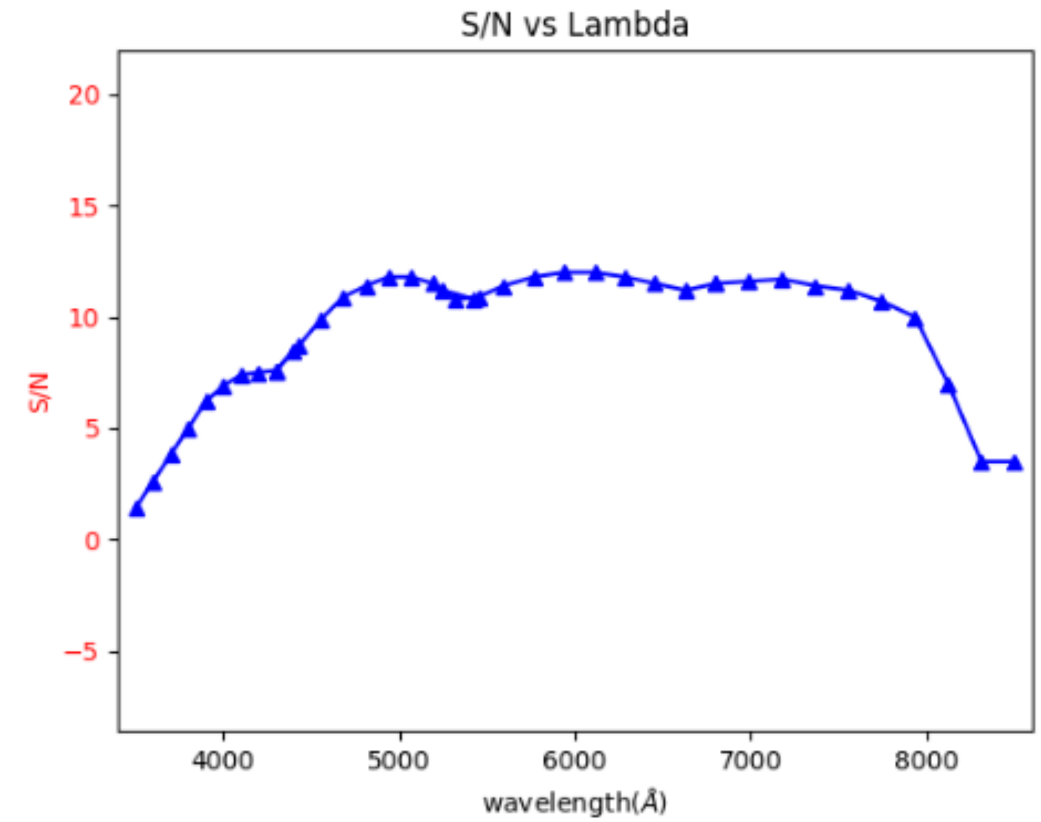
UV-VIS Arm plot:



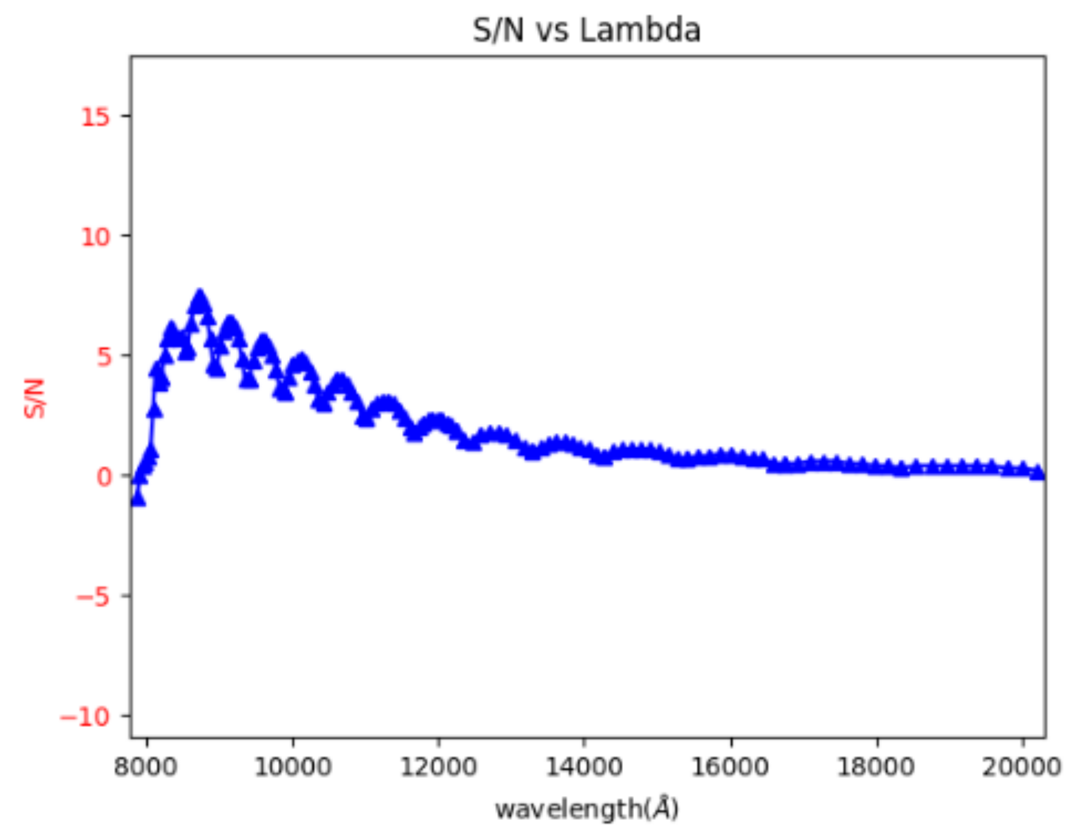
NIR Arm plot:



UV-VIS Arm plot:



NIR Arm plot:



TIMELINE (TIGHT!)

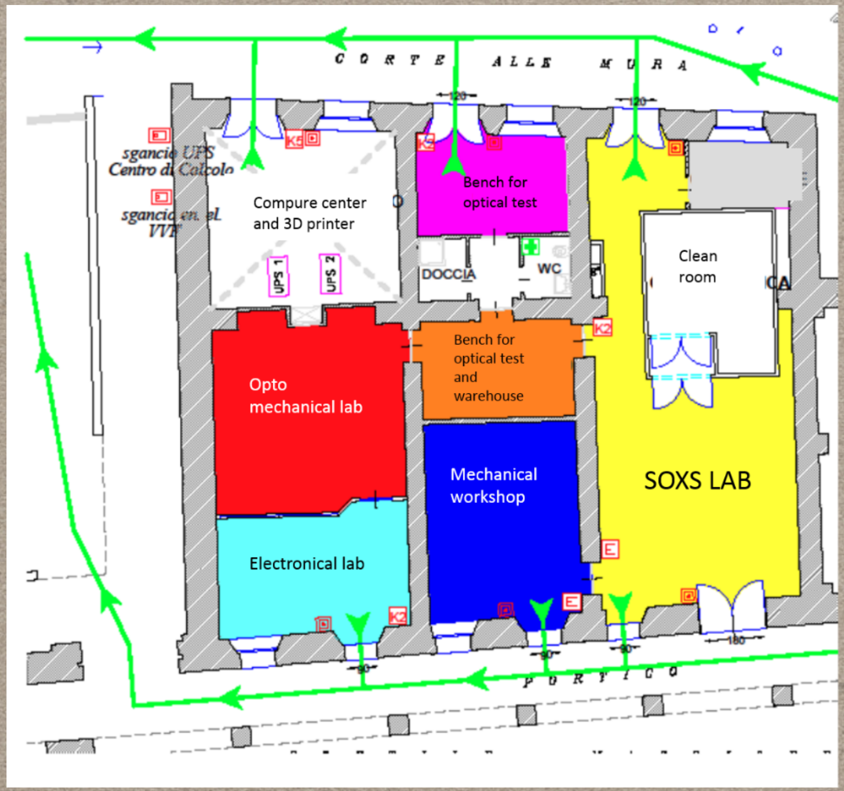
Project Phase	Start	End	Duration	
Preliminary Design	08/2016	07/2017	12 months	*Jul , 21-22* ✓
*Final Design	08/2017	07/2018	12 months	*Jul, 20-21* ✓ *
MAIT	02/2018	06/2020	29 months	
Inst. & Commissioning (Chile)	09/2020	03/2021	7 months	
Operations	2021		TBD	

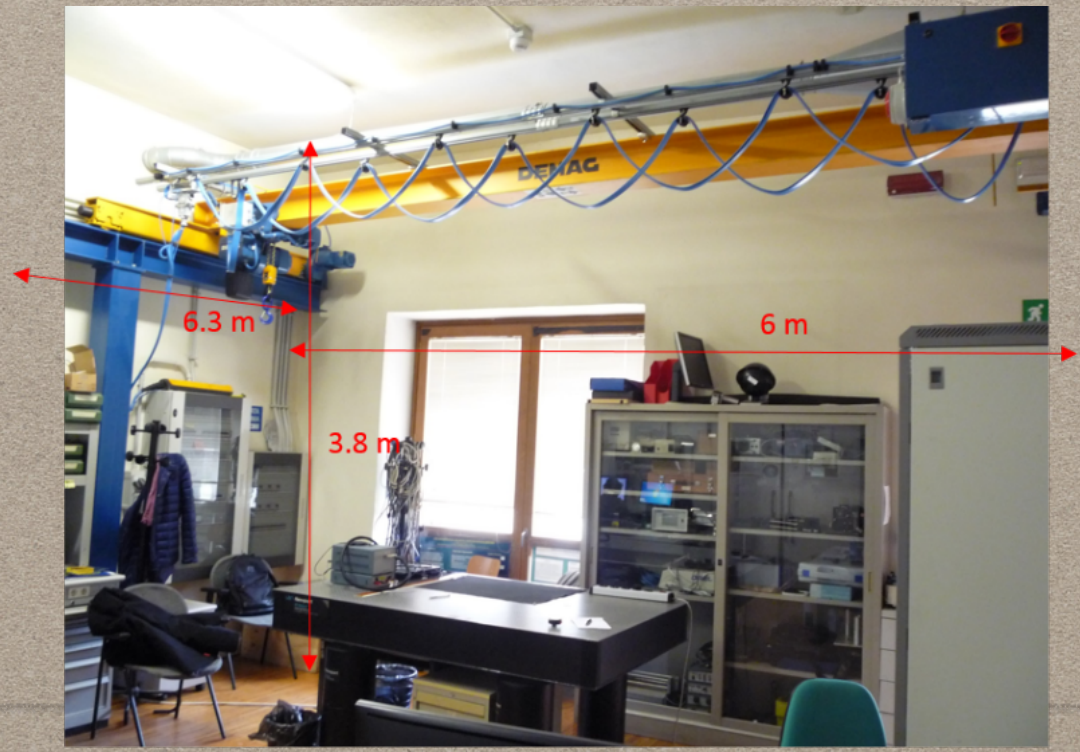
LSST - CTA - SKA

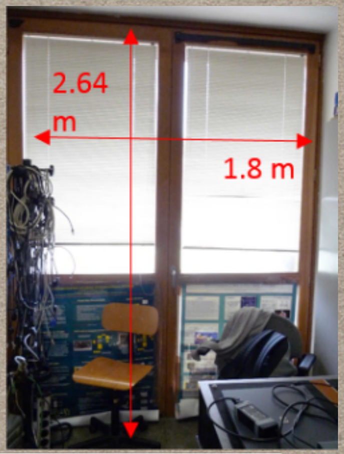
*good timing with **GW experiments** (4 detectors) -*

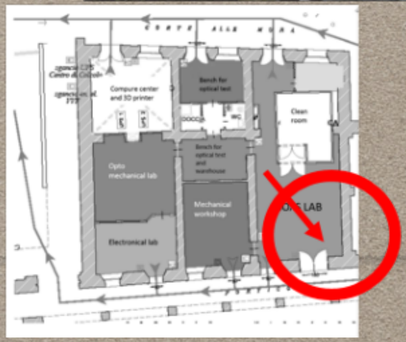
BUILDING SOXS

1. Procurement + SOW
2. Pre sub-system integration = tests on components + facilities
3. Sub-system integration and tests
4. Assembly Readiness Review
5. European System integration and tests
6. System integration and tests @ NTT

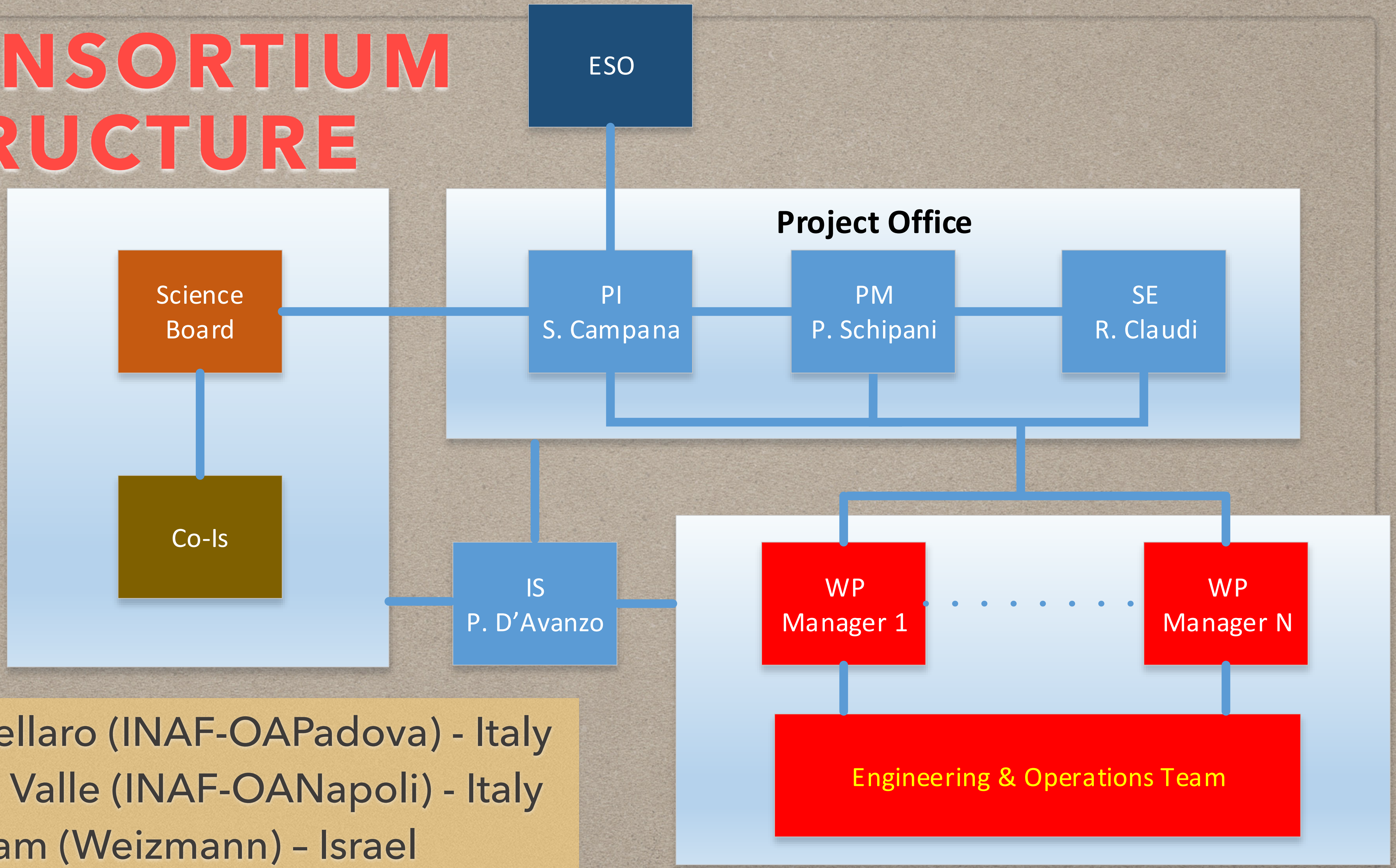








CONSORTIUM STRUCTURE



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
J. Fynbo (NBI) - Denmark
S. Campana (INAF-OABrera) - Italy

RESPONSIBILITIES

Italy ~ 45% (CP, NIR-arm, integration, management, etc.)

Israel ~30% (UV-VIS arm optics and mechanics)

Chile ~10% (Acquisition camera)

UK ~10% (VIS-CCD, reduction pipeline)

Finland ~5% (Calibration Unit)

OPERATIONS

SOXS is an instrument dedicated to the study of transient and variable sources. Some of them are predictable (eclipses, transits, periodic variability), some others have long reaction times (from days to weeks, SN, blazar variability monitoring, binary X-ray transients), but other need fast reaction times, within one night or less.

As a reward for the construction of SOXS, ESO will compensate the SOXS Consortium for 180 n/yr for 5 yr (MoU SOXS-ESO, already signed on the ESO side) at the NTT in La Silla (+5 yr TBD)

INTEGRATED APPROACH

SOXS Consortium will manage the **entire** schedule including 'SOXS' time and 'ESO' time.

SOXS GTO will pass through OPC with clear triggering criteria.

Schedule day-by-day, optimising for into account the Moon, airmass, seeing, water vapour, sky brightness, wind direction constraints.

Overall balance among ESO and SOXS time in terms of dark-grey-bright time, water vapour, seeing, etc.

MOUNTAINS 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).

SOXS people
will prepare the night schedule in advance
one scientist will remain on-call for problems and for **changing** the schedule in case of unforeseen fast-track events

ESO people
Observations are carried out by the night operator at the NTT telescope.

DATA MANAGEMENT

Data will be first processed on the mountain with the SOXS pipeline and simultaneously transferred to the ESO archive in Garching (10 min). Data processing should be very quick. Quick look on the mountain.

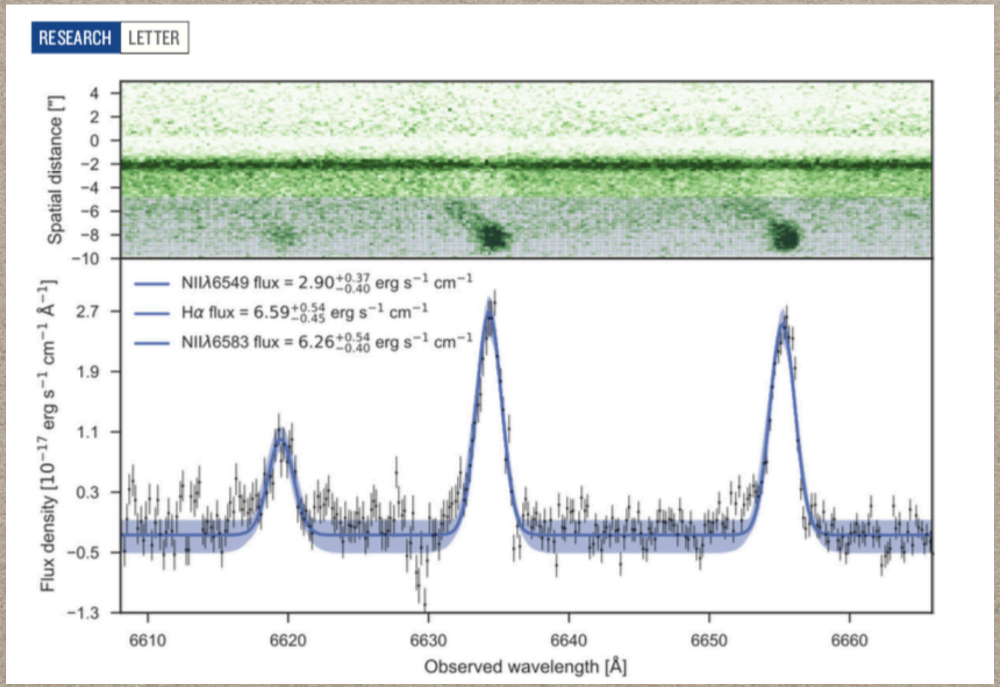
Standard 2D & 1D spectra will be available.

Data will be fully compliant with ESO standard.

Data reduction pipeline will be public.

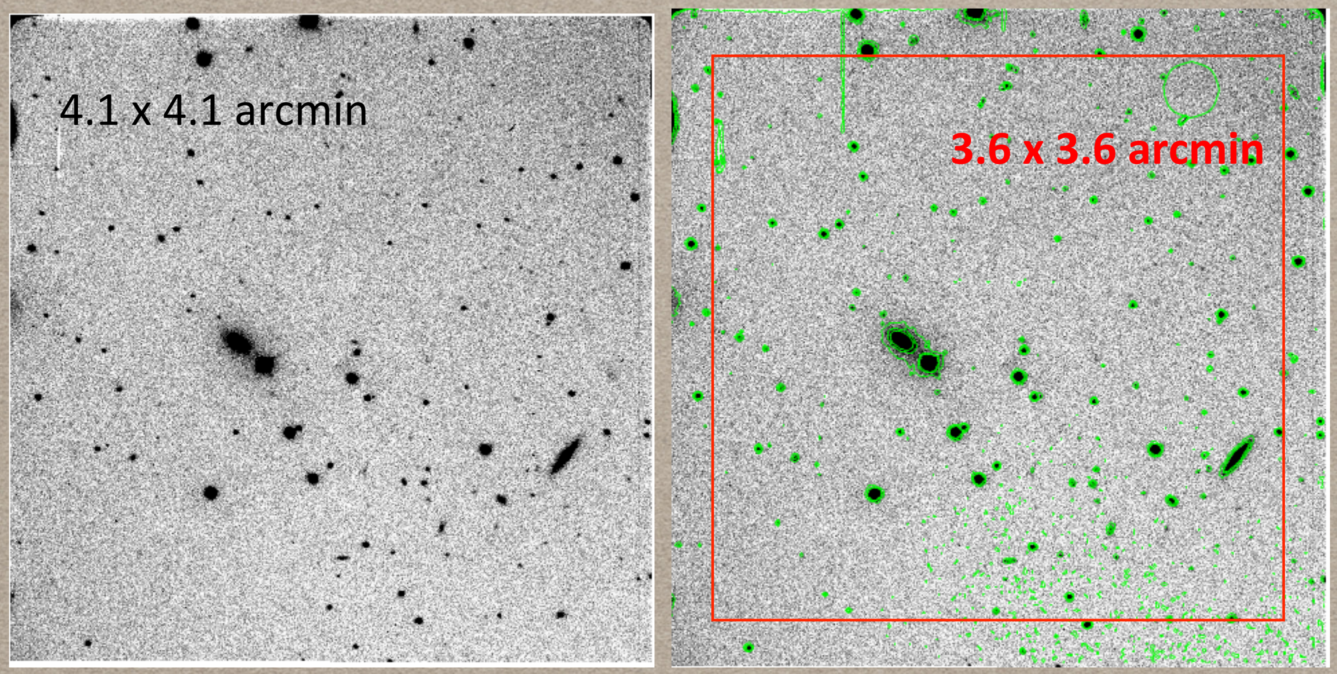
PIPELINE

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



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

Absolute flux calibration



Example : EFOSC2 automated calibrated image with PESSTO pipeline.
With sextractor objects

- SOXS acquisition camera
- Filters *ugriz*
- Automated astrometric and photometric calibration using
- Pan-STARRS, ATLAS RefCat (to dec > -40^{o}) + SkyMapper, DES, LSST
- Pipeline can use *g or r* band image to scale flux (or allow for *g* + *z* and can then do both VIS + NIR)
- Reliable absolute flux – pipeline should ensure reliable ***relative flux calibration***
- Acq camera images – flux calibration to ~ few % (irrespective of photometric conditions)

DATA POLICY

Consortium data will remain private for 12 months.

SOXS will take classification spectra of sources from (mainly) optical surveys.
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.

SUMMARY

SOXS @ NTT from 2021
Medium resolution (~4,500)
Broad-band (350-2000 nm)
ugrizy-V imaging (3′x3′)

180 n/yr for 5 years
Possibility to trigger every night
Fast reaction (probably the only instrument mounted at NTT)

GTO is fully dedicated to transient and variable sources


SOXS

Source class	Obs. Time	Key project & Aim
All	500 hr	Fast characterization of transients from other surveys
Open	500 hr	Open time for spectroscopic ToO observations
Asteroids & TNO	200 hr	Characterization of populations of minor bodies, input to models of solar system formation and mitigation of impact hazard
Comets and new comets	100 hr	
Planetary transits	200 hr	Monitor of >5 bright stars for primary and secondary eclipses
Young stellar objects	100 hr	
Stars	100 hr	
X-ray binary transients	200 hr	Derive the mass function of >10 XRB transients in outburst
Magnetars	50 hr	Fast follow up of >10 magnetar's flares
Novae	100 hr	
ILOT	300 hr	
SN Ia	500 hr	Statistical sample of >150 SNe Ia in the low-z Universe to study the local properties and dust extinction
CC-SN	500 hr	
Super-luminous supernovae	500 hr	Build a statistical spectroscopic sample of SLSN
Prompt GRB	100 hr	Fast spectroscopy of >50 GRBs to probe the galaxy host medium
High-z (z>5) GRB	50 hr	Transmission spectra of >5 high-redshift GRBs
GRB-SNe	100 hr	Follow the evolution of >5 SN associated to nearby (z<0.3) GRBs
Active galactic nuclei and blazars	200 hr	
Tidal disruption events	100 hr	Study the spectral evolution of >10 TDEs
Gravitational Wave triggers	200 hr	Spectroscopic follow up of candidate GW counterparts. This includes kilonovae from short GRBs.
Neutrino triggers	100 hr	Spectroscopic follow up of candidate neutrino counterparts
Unknown	300 hr	

PRELIMINARY