München, January 31, 2018
GW meeting

SON OF X-SHOOTER

SOXS

SERGIO CAMPANA
OSSERVATORIO ASTRONOMICO DI BRERA

ON BEHALF OF THE SOXS CONSORTIUM

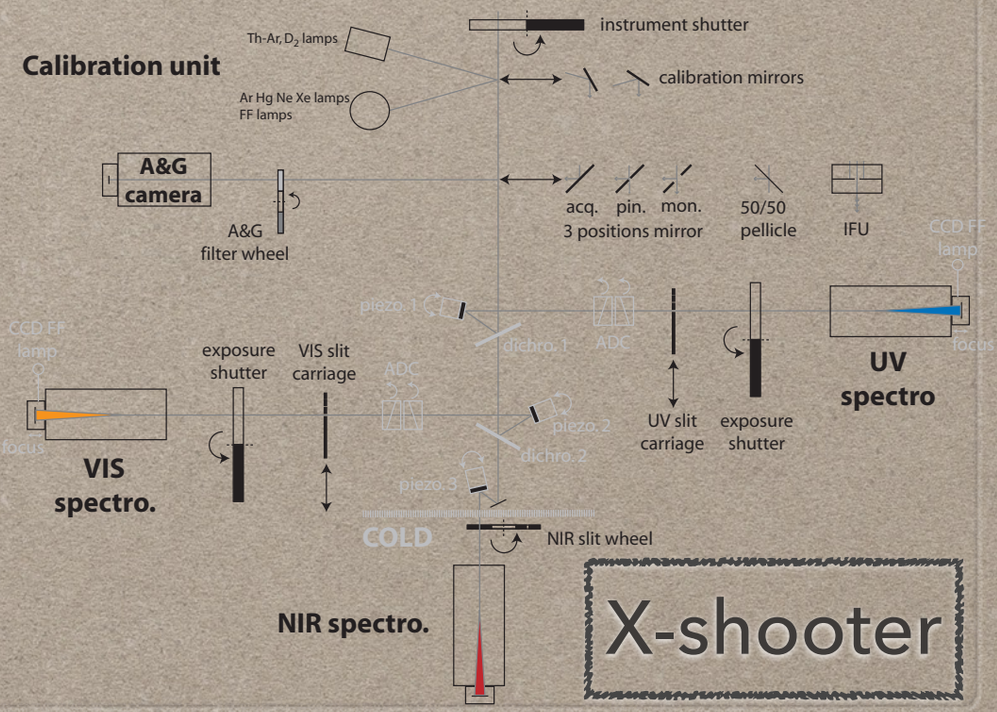
HISTORY

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



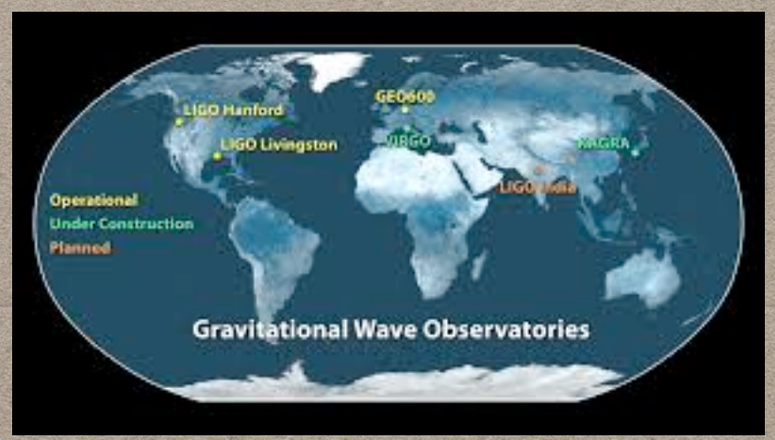
SOXS@NTT IN A NUTSHELL

- *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'x3')*

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 ~170-180 n/yr (for 5 yr)
~3,000 - 4,000 spectra/yr



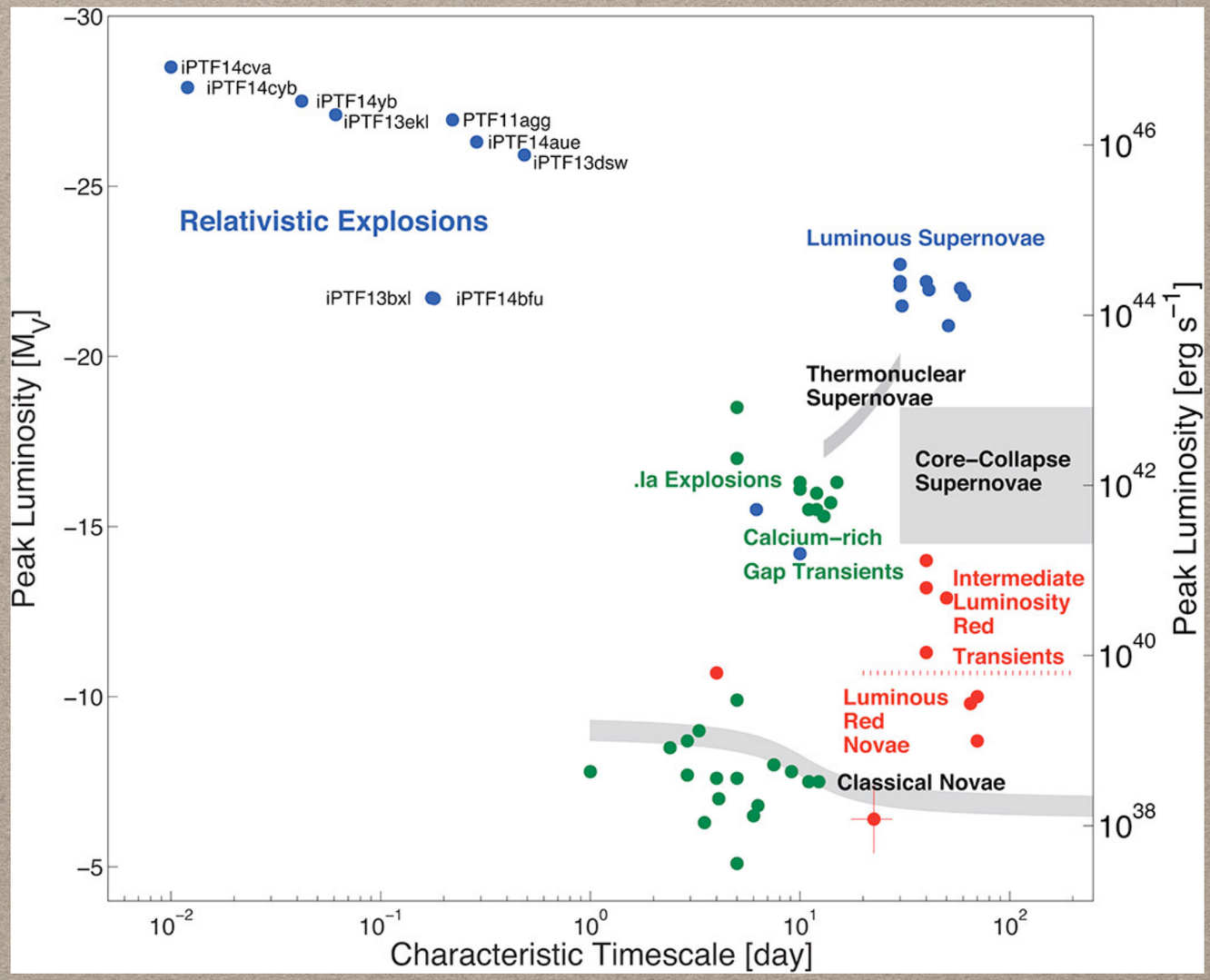
SPECTROSCOPIC BOTTLENECK

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

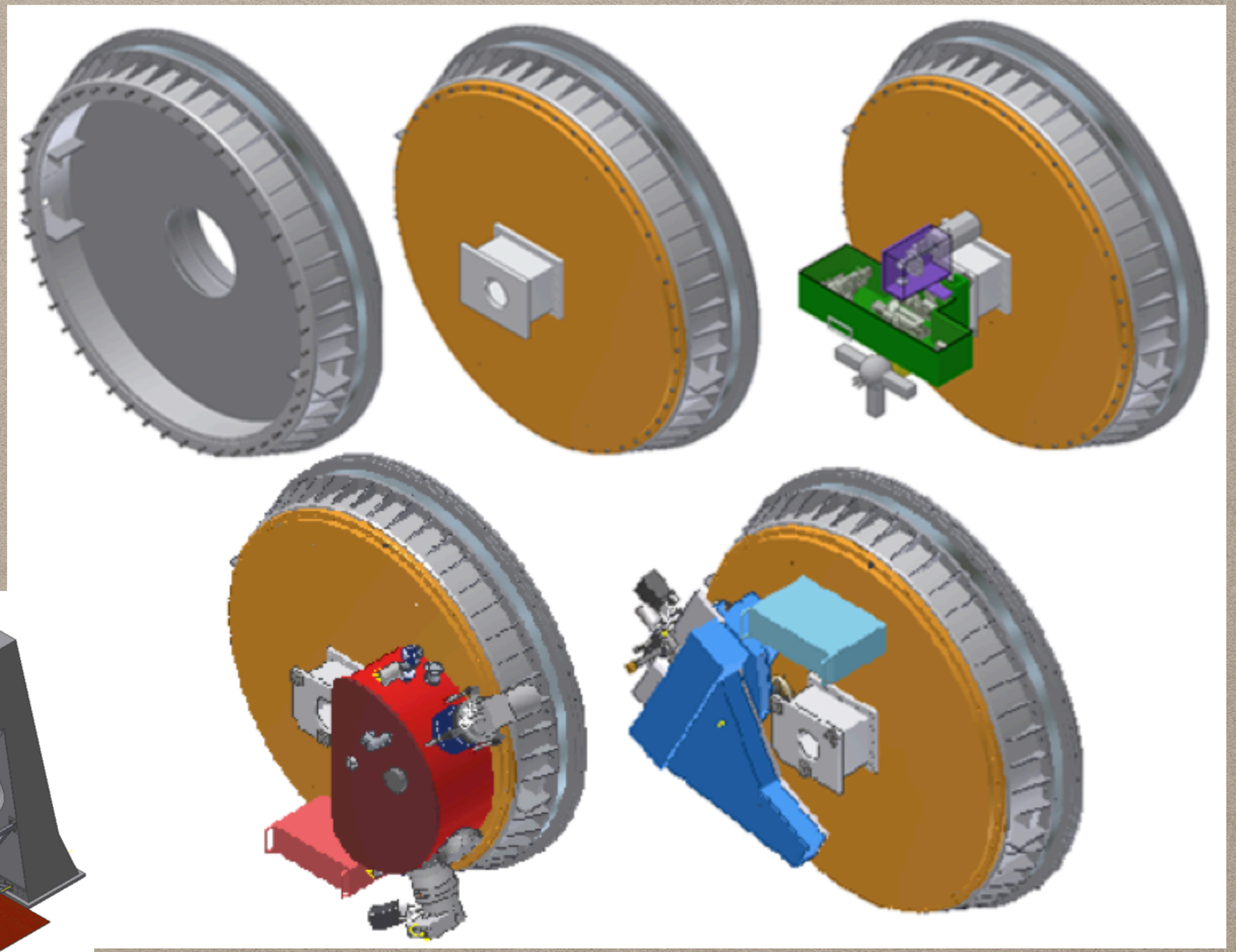
- PESSTO/ePESSTO (Large ESO program 90n/yr):
  - initially focussed on SN, now open to more science cases
  - service classification activity
  - 64 papers in 5 years and ~600 ATel

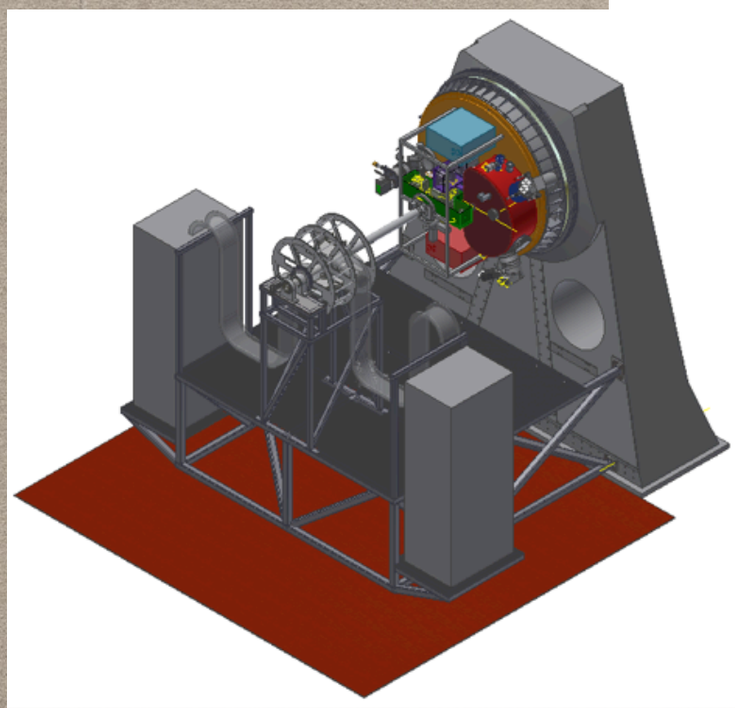
SOXS SCIENCE CASES

- 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



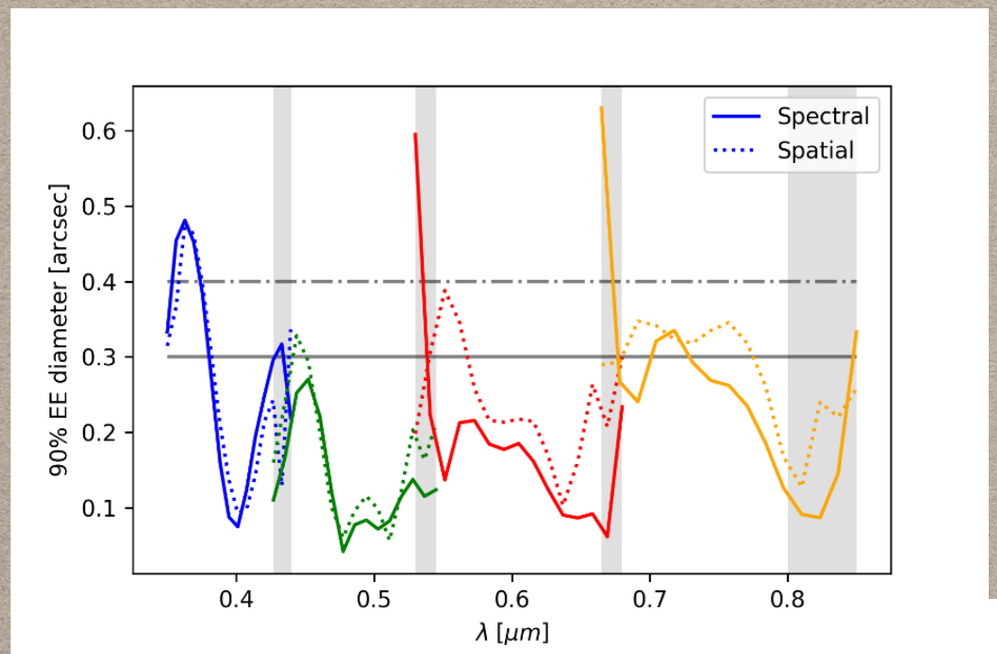
SOXS (ON PAPER)

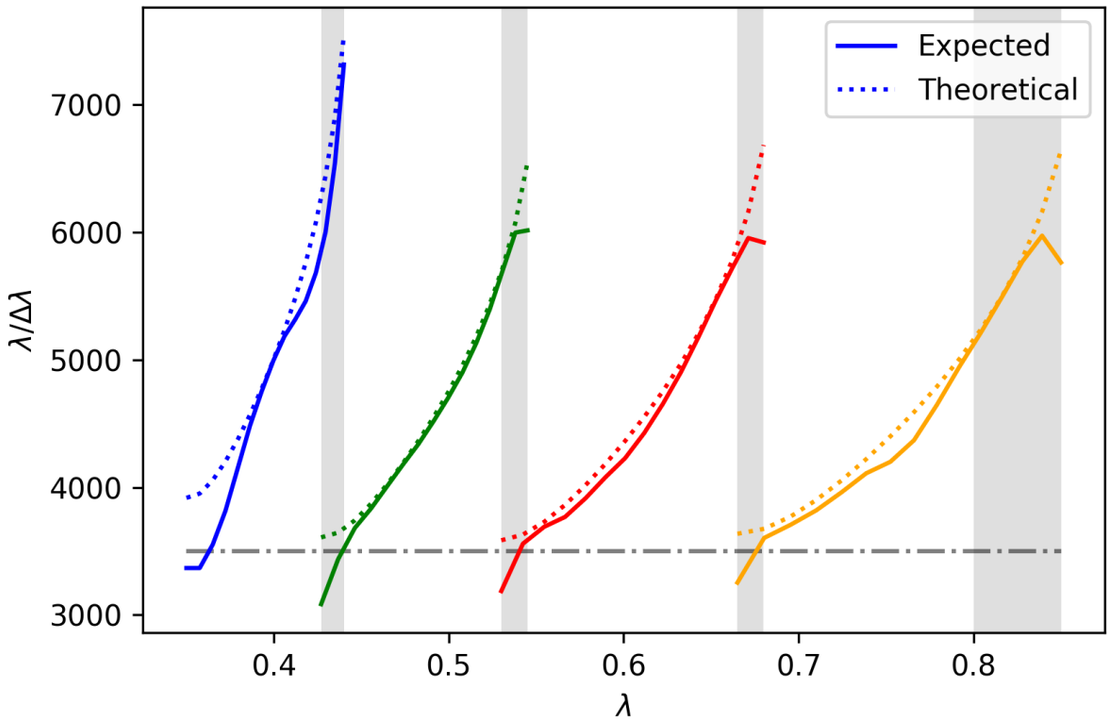


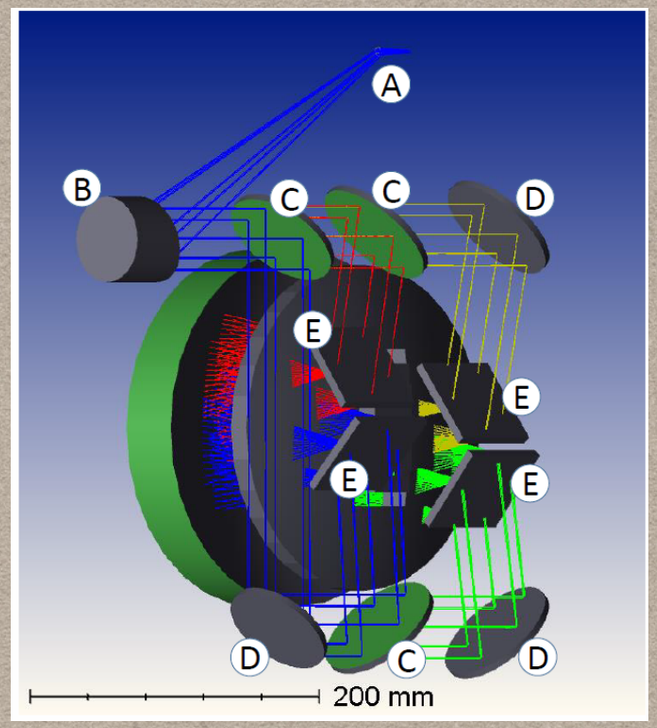


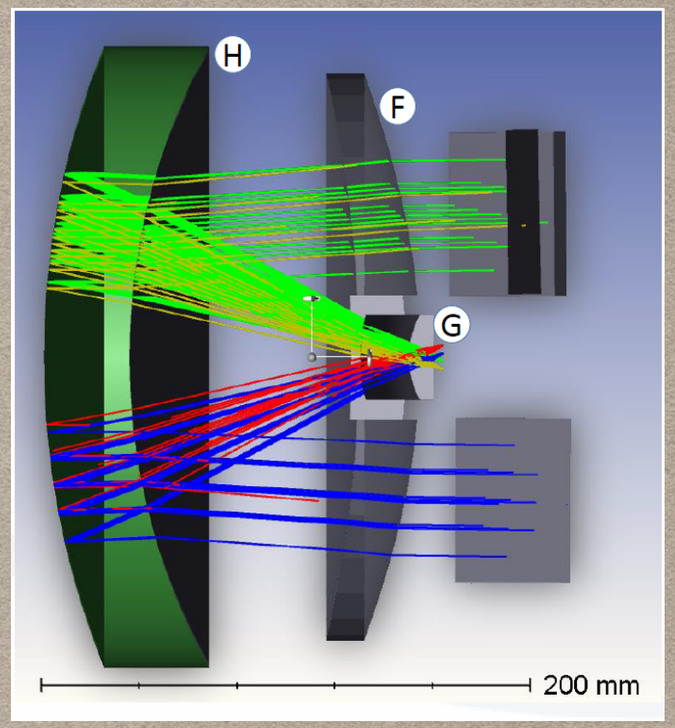
UV-VIS ARM

מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE





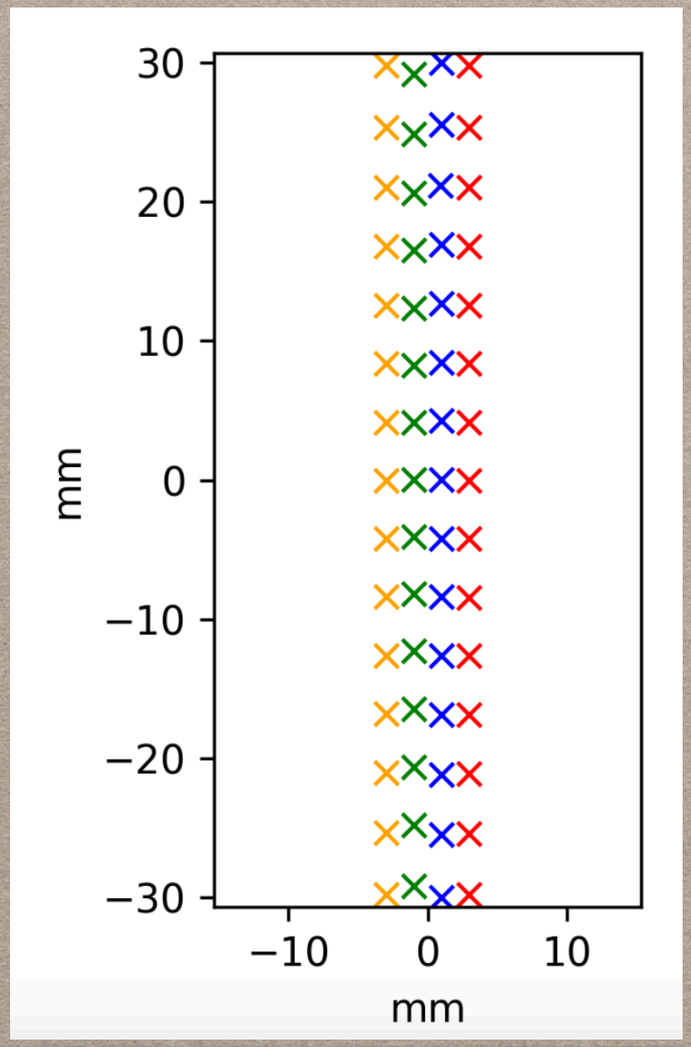


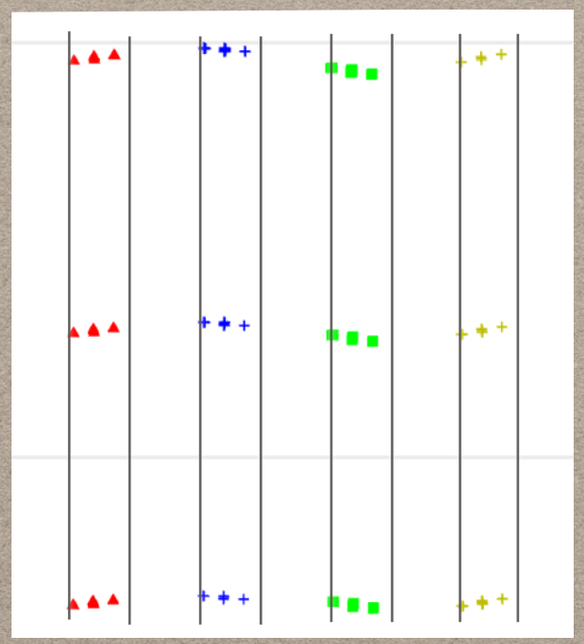


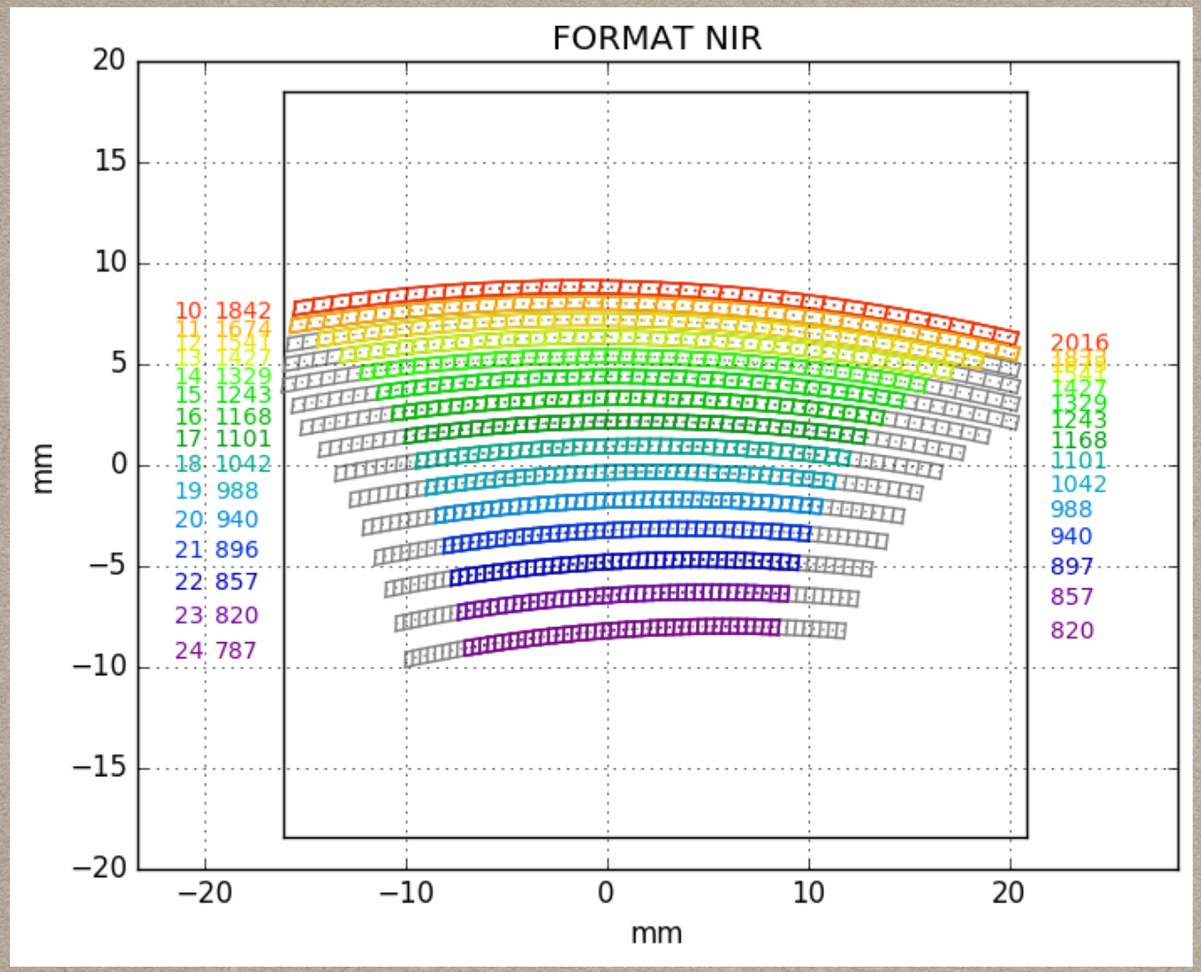
A	Pickup mirror from slit
B	OAP
C	Dichroic
D	Mirror
E	Grating
F	Aspheric corrector
G	Field flattener
H	Mangin Mirror

UV-VIS ARM

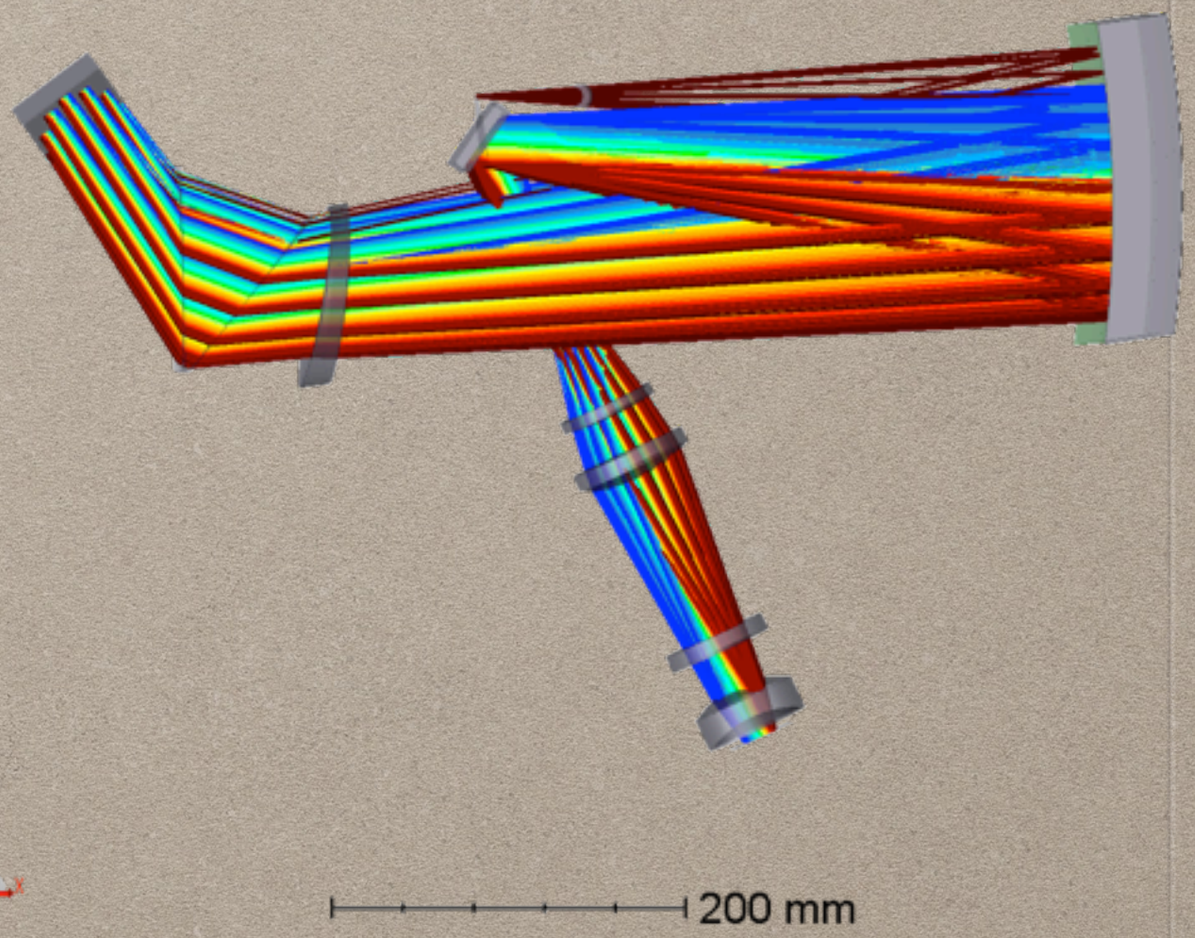
		u	*g*	*r*	*i*
Camera		0.920	0.920	0.920	0.920
UV-VIS Spectrograph		0.656	0.668	0.655	0.652
No Contingency		0.756	0.770	0.755	0.751
Common Path		0.820	0.820	0.820	0.820
Telescope		0.510	0.510	0.510	0.510
Overall		0.274	0.279	0.274	0.272
	No Contingency	0.316	0.322	0.316	0.314





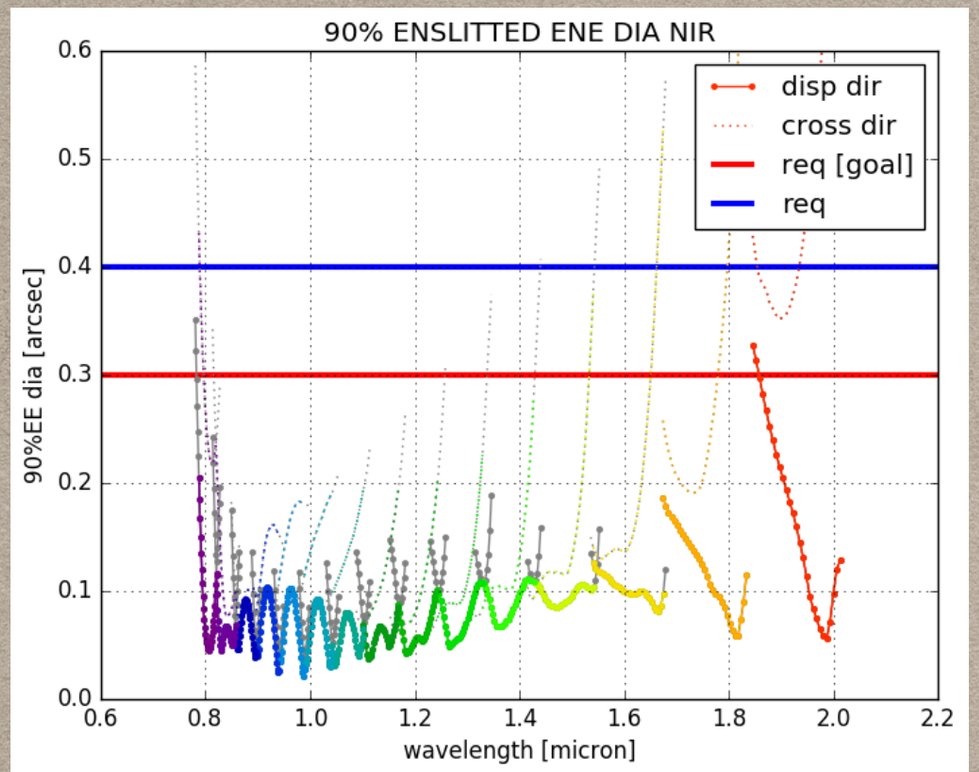


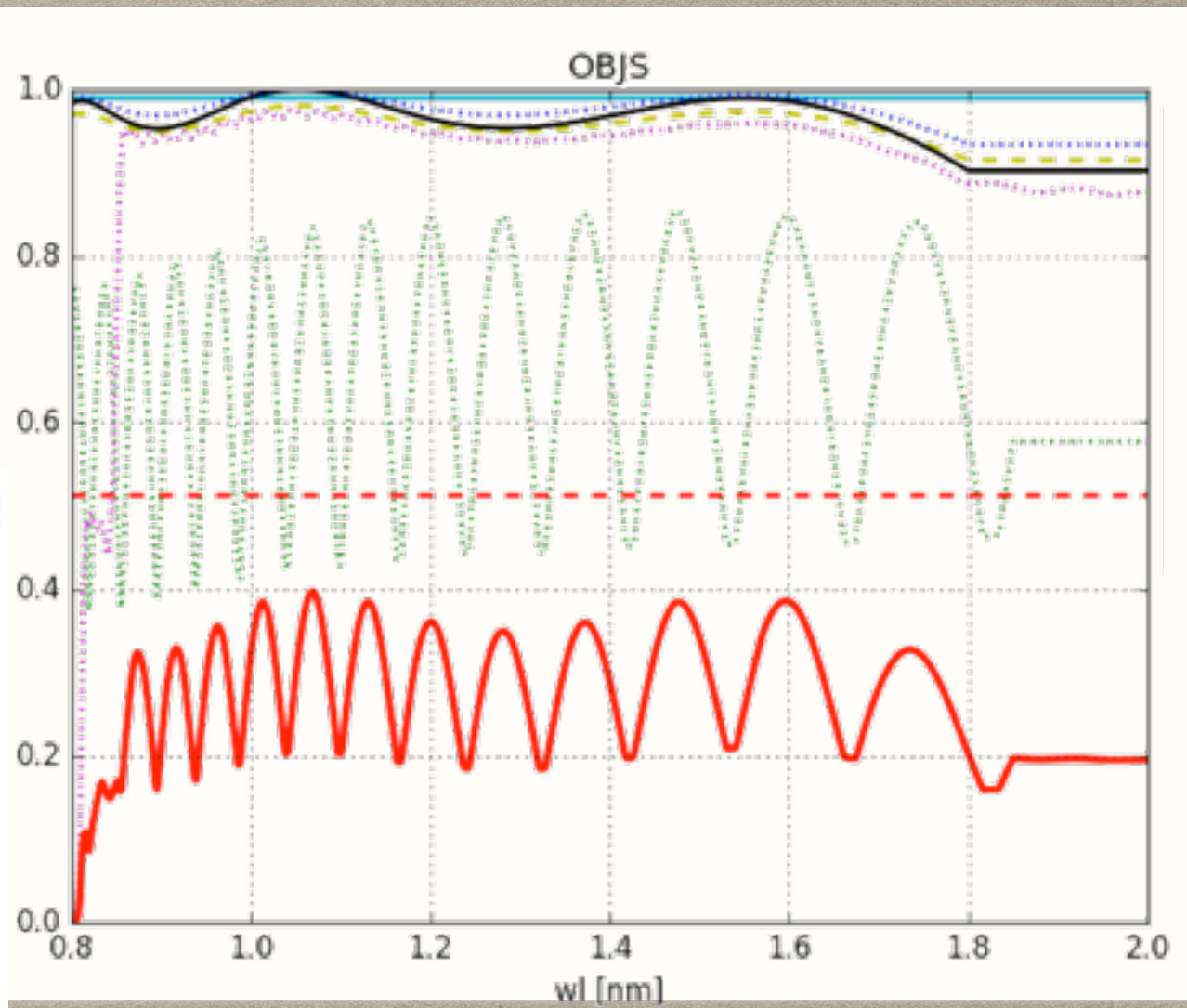
NIR ARM

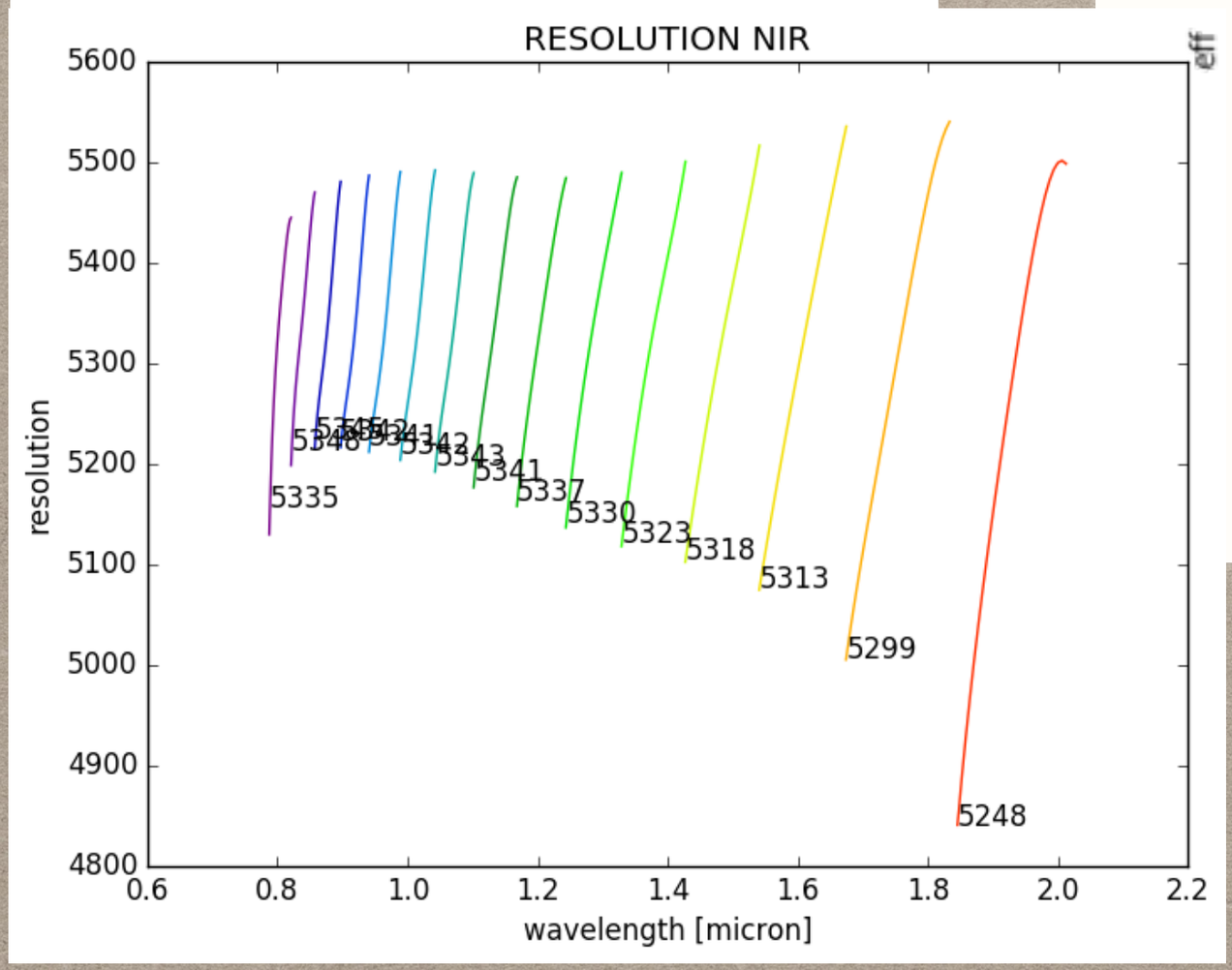


ORDER	FSR	MIN WL	BLAZE WL	MAX WL
10	(0.193)	(1833)	1.930	(2.016)
11	0.159	1.674	1.754	1.834
12	0.134	1.541	1.608	1.675
13	0.114	1.427	1.484	1.541
14	0.098	1.329	1.378	1.428
15	0.086	1.244	1.286	1.329
16	0.075	1.168	1.206	1.244
17	0.067	1.102	1.135	1.168
18	0.06	1.042	1.072	1.102
19	0.053	0.989	1.016	1.042
20	0.048	0.941	0.965	0.989
21	0.044	0.897	0.919	0.941
22	0.04	0.857	0.877	0.897
23	0.036	0.821	0.839	0.857
24	0.034	0.787	0.804	0.821

NIR ARM


90% ENSLITTED ENE DIA NIR
disp dir
cross dir
req [goal]
req
90%EE dia [arcsec]
wavelength [micron]


OBJS
wl [nm]


RESOLUTION NIR
resolution
wavelength [micron]
5335
5299
5248

TIMELINE (TIGHT!)

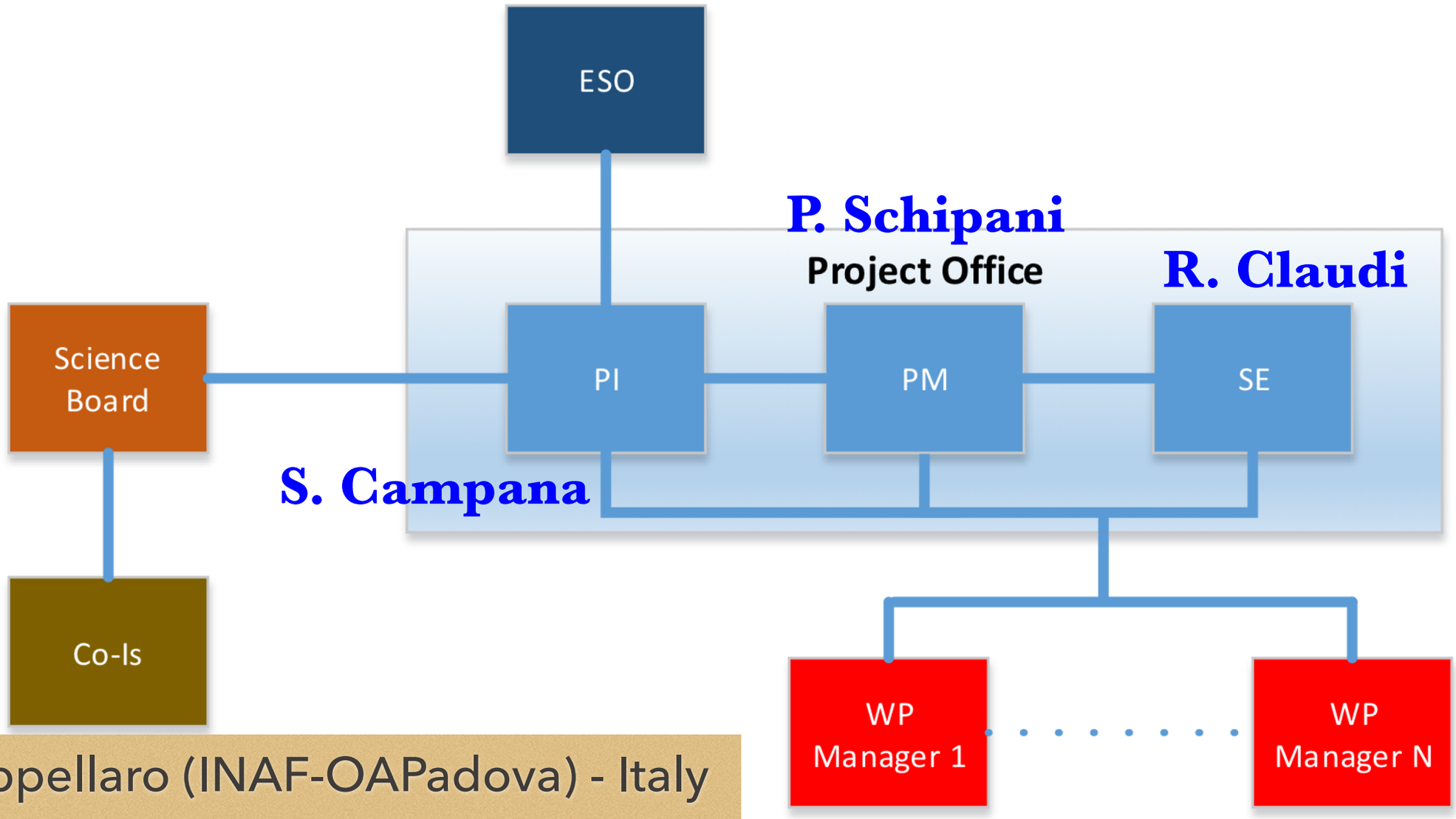
Date to be operational on sky: end 2020

PDR	July 2017, ***21-22*** ✓
FDR	July 2018
End of Procurement	April 2019
AIT & Test in Europe	June 2020
Instrument in Chile	August 2020
End of Commissioning	December 2020

LSST - CTA - SKA

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

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 ~ 50% (CP, NIR-arm, integration, management, etc.)

Israel ~25% (UV-VIS arm optics and mechanics)

Chile ~10% (Acquisition camera)

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

Finland ~5% (Calibration Unit)

OPERATIONS

ESO will reward the SOXS consortium with NTT observing time:
now ePESSTO 90n/yr — future SOXS ~180n/yr.

SOXS consortium responsible for the operations.
Flexible schedule of a day-by-day basis (one day in advance) SOXS+ESO targets).
SOXS team (3 people) on weekly rounds to cope with observations (schedule, classification, etc.) and on call for reaction to GW (GRBs, etc.) with fast (<1hr) ToO and problems. ESO-TNO to carry out observations.

<5% of the consortium time open to the community as ToO (Swift-like) observations (public data).

Relevant information (classification, peculiar sources, etc.) announced in real time through GCN, ATel, IAUC, etc.

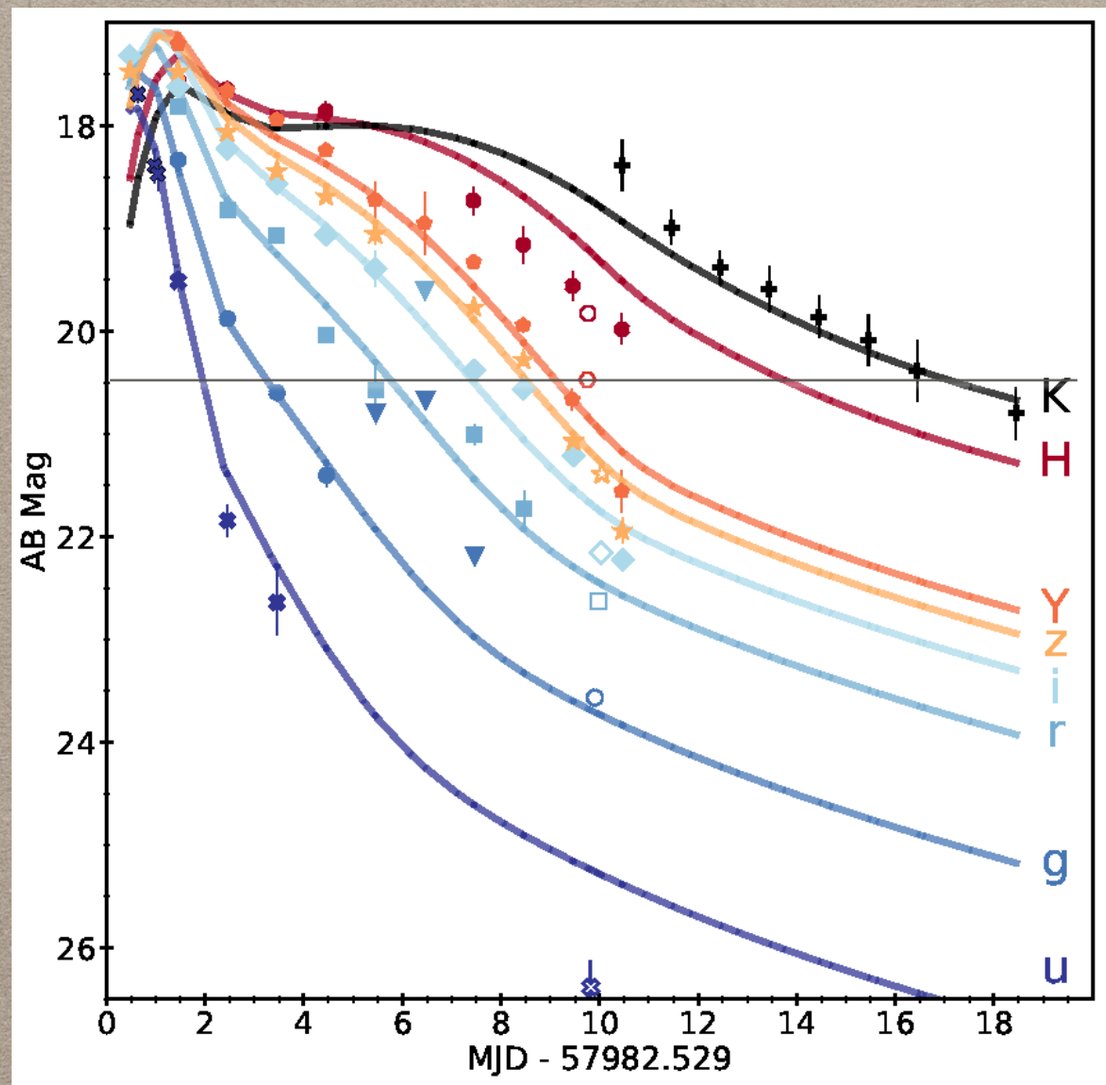
Consortium data public after a short (6-12 months TBD) proprietary period.

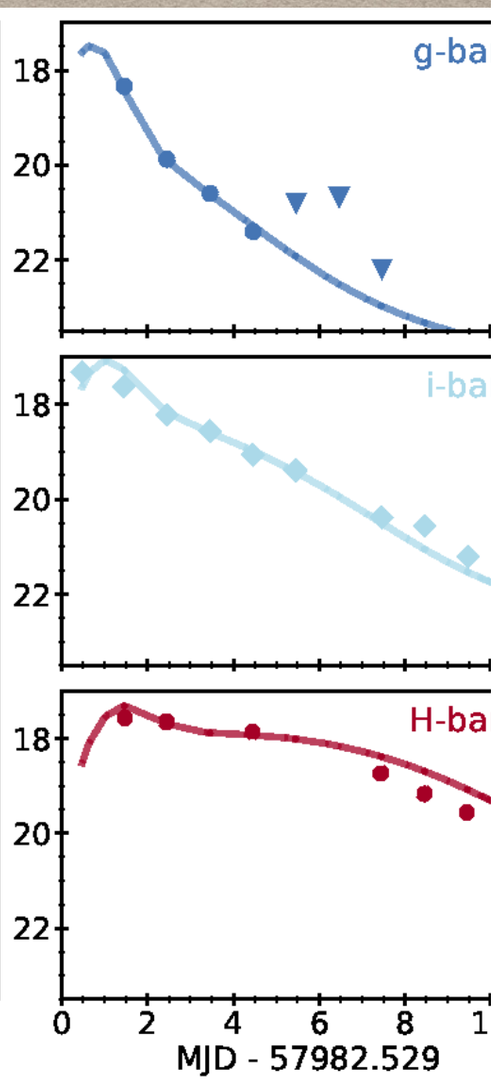
SOXS FOR GW

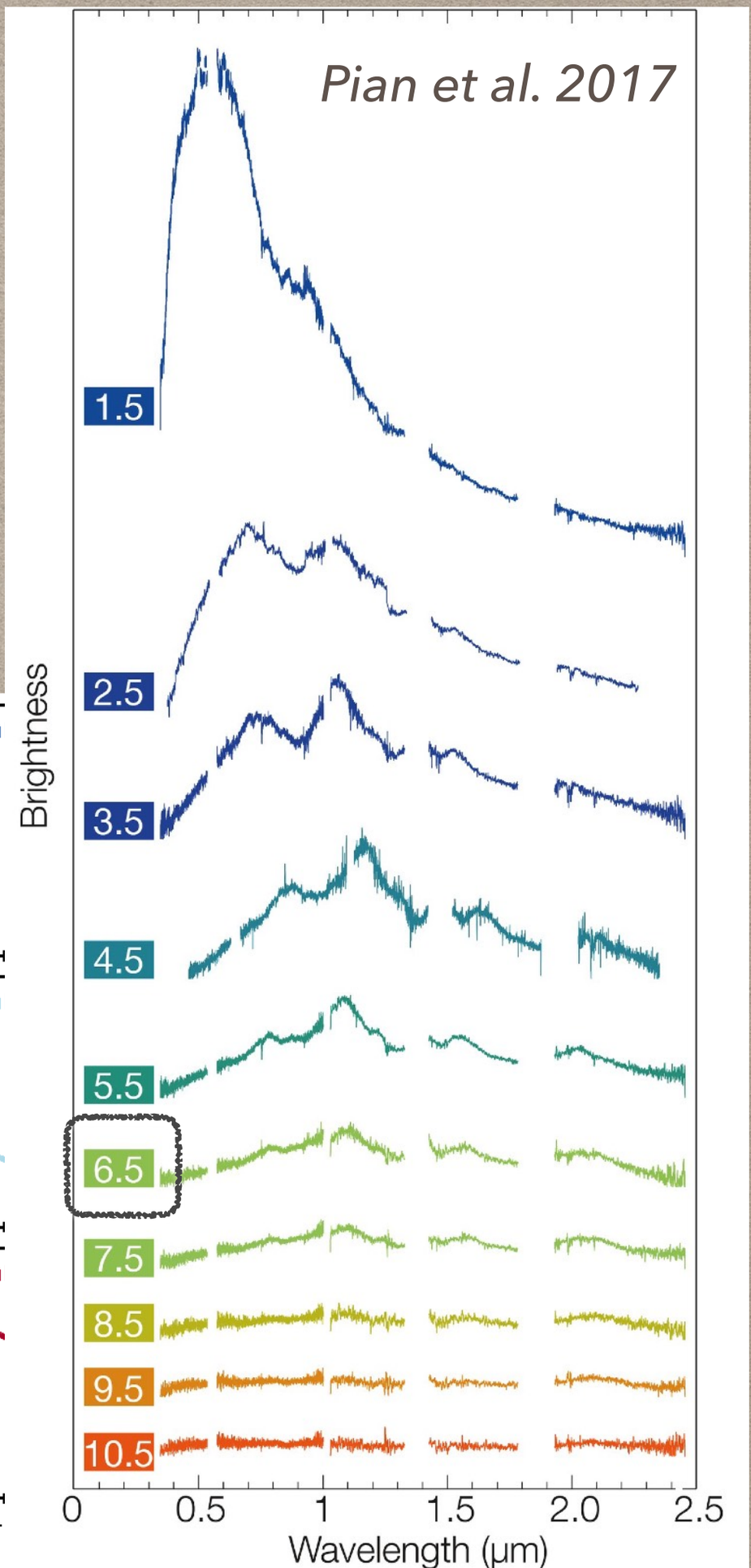
High priority targets

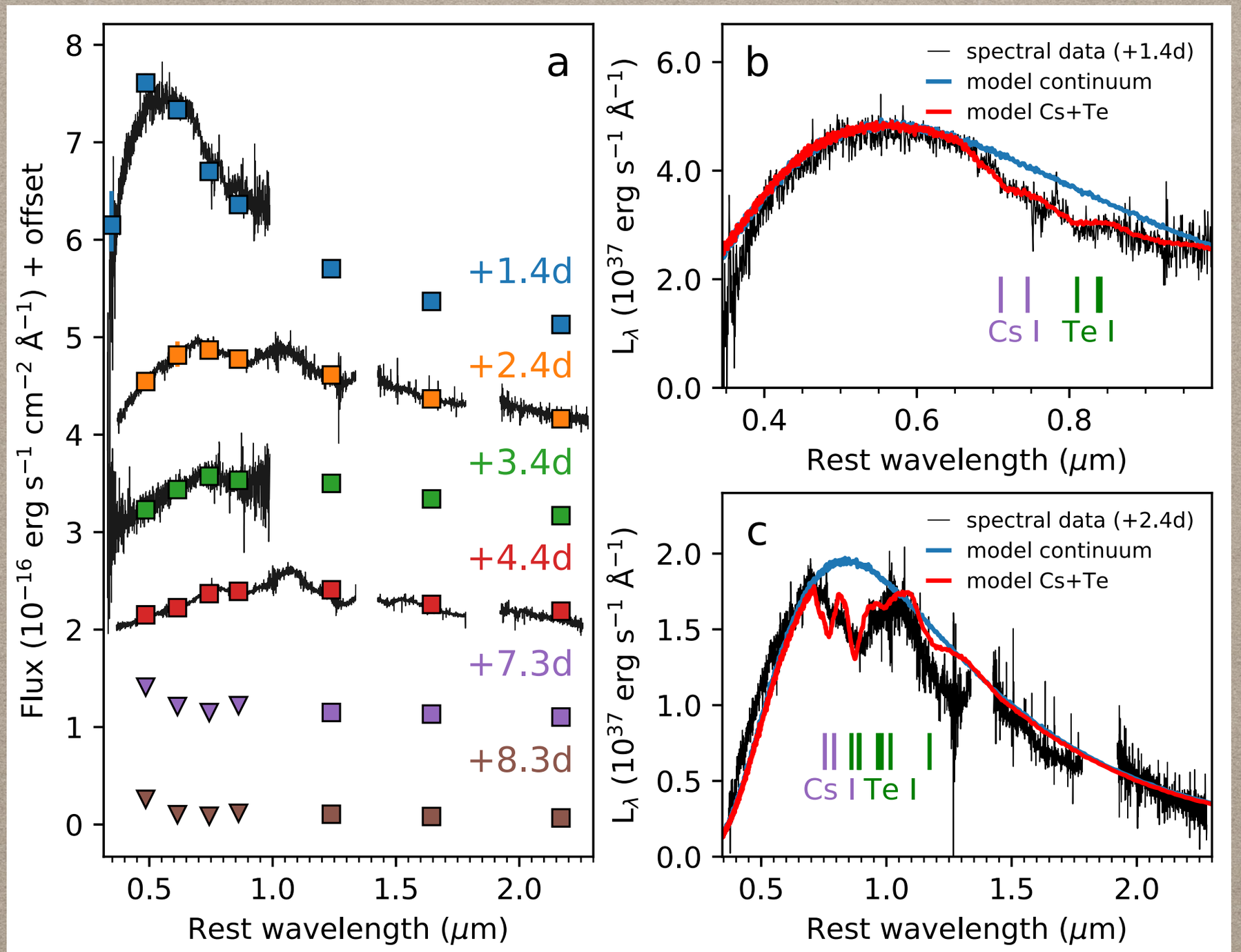
Spectroscopic study of GW candidates

Deep follow-up of GW counterparts









Smartt et al. 2017

SUMMARY

SOXS @ NTT from 2021
Medium resolution (~4,500)
Broad-band (350-2000 nm)
ugrizY imaging (3'x3')
Dedicated to transient astrophysics

Possibility to trigger every night
Fast reaction (probably the only instrument mounted at NTT)

GW is one of the main  *science cases*

Thanks

A call for new instruments was made in 2014, aimed primarily at replacing the ageing instrumentation at the NTT. The medium-resolution (R = 5000) optical and near-infrared (0.4–1.8 μm) spectrograph SOXS (Son of X-shooter) was selected as the future workhorse instrument at the NTT. SOXS addresses in particular — but not exclusively — the needs of the time-domain research community. Furthermore, the high-speed, triple-beam imager ULTRACAM, a visitor instrument, was offered for up to 25 % of NTT time in exchange for cash contributions to NTT operations. In addition, the Near Infra-Red Planet Searcher (NIRPS) was selected as the near-infrared extension of HARPS on the 3.6-metre telescope, creating the most powerful optical to near-infrared precision radial velocity machine for exoplanet research in the southern hemisphere.

The availability of SOXS on the NTT (and X-shooter on the VLT) will put the ESO community in an excellent position to follow up the most interesting transients to be discovered by the LSST from 2023 onwards. The combination of HARPS and NIRPS on the 3.6-metre telescope is crucial for providing critical ground-based complementary data for the ESA/Swiss mission CHaracterising ExOPlanet Satellite (CHEOPS) and for PLATO.

The extension of La Silla operations beyond 2020 as described above requires both NIRPS and SOXS to be successful. If NIRPS were to fail for some unforeseen reason, then the 3.6-metre telescope with HARPS would still be valuable for exoplanet research, but it would be reasonable for ESO to require external contributions to the operation costs. If SOXS were to fail, then the future of the NTT would be in serious doubt. This would threaten the viability of the entire La Silla operations model, as it is not cost-effective for ESO to run the complete site for a single medium-sized telescope. External funding or support could come from (consortia of) institutes in the Member States, or from partners elsewhere including the Host State Chile.

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	