SOXS: a wide band spectrograph to follow up the transients

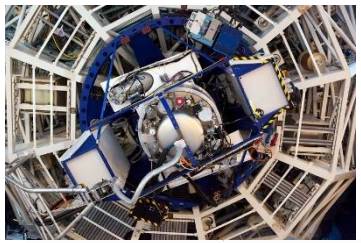
P. Schipani (INAF)

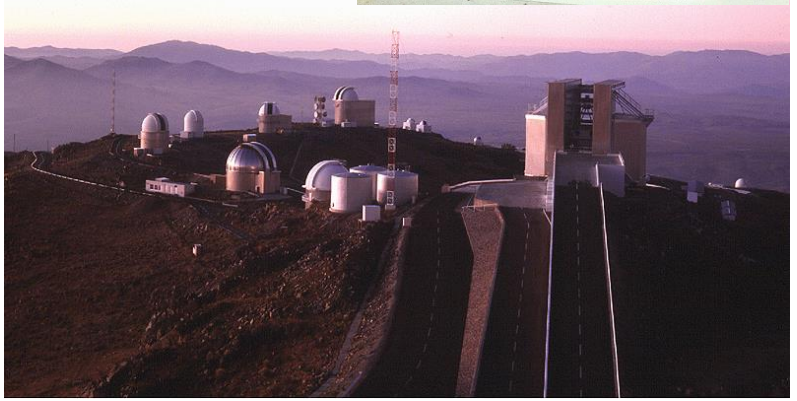
on behalf of the SOXS Consortium

GW170817 - Italian contributions to the dawn of the multi-messenger astronomy, GSSI, 30.11.2017

SOXS (Son Of X-Shooter) in a nutshell

- Single-object wide band spectrograph from U to H band @ESO-NTT 350-1750 (2000) nm
- *'Similar'* to X-Shooter
- Two arms (VIS + NIR) with partial overlap around 800nm to cross-calibrate spectra
- R~4,500 (3,500-6,000)
- S/N~10 spectrum - 1 hr exposure for R~20-20.5
- Acquisition camera to perform photometry ugriz (3'x3')





Project History

- ESO Call for new instruments at NTT (2014)
- Proposal submission (02/2015)
- Selected by ESO (2015) out of 19
- Kick-off (2016)
- PDR ok (07/2017)
- Currently in Final Design Phase (till 2018)

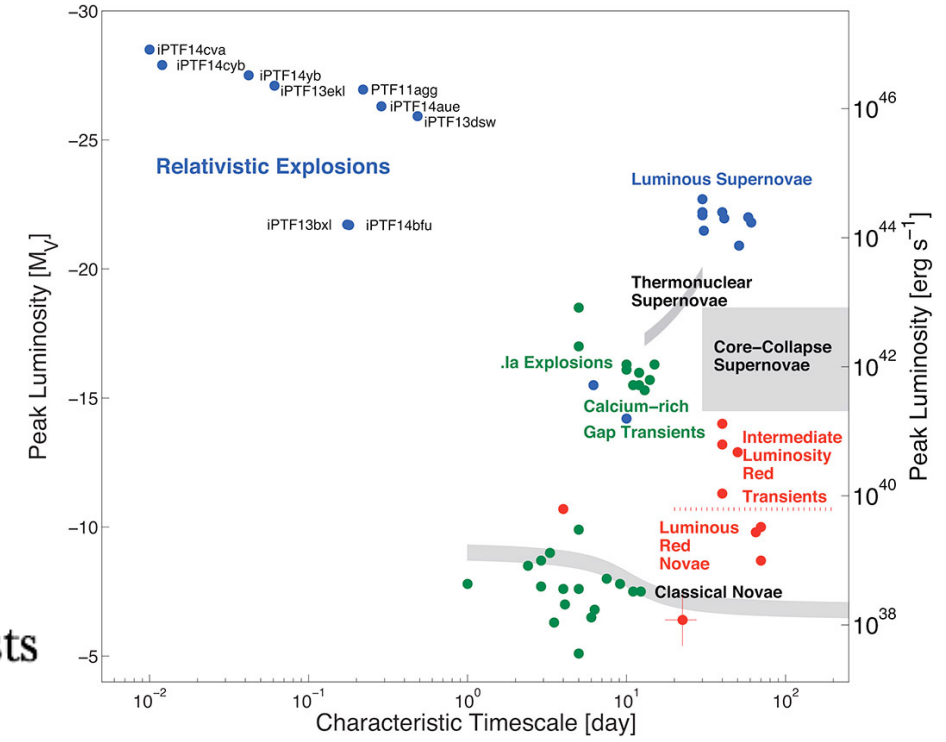
ESO Long Term Perspectives

"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 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."

SOXS is dedicated to the spectroscopic follow up of transients

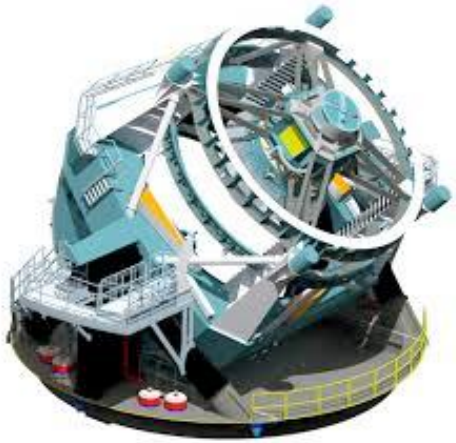
- Minor planets and asteroids
- Young stellar objects
- Planetary transits
- X-ray binary transients
- Novae
- Supernovae (Ia, CC)
- GRB
- GW-&neutrino EM counterparts
- Radio sky transients & fast radio bursts



The PESSTO => ePESSTO experience

- PESSTO evolved into **ePESSTO**
- Large program at ESO
- No longer fully public (even if there is still a service activity to classify transients)
- Approved for 4 semester for 90n/yr
- Not only SNe but **open** to other science cases
- Pathway to SOXS
- Italy involved (also thanks to SOXS)
- Two Italian scientists (out of 12) within the ePESSTO board
- >70% of the transients remain unclassified

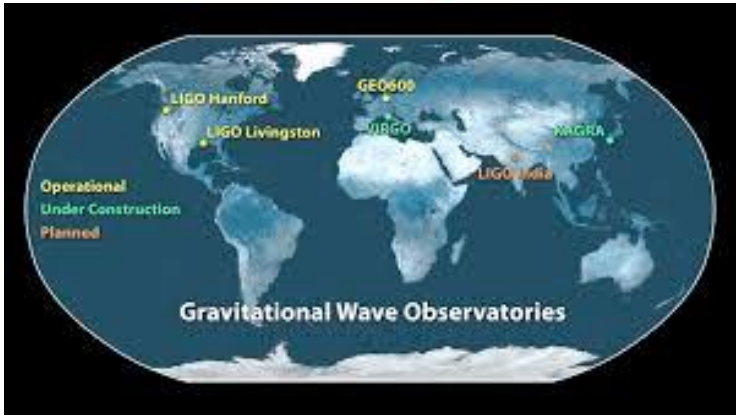
Many sinergies



Spectroscopic machine for the transient sky.

Even now with PESSTO in place >70% of newly discovered transients remain without spectroscopic follow-up.

In the near future years there will be many imaging survey wide-field telescopes (iPTF, DES, Pan-STARRS, LSST) as well as high-energy transients (Swift, INTEGRAL, MAXI), GAIA-alters GW-alters, TeV alerts, etc. but very limited spectroscopic follow-up

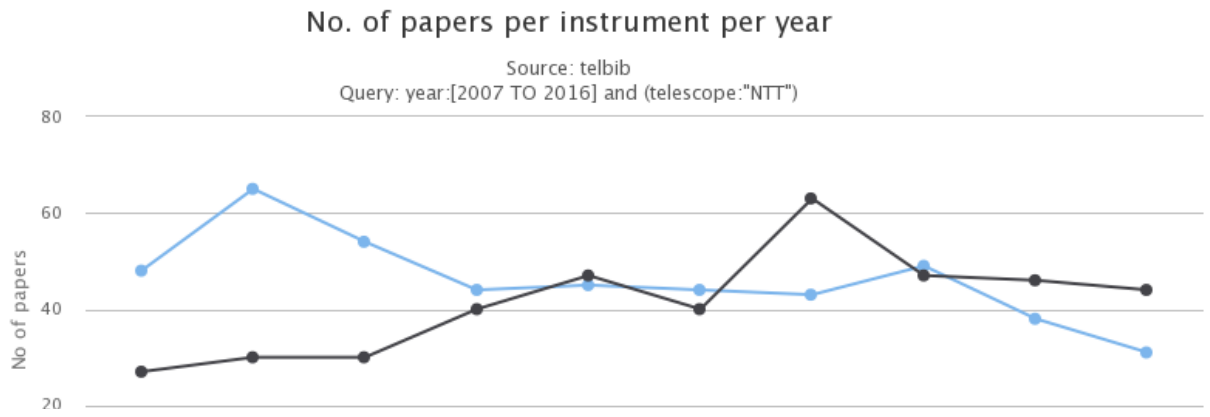


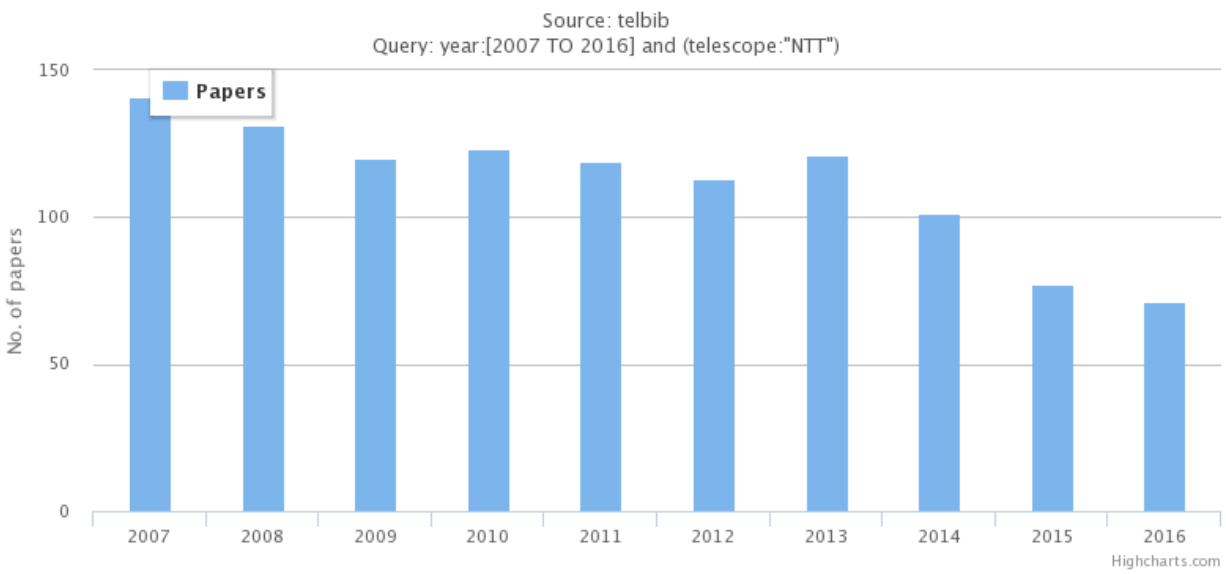
SOXS@NTT will have 180 n/yr (for >5 yr)
~3,000 - 4,000 spectra/yr

ANTARES

SVOM

NTT productivity





Consortium

Institutes from 6 Countries

- Common Path (INAF)
- UV/VIS Spectrograph (Weizmann)
- NIR Spectrograph (INAF)
- Acquisition Camera (Un. Andres Bello-MAS)
- Calibration Unit (Turku University)

- Data Reduction (Queen's Un. Belfast)
- Tel Aviv University
- *Dark Cosmology Center

- Control Software & Electronics, Vacuum and Cryogenics, Detectors control (INAF)

Project Schedule

Project Phase	Start	End	Duration
Preliminary Design	08/2016	07/2017	12 months
*Final Design	08/2017	07/2018	12 months
**MAIT	02/2018	06/2020	29 months
Commissioning	09/2020	12/2020	4 months
Operations	2021		TBD

*Split in 3 intermediate steps

**(Some) procurements anticipated

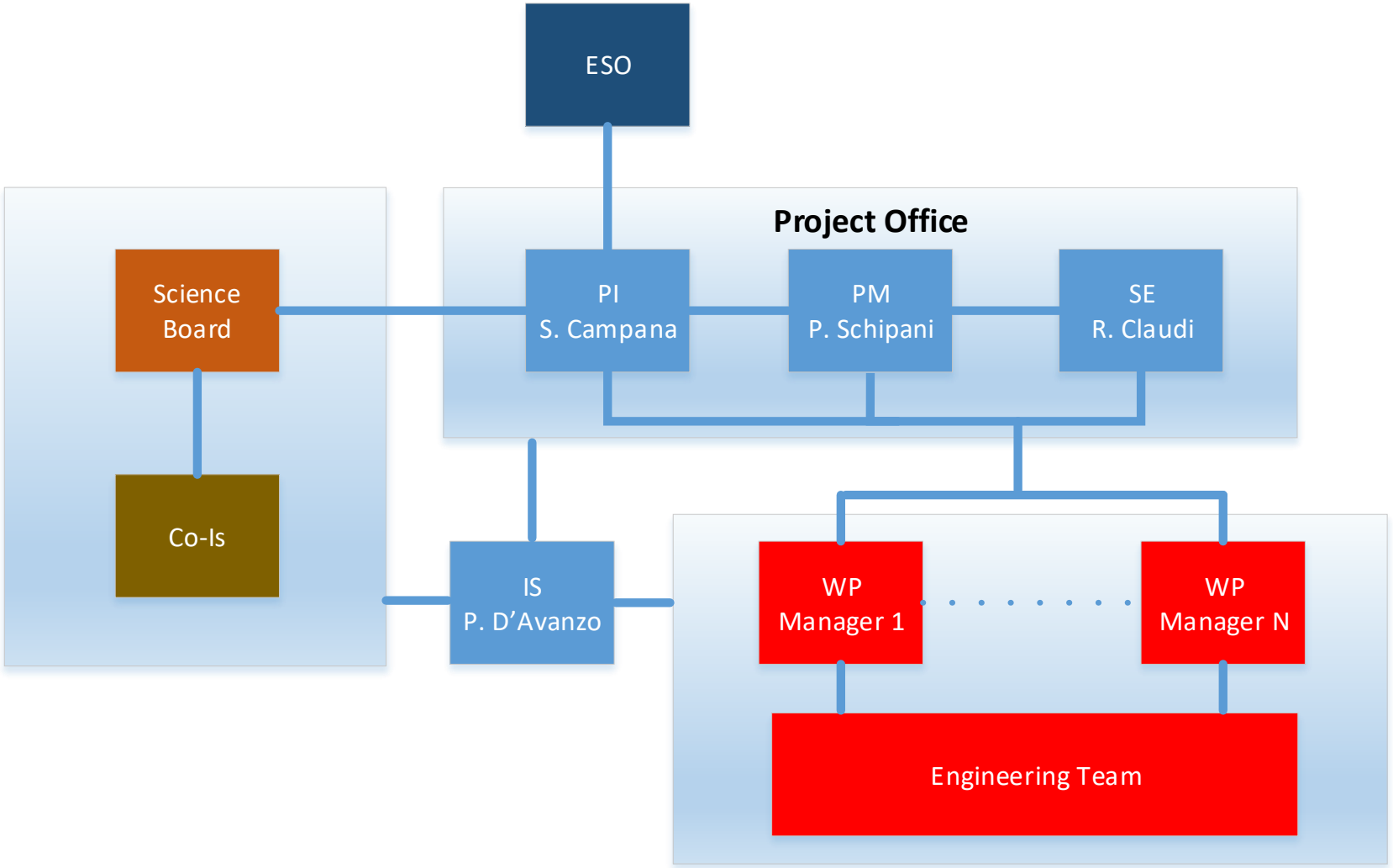
In SOXS case, consortium duties don't end with instrument acceptance

Operations

After commissioning no SOXS scientists is supposed to be in La Silla unless for limited periods

- SOXS Consortium will manage the entire schedule including Consortium time and open time.
- SOXS will not have a pre-planned program.
- All observations will be TOO
- The schedule is worked out every day (one day in advance).
- One scientist will be on-call for problems and for changing the schedule in case of unforeseen fast-track events
- SOXS Helpdesk: 3 people on duty for the observing runs

Organization structure



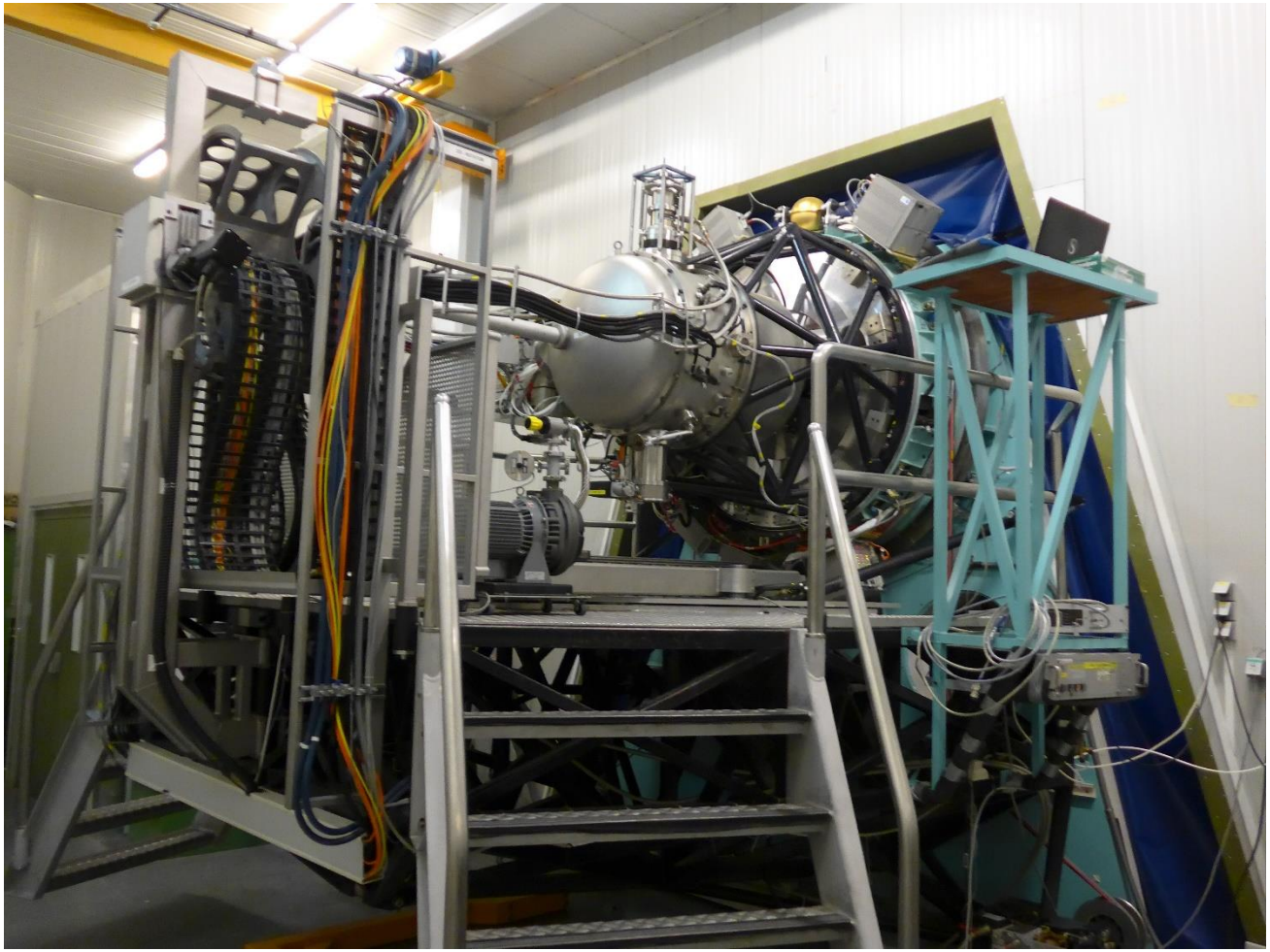
Science Board

Name	Affiliation
S. Campana (PI)	INAF-OA Brera (Italy)
E. Cappellaro	INAF-OA Padova (Italy)
M. Della Valle	INAF-OA Capodimonte (Italy)
A. Gal-Yam	Weizmann Institute (Israel)
S. Mattila	Turku Univ. (Finland)
G. Pignata	Univ. A. Bello (Chile)
S. Smartt	Queen's University Belfast (UK)
I. Arcavi	Tel Aviv University (Israel)
J. Fynbo	Dark Cosmology Centre (Denmark)

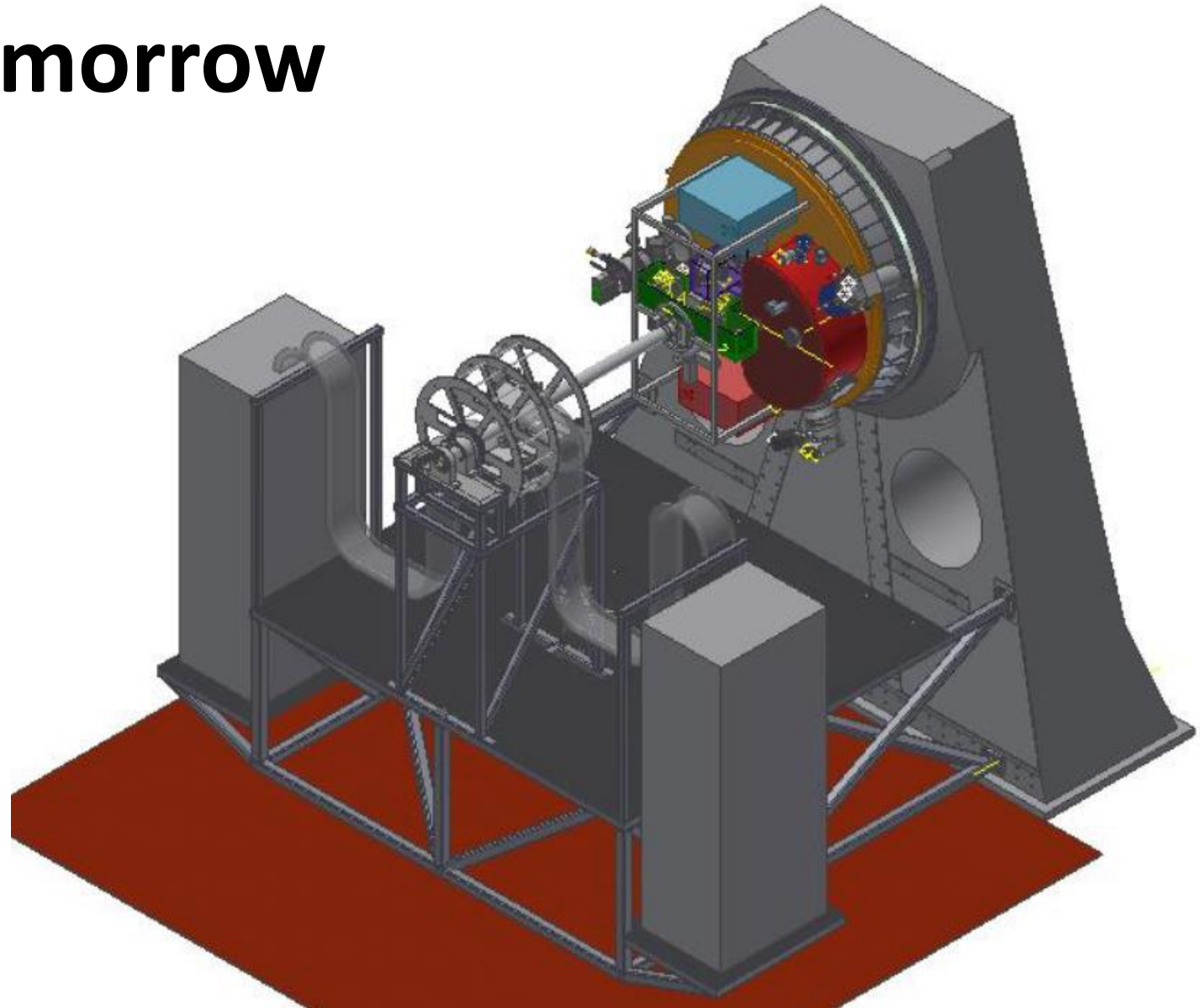
WP Managers

Function	Name	Affiliation
Project Manager	P. Schipani	INAF-OA Capodimonte (Italy)
System Engineer	R. Claudi	INAF-OA Padova (Italy)
Instrument Scientist	P. D'Avanzo	INAF-OA Brera (Italy)
Optics WP Manager	M. Munari	INAF-OA Catania (Italy)
Mechanics WP Manager	M. Aliverti	INAF-OA Brera (Italy)
Electronics WP Manager	G. Capasso	INAF-OA Capodimonte (Italy)
Software WP Manager	A. Baruffolo	INAF-OA Padova (Italy)
VIS Detector WP Manager	R. Cosentino	INAF-TNG (Italy)
NIR Spectrograph WP Manager	F. Vitali	INAF-OA Roma (Italy)
NIR Detector WP Manager	F. D'Alessio	INAF-OA Roma (Italy)
Calibration Unit WP Manager	H. Kuncaraycti	Turku Univ. (Finland)
Vacuum & Cryogenics WP Manager	S. Scuderi	INAF-OA Catania (Italy)
AIT WP Manager	F. Biondi	INAF-OA Padova (Italy)
Instrument Modelling WP Manager	D. Gardiol	INAF-OA Torino (Italy)
Acquisition Camera WP Manager	A. Brucalassi	Univ. A. Bello (Chile) & ESO
VIS Spectrograph WP Manager	S. Ben-Ami	Weizmann Institute (Israel)
VIS Spectrograph Optics WP Manager	A. Rubin	Weizmann Institute (Israel)
VIS Spectrograph Mechanics WP Manager	O. Diner	Weizmann Institute (Israel)

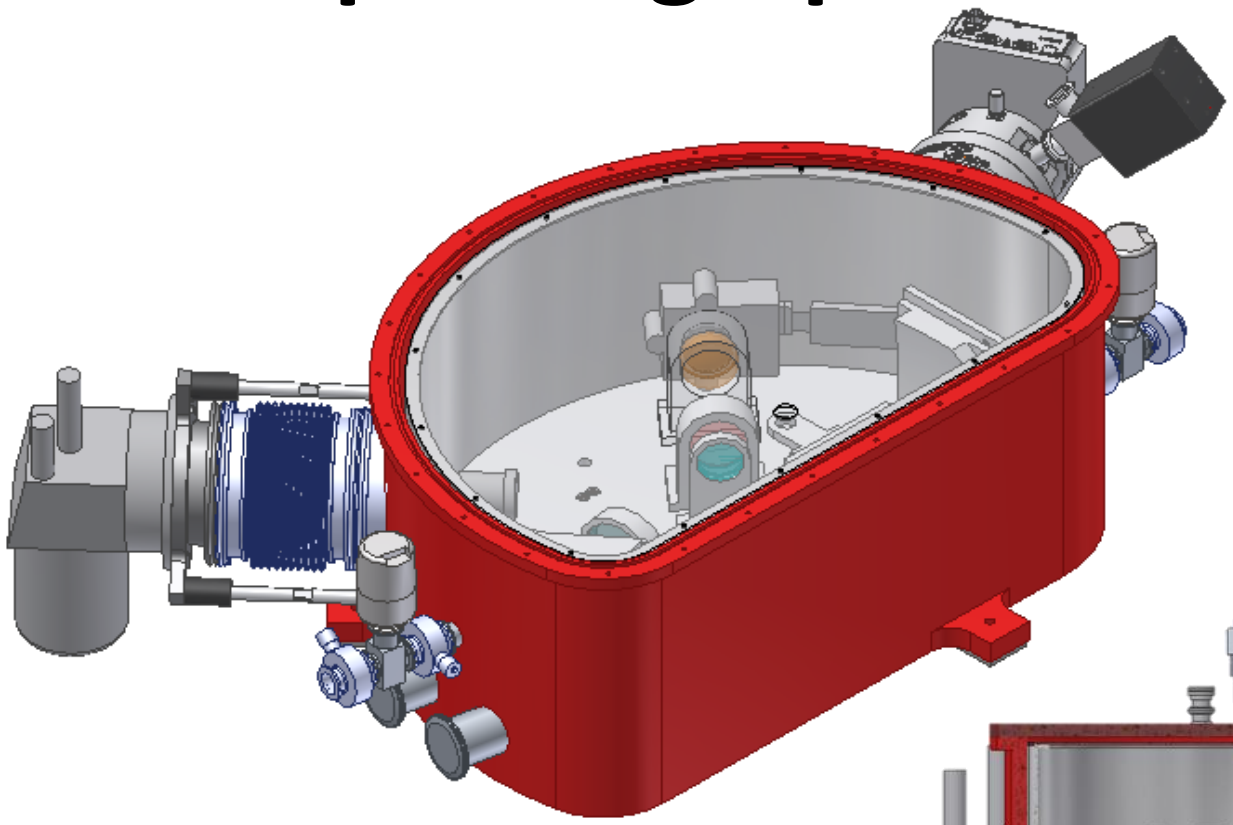
NTT Now (SOFI Side)



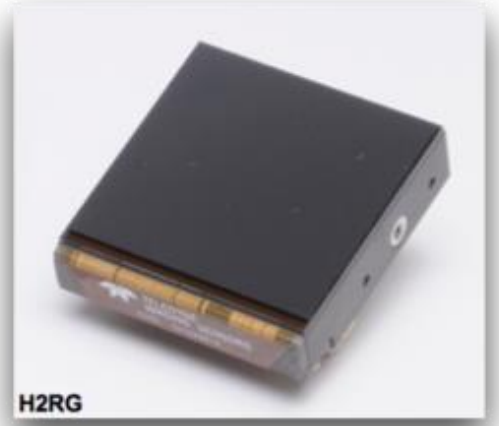
Tomorrow

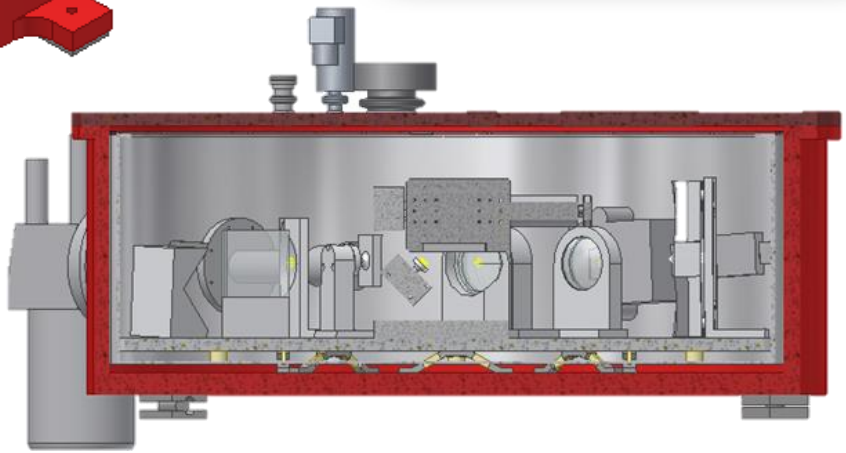


NIR spectrograph



Hawaii H2RG 2K x 2K
Substrate removed

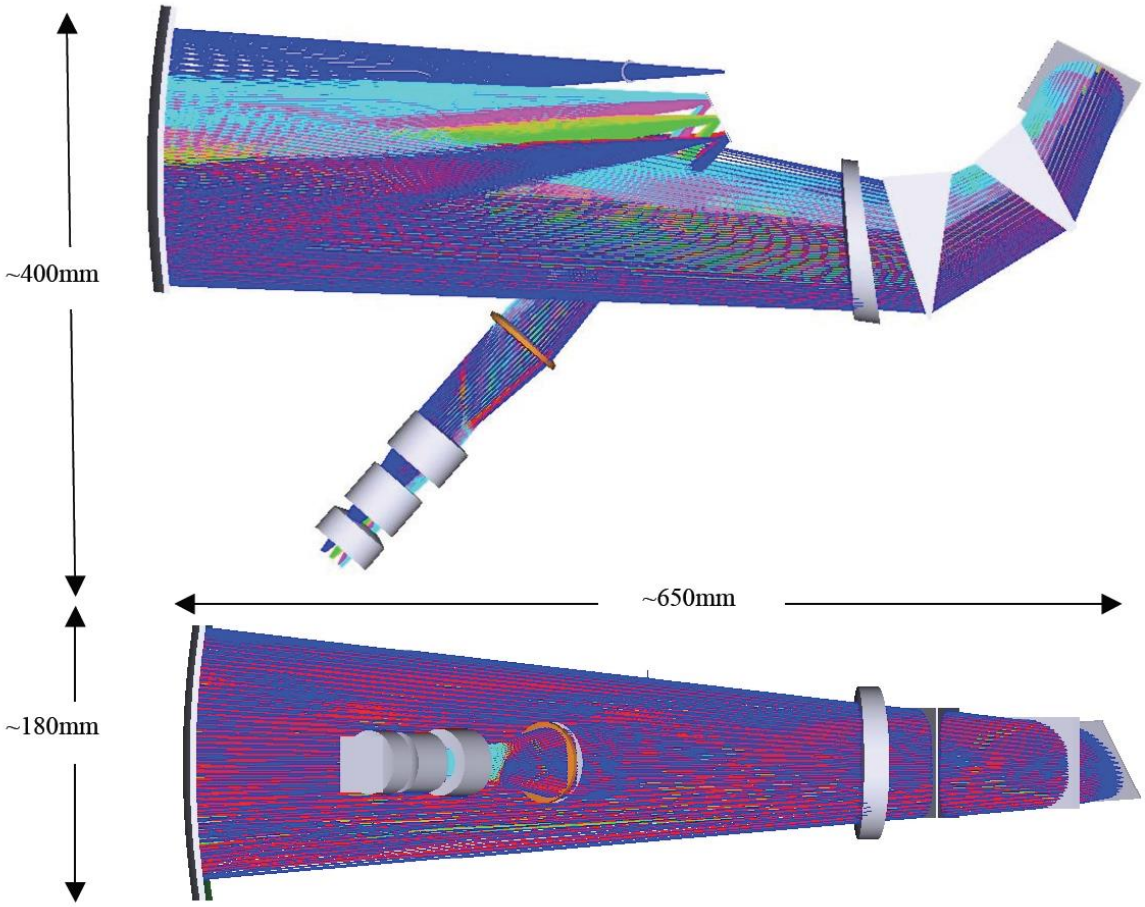




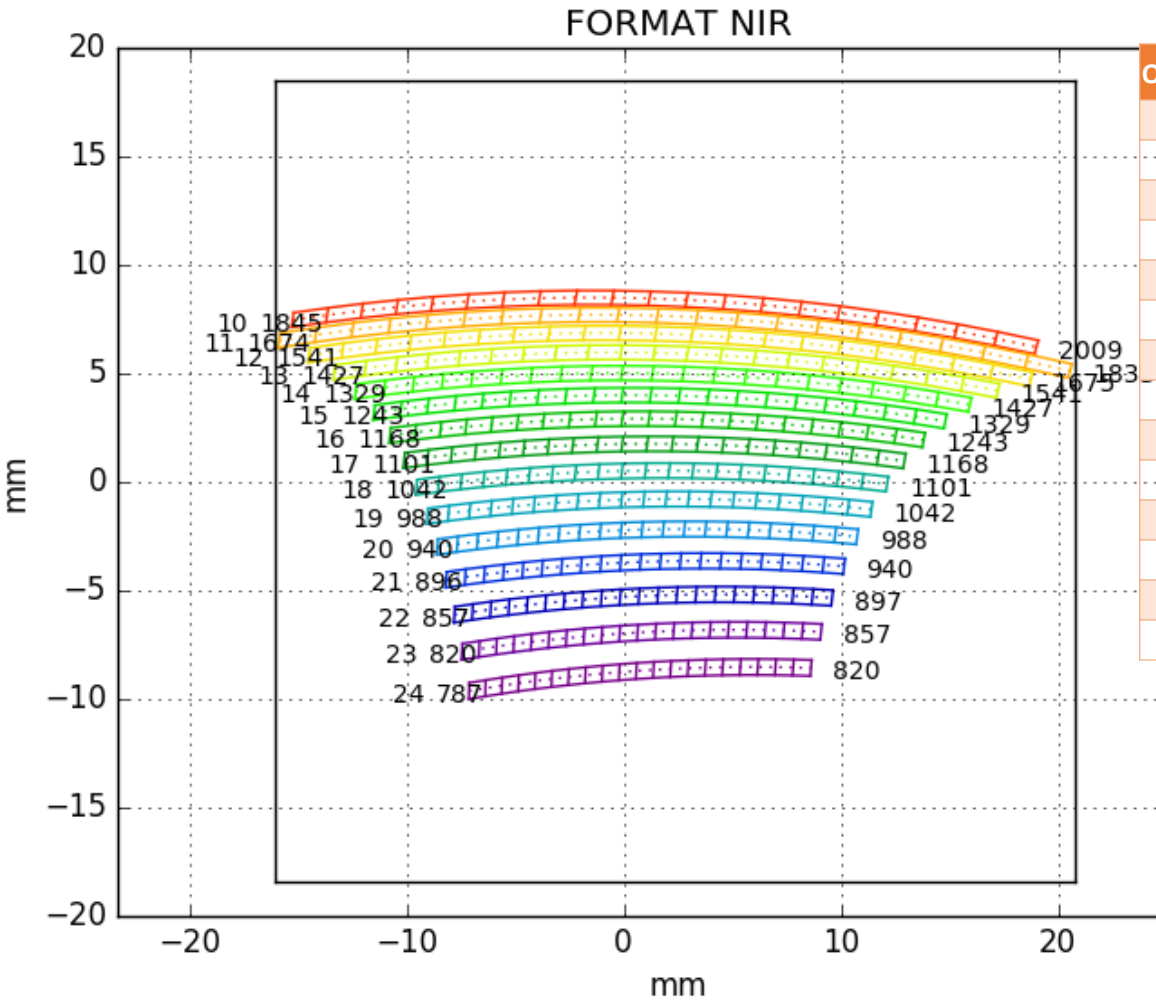
NIR 4C Design

Spectrograph with
Collimator
Compensation of
Camera
Chromatism
(Delabre)

Echelle
Cross-Dispersed



NIR Spectral Format



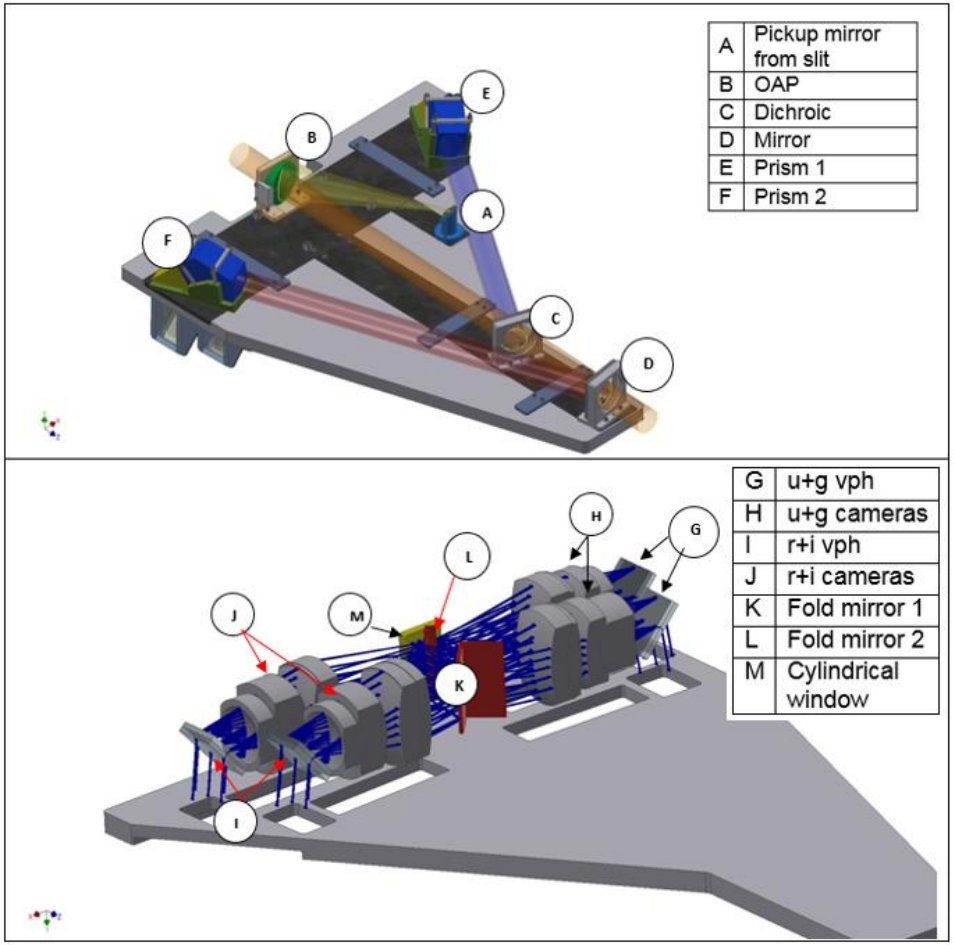
ORDER	FSR	MIN WL	BLAZE WL	MAX WL
11	0.159	1.674	1.754	1.834
12	0.134	1.541	1.608	1.675
13	0.114	1.427	1.484	1.541
14	0.098	1.329	1.378	1.428
15	0.086	1.244	1.286	1.329
16	0.075	1.168	1.206	1.244
17	0.067	1.102	1.135	1.168
18	0.06	1.042	1.072	1.102
19	0.053	0.989	1.016	1.042
20	0.048	0.941	0.965	0.989
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

- 15 Orders
- 0.787-2.009 µm

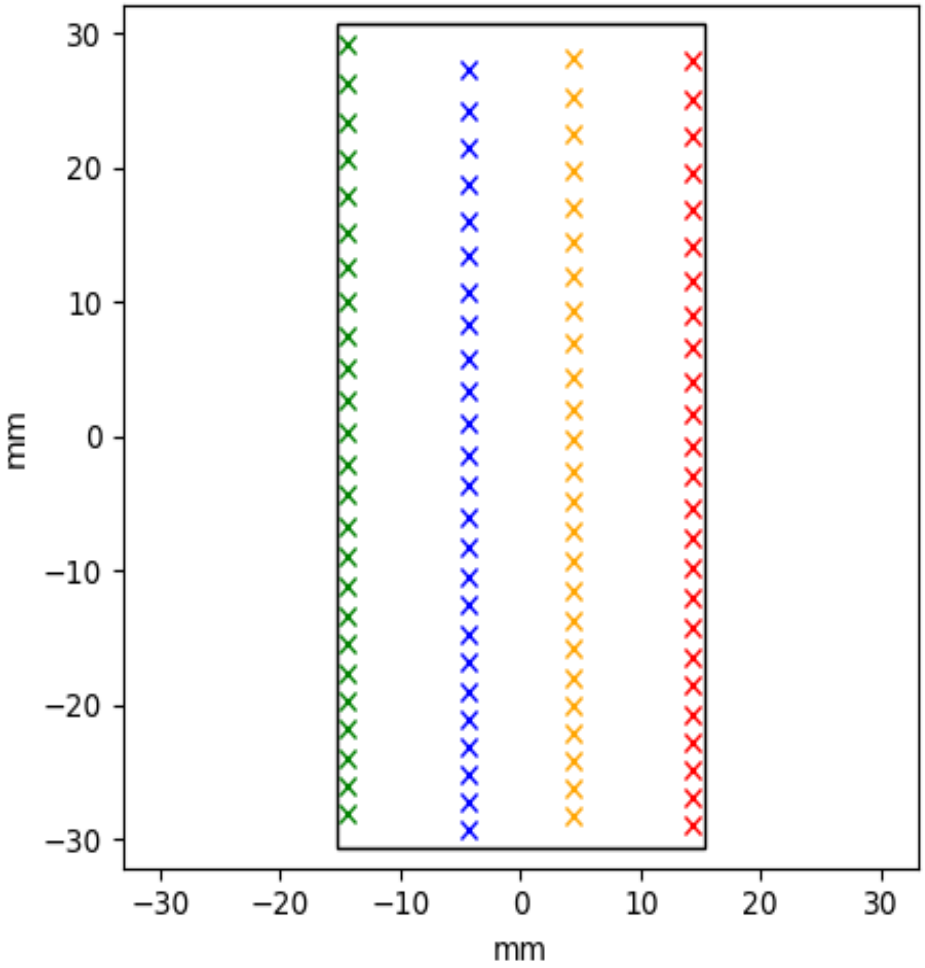
UV-VIS: Multi-Imager Spectrograph

- Collimated beam is divided to 4 bands using 3 dichroics.
- Each band has its own optimized optics (disperser + camera).
- 1st order dispersion, $\mathcal{R}\sim4500$ at α_{Lit}.
- 4 bands quasi-orders are imaged onto a single 4k×2k CCD.

Quasi-Order	Wavelength Range [nm]
u	350 - 438
g	438 - 552
r	552 - 700
i	700 – 850 (880)



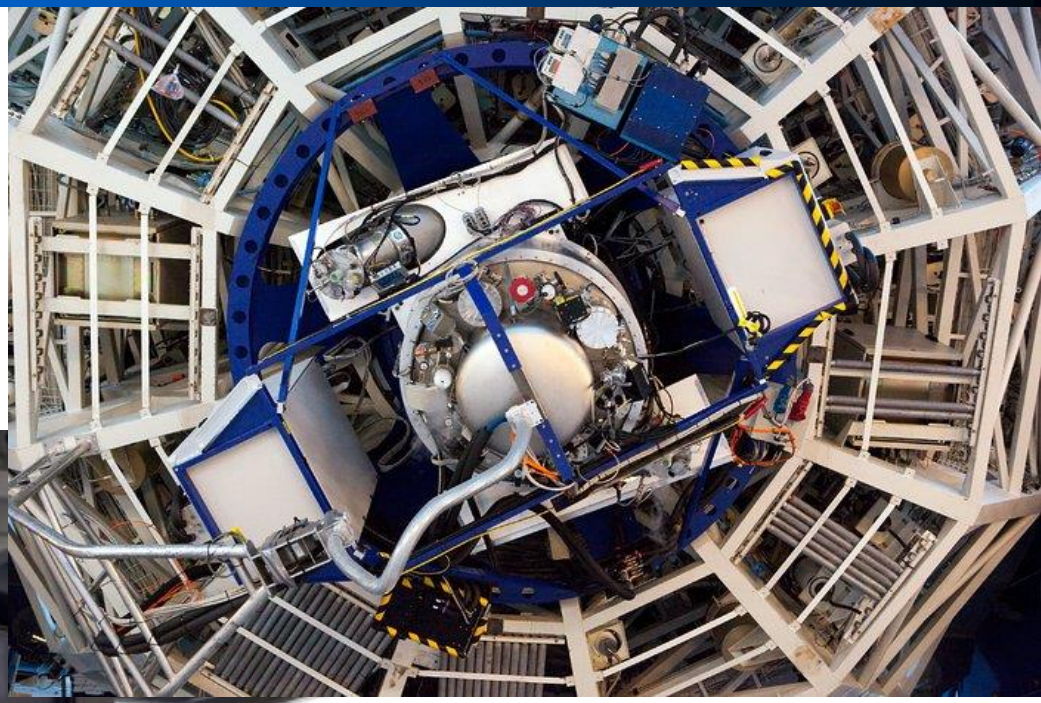
VIS Spectral Format



4 quasi orders images along the long axis of the detector

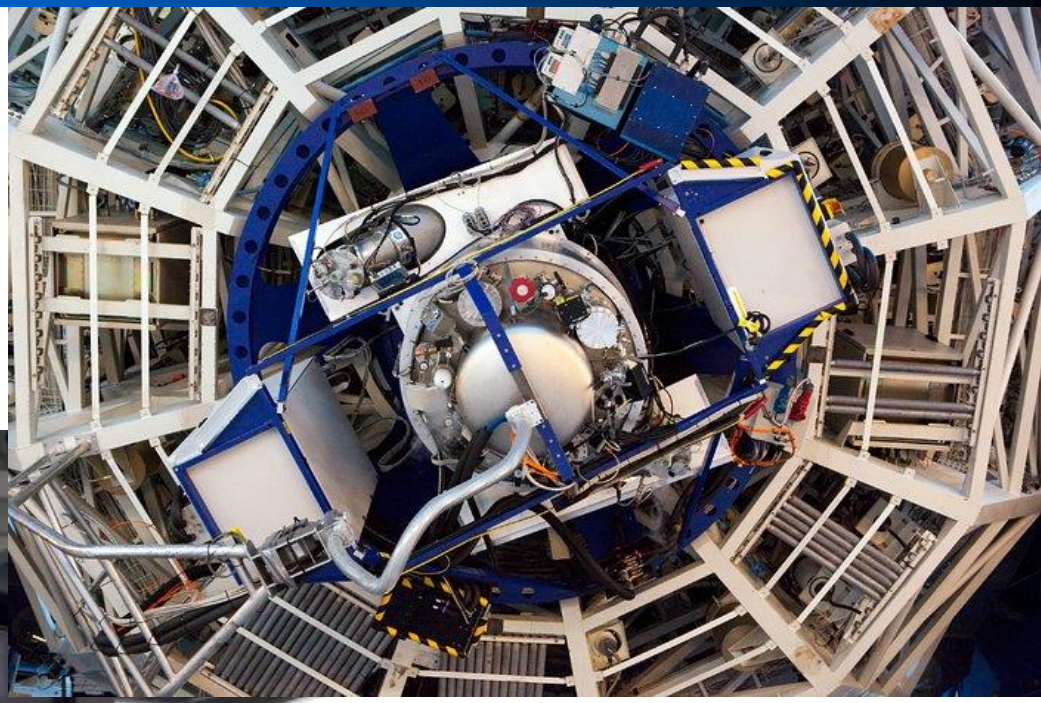
- Efficient use of detector
- Large separation between quasi orders: no overlap/leak between orders.
- No inherent curvature – linear trace, easy data reduction.

X-Shooter



SOXS

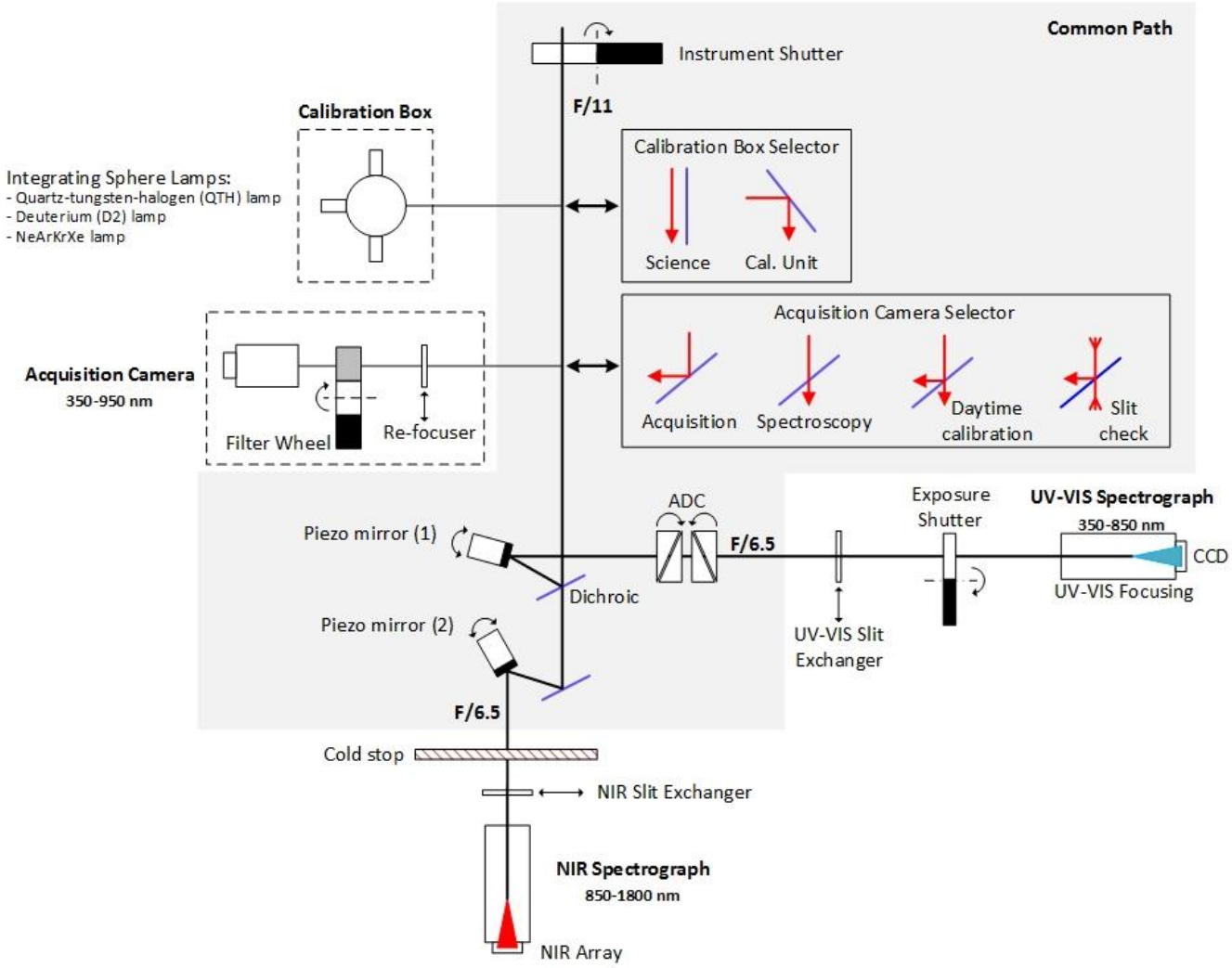
FOS
(Father Of SOXS)



SOXS

Extra-Slides

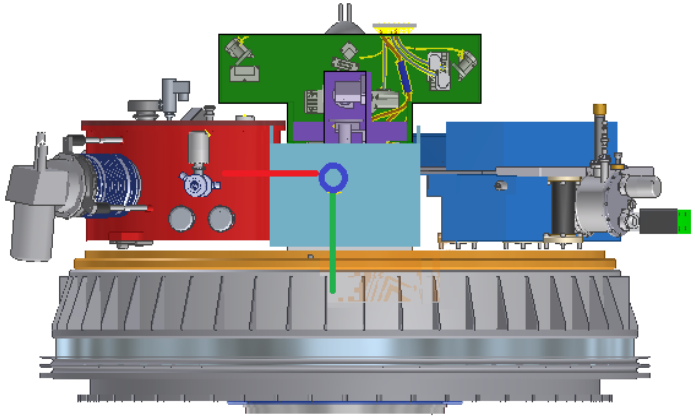
Functional Diagram

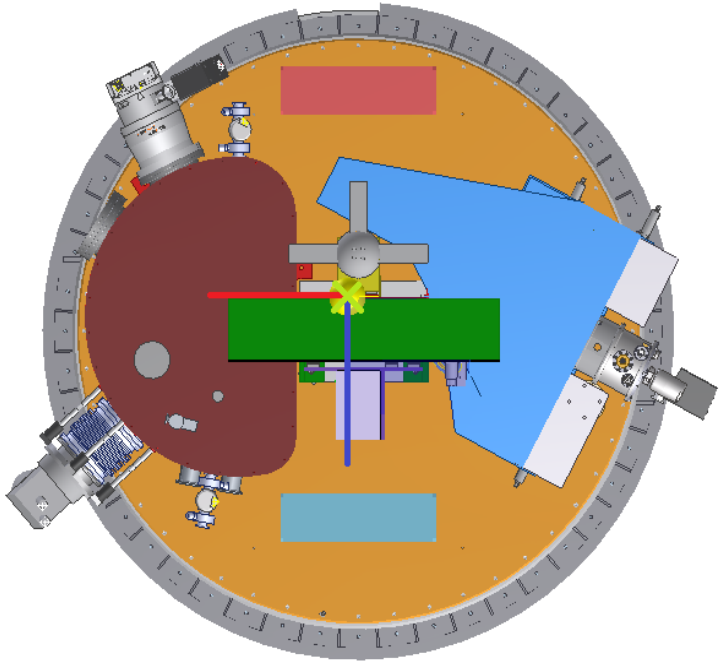


A working example

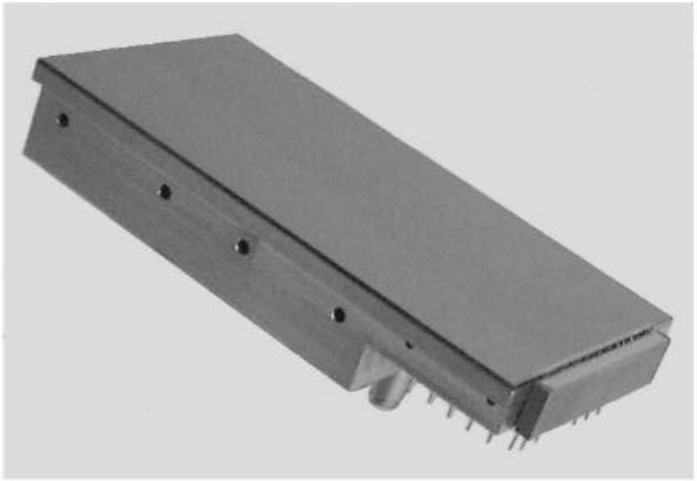
During 2005-2013 Nature published ~180 astronomical papers with more than 50 citations.

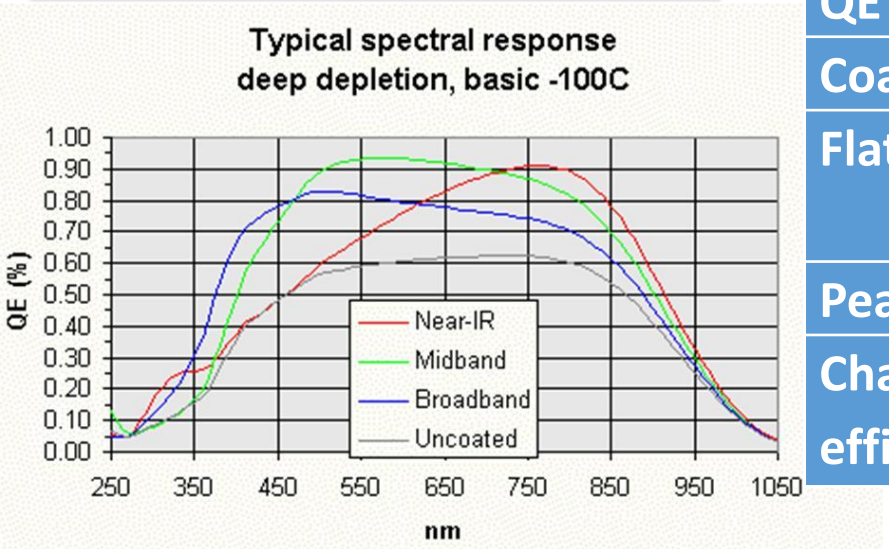
Among them **36%** are on transients objects.





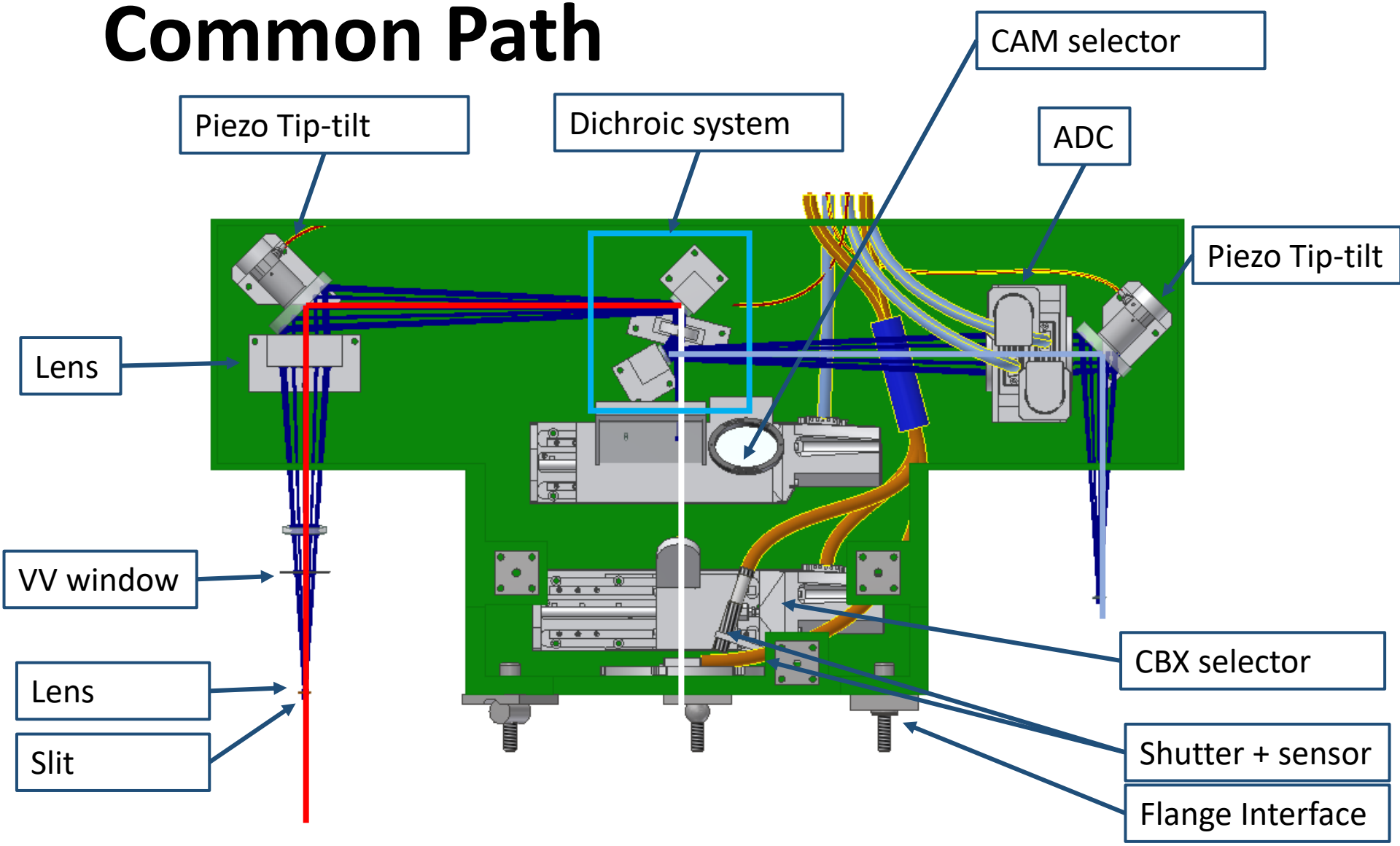
VIS Detector E2V CCD44-82





Detector	CCD44-82
Chip type	Thinned back illuminated
Pixel size	15 µm
Area (pixels)	2048 x 4096
Area (mm)	30.7 x 61.4
QE at 500 nm	90%
Coating	yes
Flatness	Better than 20 µm peak to valley
Peak signal	200 K e^-/pixel
Charge transfer efficiency	99.9995%

Common Path


CAM selector
Piezo Tip-tilt
Dichroic system
ADC
Piezo Tip-tilt
Lens
VV window
Lens
Slit
CBX selector
Shutter + sensor
Flange Interface