The SOXS instrument and its significance in the future of La Silla

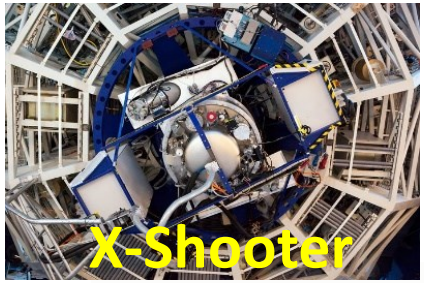
P. Schipani

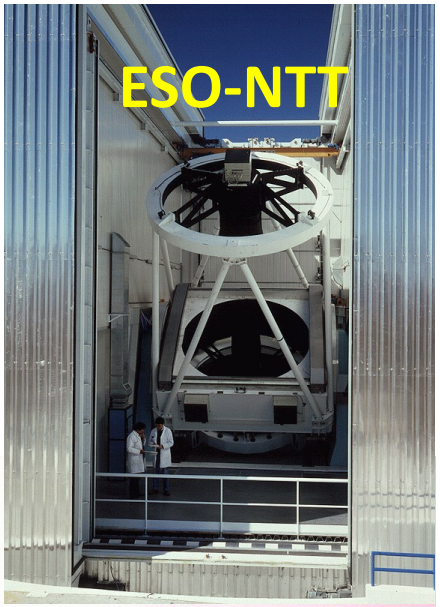
on behalf of the SOXS Team

S. Campana, R. Claudi, H. U. Käufl, M. Accardo, M. Aliverti, A. Baruffolo, S. Ben-Ami, F. Biondi, A. Brucalassi, G. Capasso, R. Cosentino, F. D'Alessio, P. D'Avanzo, O. Hershko, H. Kuncarayakti, M. Munari, A. Rubin, S. Scuderi, F. Vitali, J. Achrén, J. Antonio Araiza-Duran, I. Arcavi, A. Bianco, E. Cappellaro, M. Colapietro, M. Della Valle, O. Diner, S. D'Orsi, D. Fantinel, J. Fynbo, A. Gal-Yam, M. Genoni, M. Hirvonen, J. Kotilainen, T. Kumar, M. Landoni, J. Lehti, G. Li Causi, L. Marafatto, L. Marty, S. Mattila, G. Pariani, G. Pignata, M. Rappaport, D. Ricci, M. Riva, B. Salasnich, R. Zanmar Sanchez, S. Smartt, M. Turatto

The La Silla Observatory: from the inauguration to the future, La Serena, 25-29 March 2019

- Single-object wide band spectrograph from U to H band @ESO-NTT 350-2000 nm
- *'Similar'* to X-Shooter @VLT
- Two arms (VIS + NIR) with partial overlap around 800nm to cross-calibrate spectra
- R~4,500 (3,500-6,000)
- Acquisition camera to perform photometry ugrizy-V (3.5'x3.5')





Consortium

Institutes from 6 Countries

- Istituto Nazionale di AstroFisica (INAF), Italy
- Department of Particle Physics and Astrophysics, Weizmann Institute of Science, Rehovot, Israel
- Universidad Andres Bello & Instituto Milenio de Astrofisica (MAS), Santiago, Chile
- FINCA - Finnish Centre for Astronomy with ESO & Turku University, Turku, Finland
- Queen's University Belfast, UK
- Tel Aviv University, Israel
- Niels Bohr University, Copenhagen, Denmark

The

SOXS Consortium Institutes

Institute	Responsible	Country
INAF	S. Campana (PI)	Italy
Weizmann Institute	A. Gal-Yam	Israel
Instituto Milenio de Astrofisica	G. Pignata	Chile
Turku University	S. Mattila	Finland
Queen's University Belfast	S. Smartt	UK
Tel Aviv University	I. Arcavi	Israel
Niels Bohr University Copenhagen	J. Fynbo	Denmark

Project History

- ESO Call for new instruments at NTT (2014)
- Proposal submission (02/2015)
- Selected by ESO (2015) out of 19
- Kick-off (2016)
- MoU signed for PDR phase (02/2017)
- PDR ok (07/2017)
- FDR ok (01/2018 + 04/2018 + 07/2018 + 10/2018)
- MoU signed (10/2018)

MoU signed for a 5-year agreement
October, 2018

European Organisation for Astronomical Research in the Southern Hemisphere

Memorandum of Understanding

No. 11378/LET/CP/AMA

for the SOXS Instrument on the NTT Telescope

BETWEEN

the **European Organisation for Astronomical Research in the Southern Hemisphere**, hereinafter referred to as **ESO**, having its Headquarters at Karl-Schwarzschild-Straße 2, D-85748 Garching bei München (Germany), represented by its Director General Xavier Barcons,

on the one hand,

AND

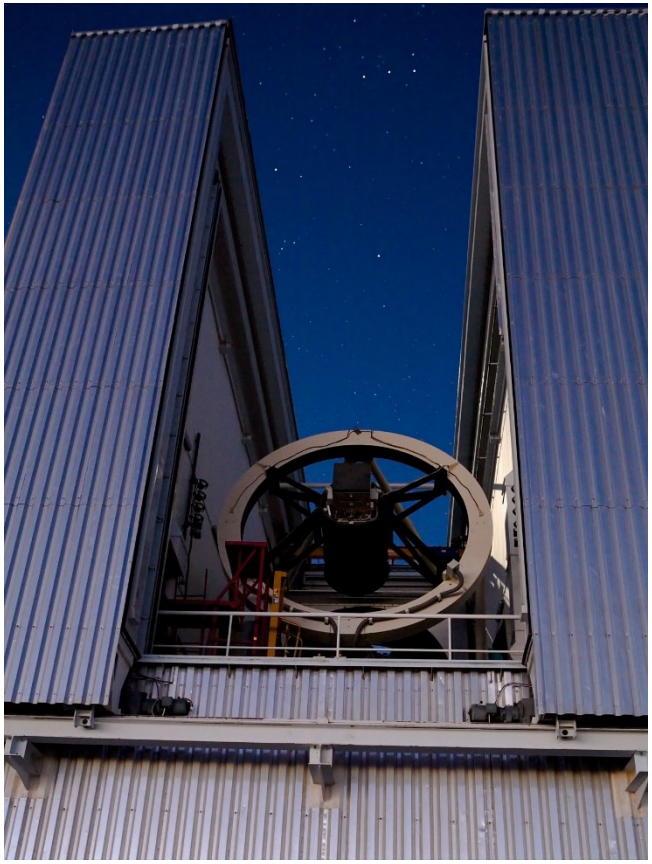
SOXS Consortium (whose members are listed in the preamble), hereinafter referred to as ***the Consortium***, represented at equal level by its PI, Dr. Sergio Campana (INAF/Osservatorio di Brera), and the INAF Scientific Director Dr. Filippo Zerbi (INAF Headquarter), which acts in the name and on behalf of the Consortium.

on the other hand.

SOXS

ESO Telescopes @La Silla

SOXS @NTT: Transients



NIRPS @3p6: Exoplanets

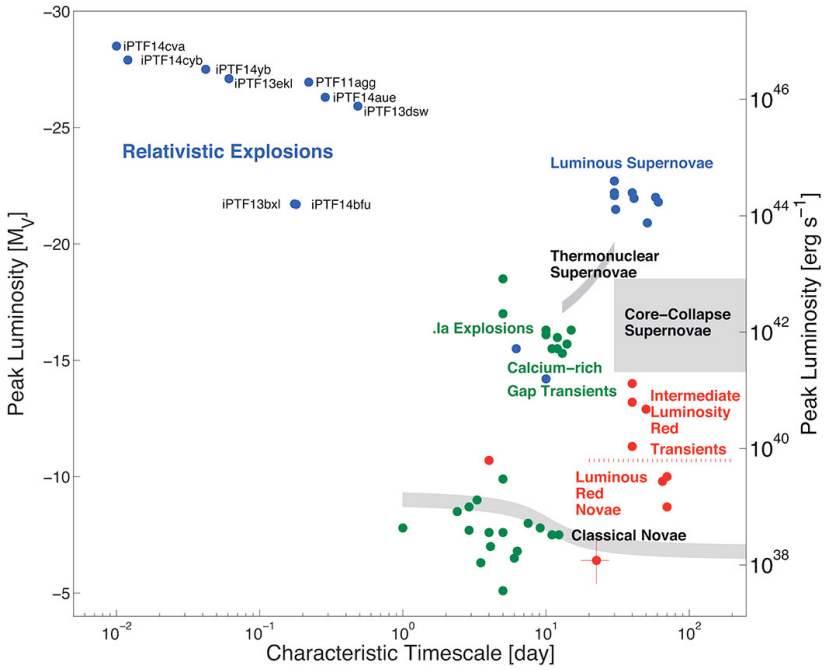
Science Case

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

SOXS

Spectroscopic follow up of transients

- ❑ Classification of transients
- ❑ Supernovae (all flavours)
- ❑ Gravitational Wave events
- ❑ Neutrino events
- ❑ Nuclear transients and Tidal Disruption Events
- ❑ Gamma-ray Bursts and Fast Radio Bursts
- ❑ X-ray binaries and novae, magnetars
- ❑ Asteroids and Comets
- ❑ Young Stellar Objects & stars
- ❑ Blazars and AGN
- ❑ The Unknown



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

PESSTO / ePESSTO 'pathfinder'

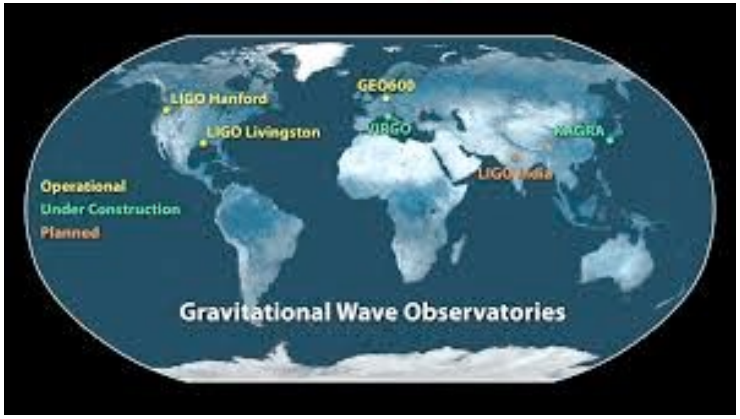
- PESSTO evolved into ePESSTO
- Large program at ESO
- Approved for several periods for 90n/yr
- Pathway to SOXS
- Even with PESSTO, >70% of the transients remain unclassified

P.I.: S. Smartt (QUB)

Sinergies

Spectroscopic machine for the transient sky

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, …



Consortium will have 180 n/yr (for ≥5 yr)
~3,000-4,000 spectra/yr

Project Schedule

Project Phase	Start	End
Preliminary Design	08/2016	07/2017
*Final Design	08/2017	10/2018
MAIT	11/2018	2020
Inst. & Commissioning (Chile)	2020	2021
Operations	2021	>=2026

*Split in several steps

In SOXS case, consortium duties go after the instrument realization

(Other) Consortium Duties

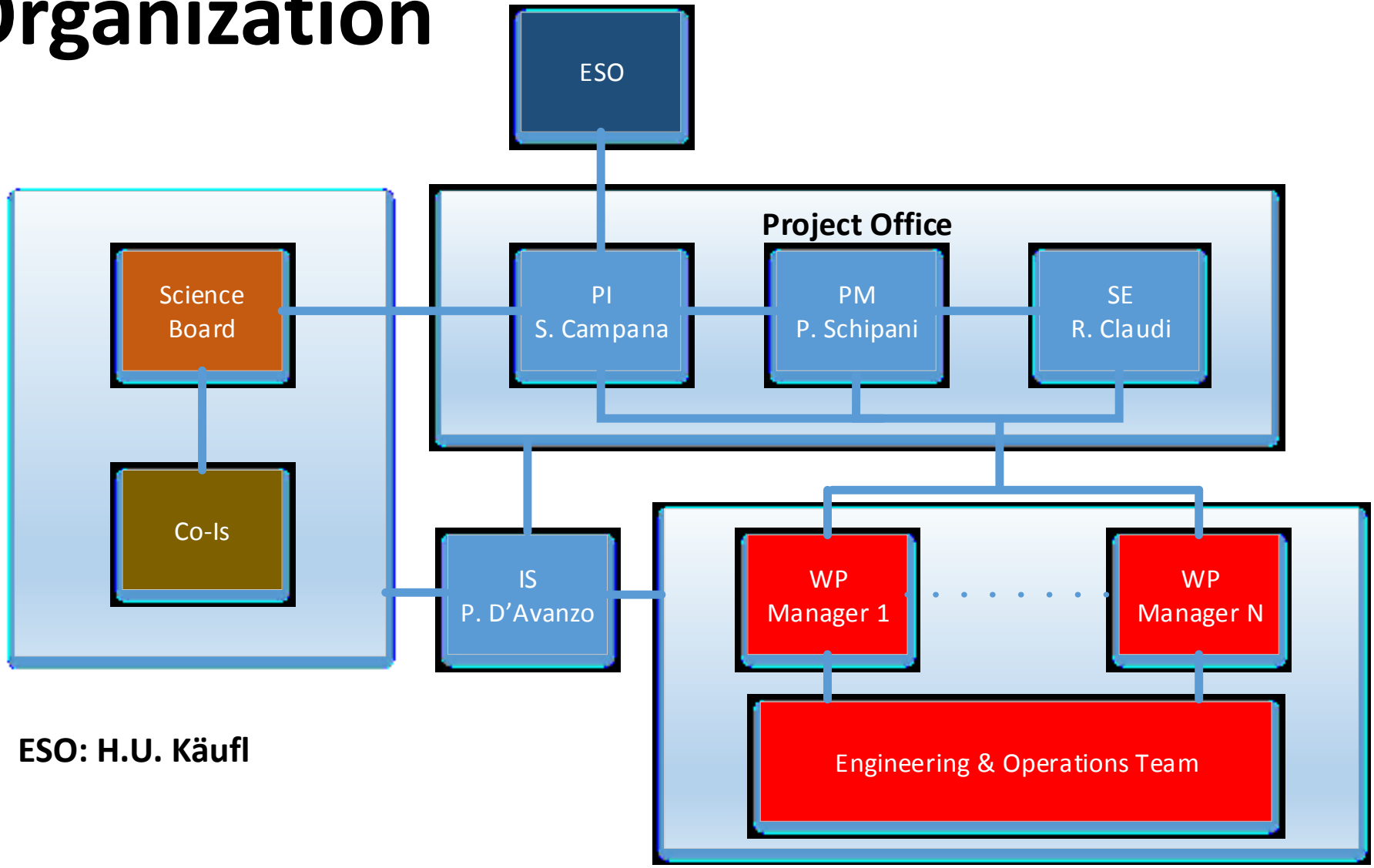
- ETC (preliminary version ready)
- Helpdesk to assist the community
- P2 to build OBs
- Schedule
- Pipeline
- QC0 control

In SOXS case, consortium duties go on after the instrument realization

Operations

- Flexible scheduling, 365 days/yr, by SOXS consortium
  - Dynamical merging of GTO targets and ESO targets
- Observations carried out by ESO operator
- SOXS people on call
  - in case of real need, and/or of new, interesting transients
- GTO proposals will go to OPC, as usual
  - Defining triggers clearly will be crucial
- Consortium data: 12-month proprietary period

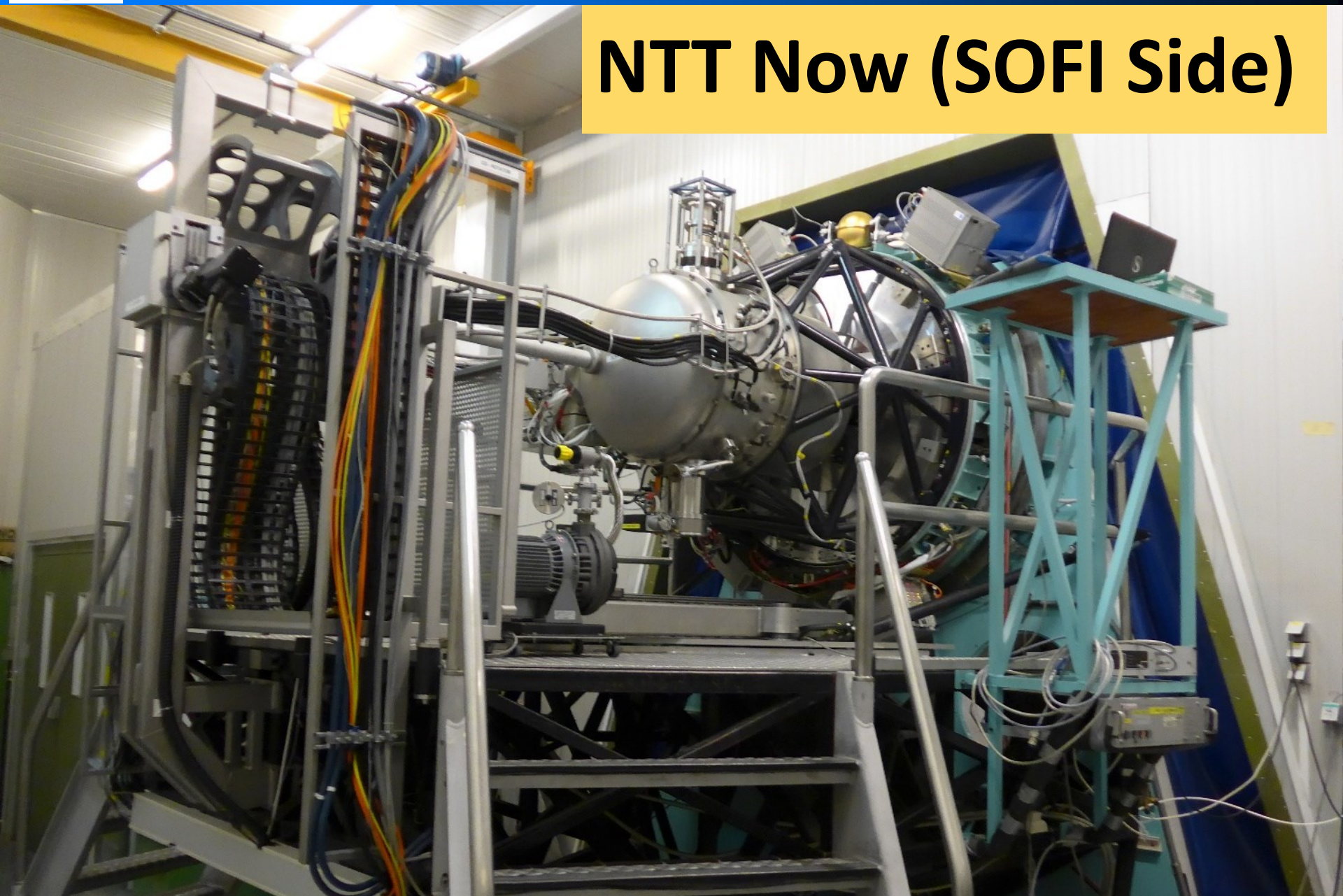
Organization



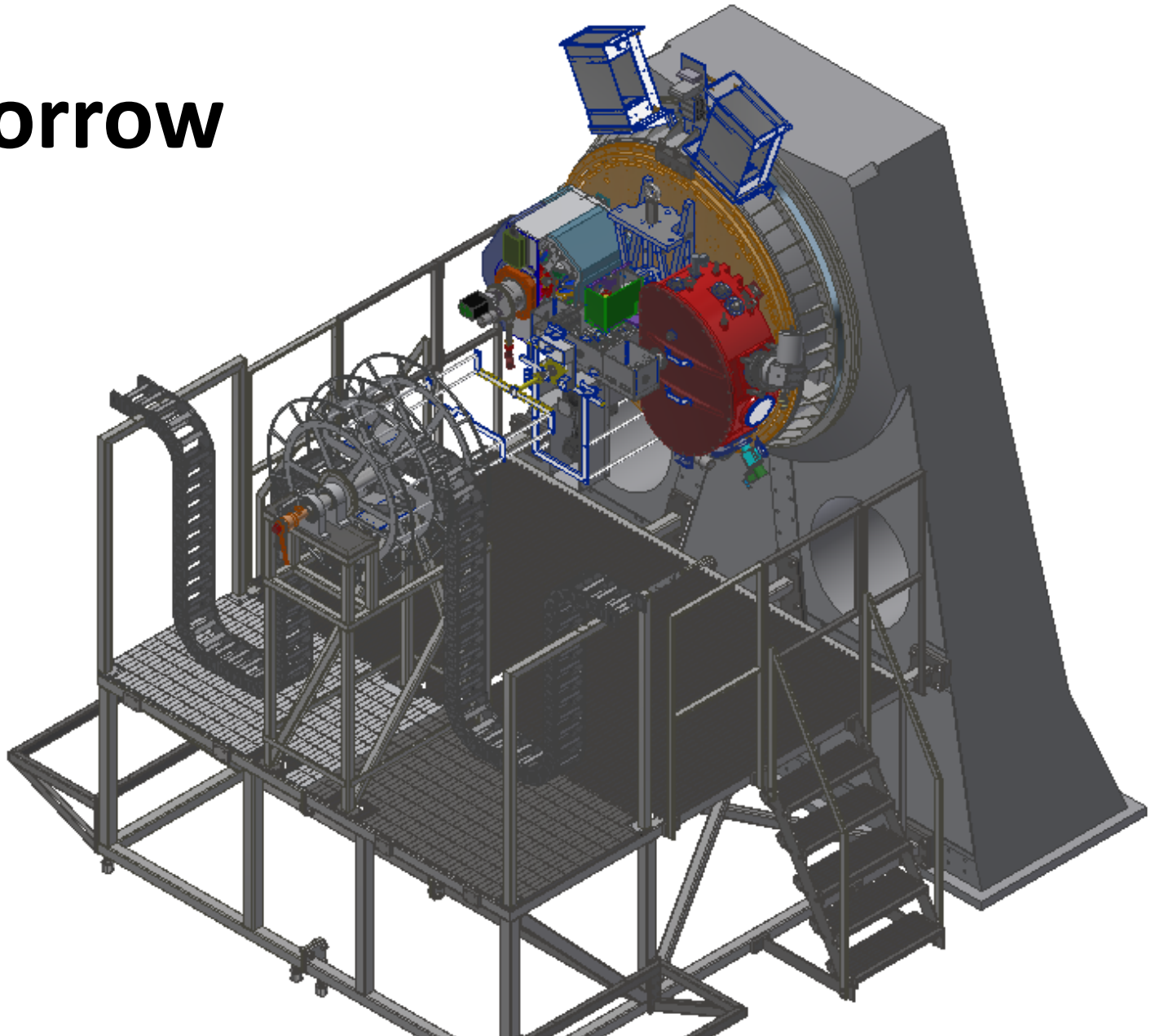
ESO: H.U. Käufl

SOXS

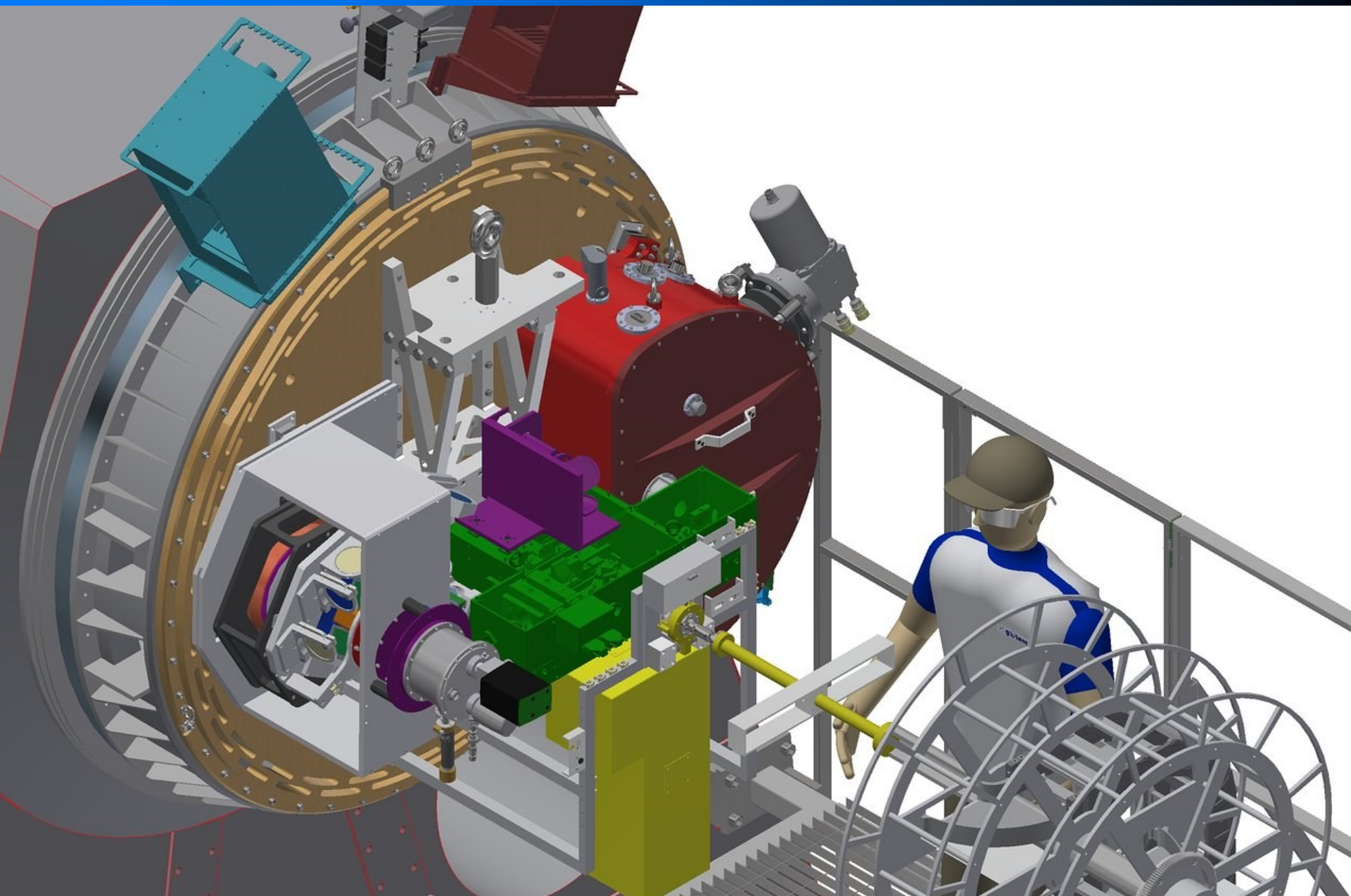
NTT Now (SOFI Side)

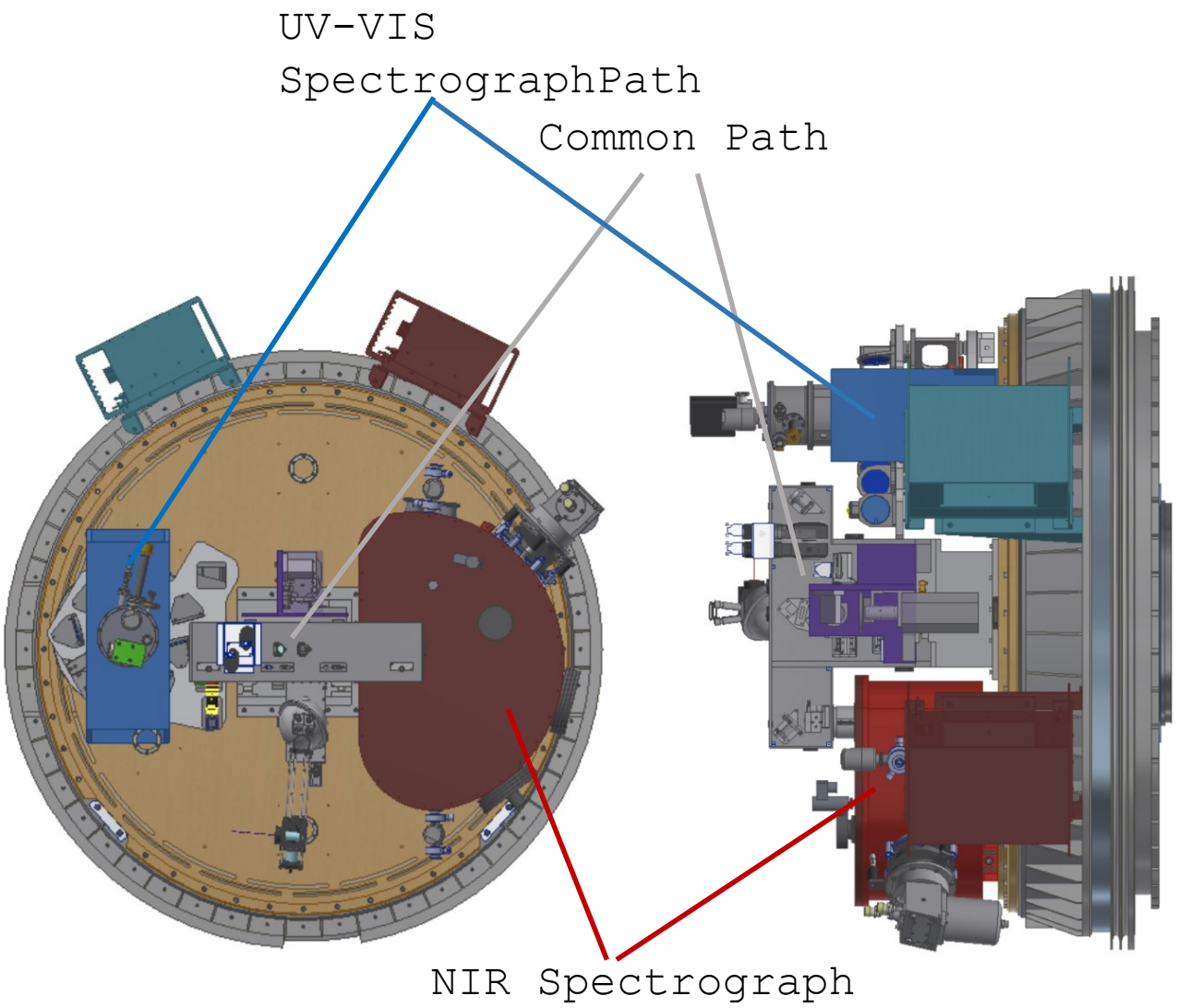


Tomorrow

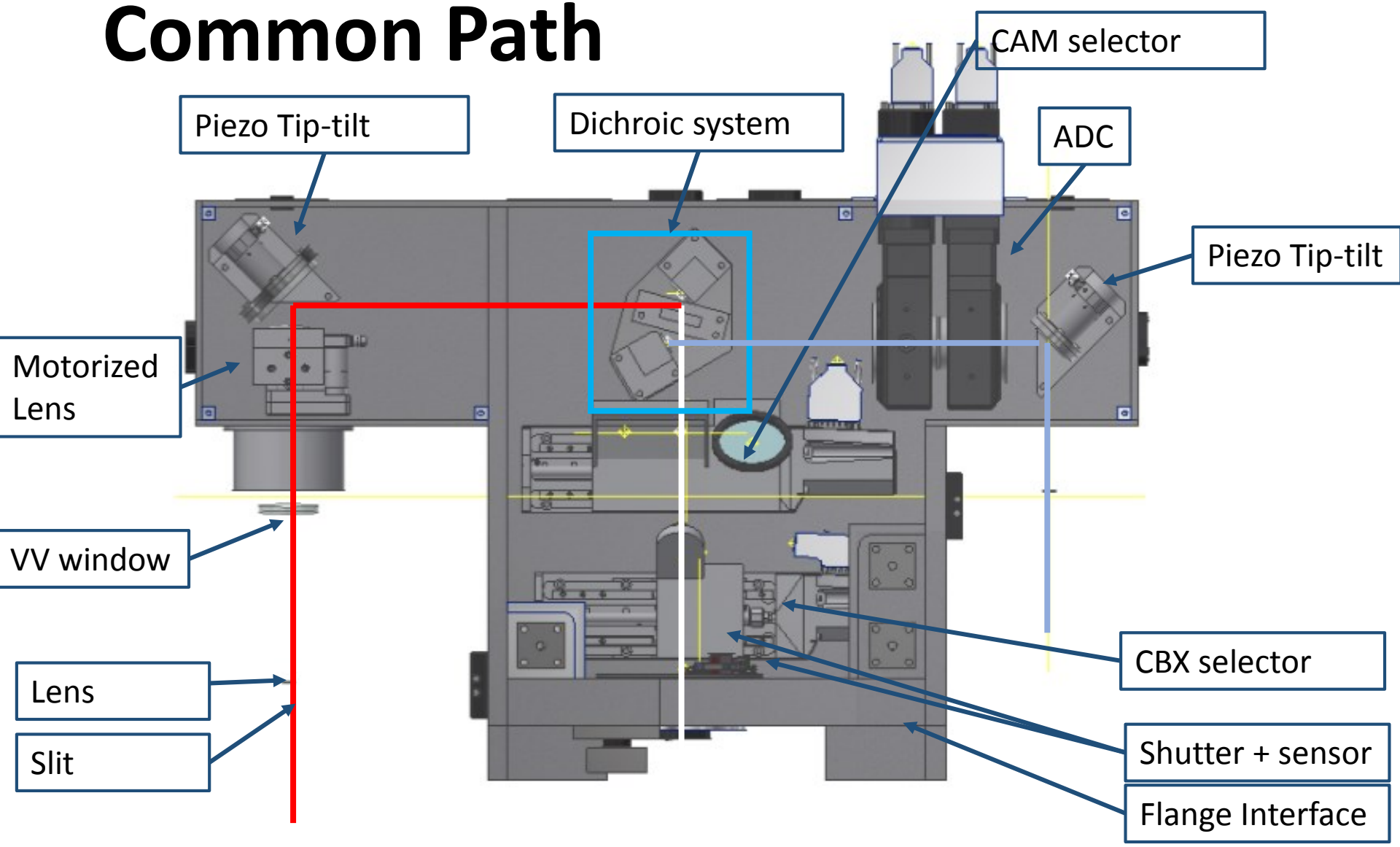


SOXS



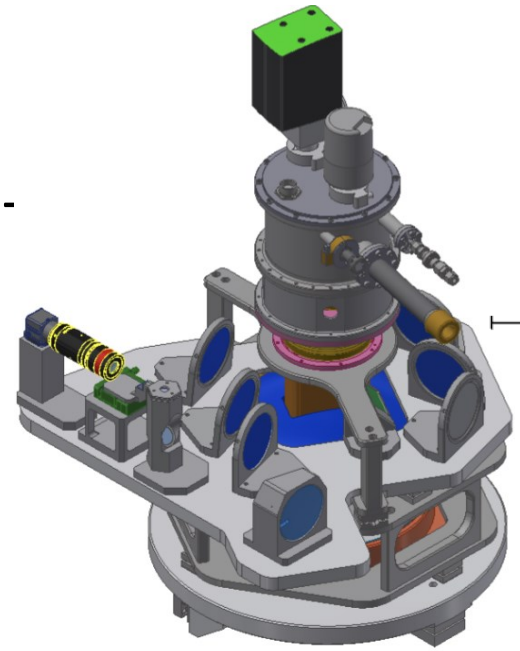

UV-VIS
SpectrographPath
Common Path
NIR Spectrograph

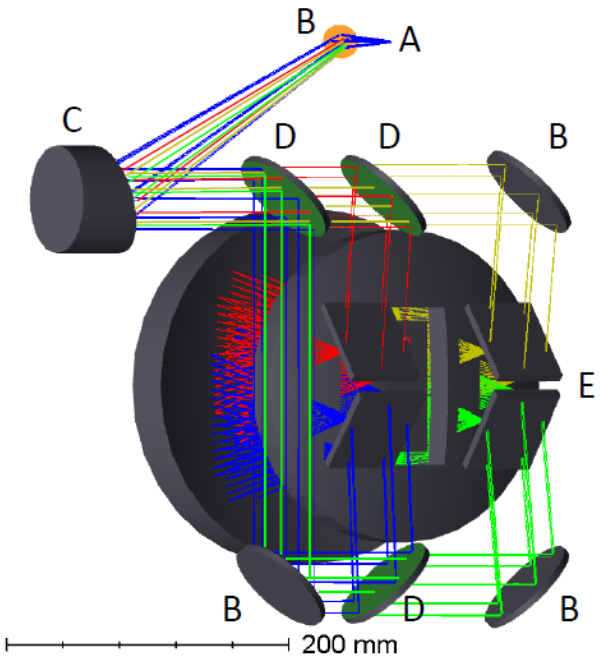
Common Path


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

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.

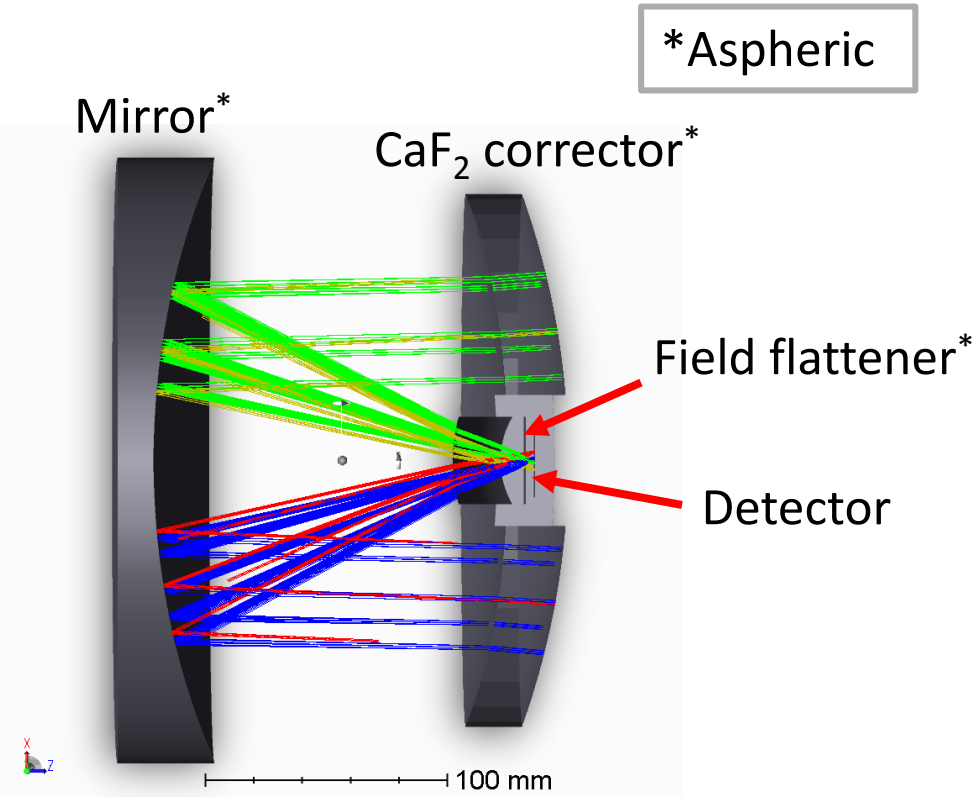




Quasi-Order	Wavelength Range [nm]
u	350 – 439.5
g	427 - 545
r	522 - 680
i	656 – 850

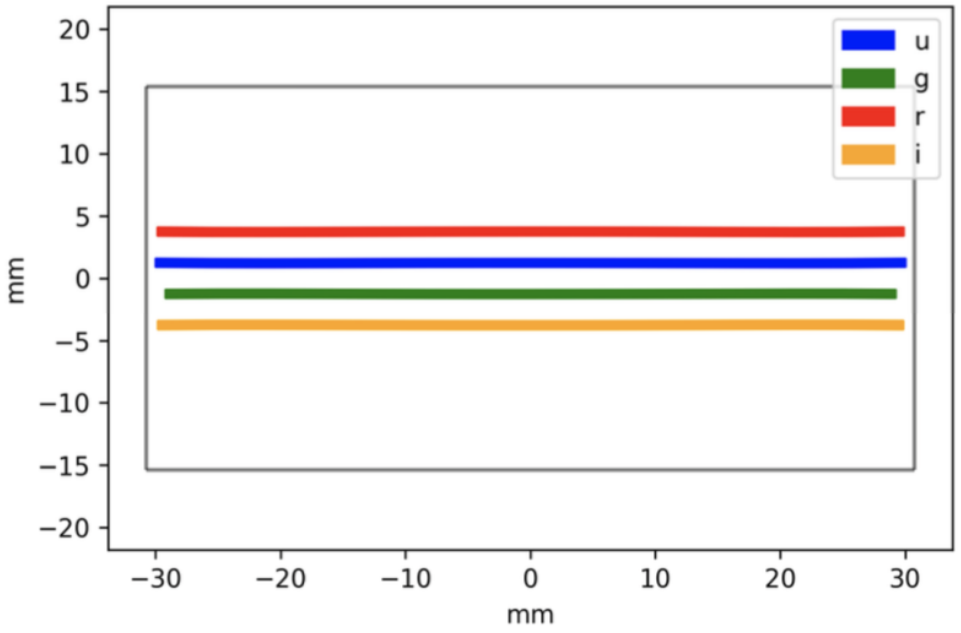
Camera

- Three element catadioptric camera: all aspheric
- Used as 4 off axis F/3.1 cameras.
- CaF2 corrector + Fused Silica Field Flattener
  - Negligible absorption losses in the glass



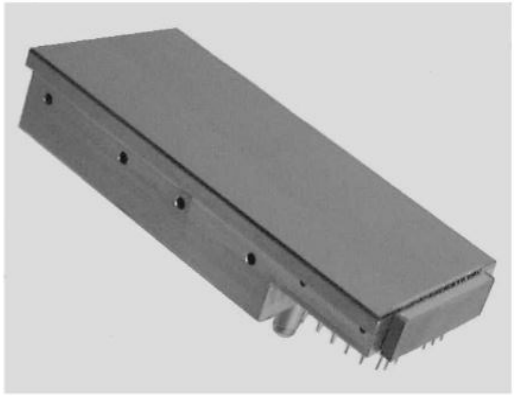
VIS Spectral Format

4 quasi orders images along the long axis of the detector

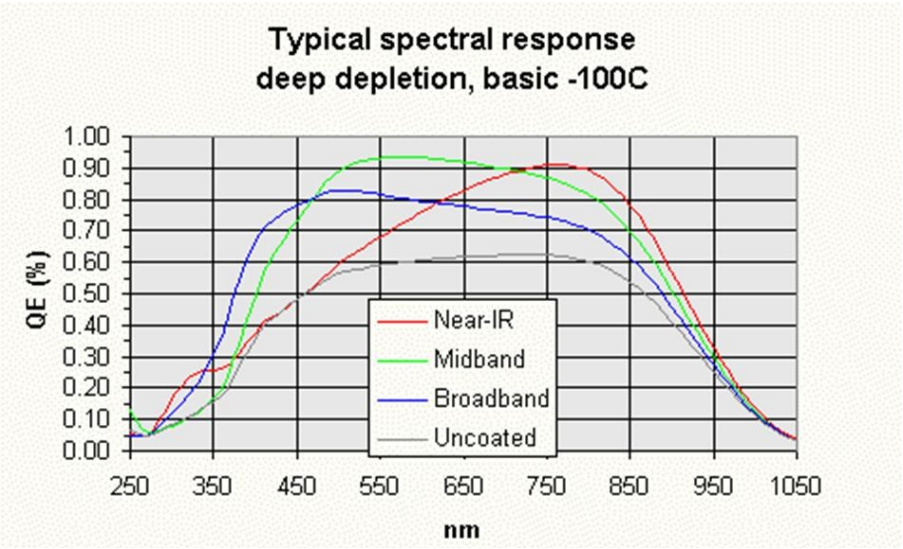


- Efficient use of detector
- Large separation between quasi orders: no overlap/leak between orders.
- No inherent curvature – linear trace, easy data reduction.

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
CTE	99.9995%



ESO NGC Controller

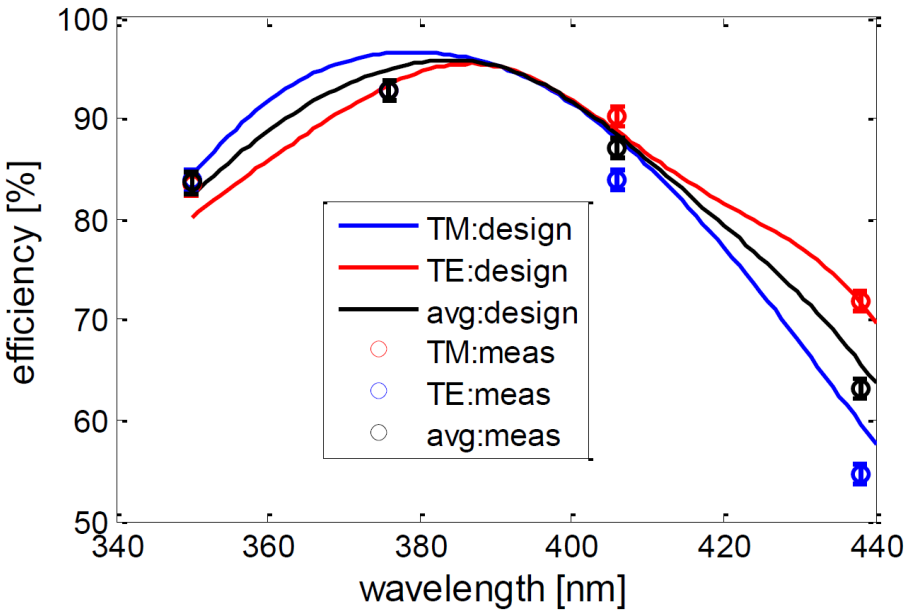
ION Etched Gratings

Ion etched gratings (Fraunhofer):

u and g delivered

r and i to be shipped later this month

As built average efficiency ~85%

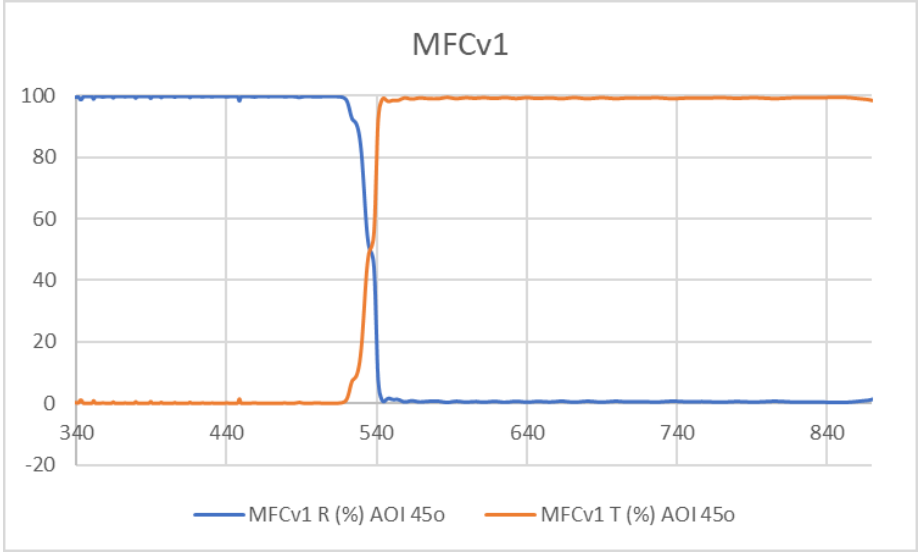


WL	AVG TETM
350	83.6
376	92.7
406	87.1
438	63.2

WL	AVG TETM
438	79.15
475	92.45
510	88.35
545	70.2

Dichroic Mirror Performance

- Dichroic/dielectric mirrors from Thin Film Physics
- Simulated performance of dichroic mirrors. >99% reflectivity (transmission) in reflection (transmission) band.
- Vendor commitment to <5% RMS deviation.



Dichroic and dielectric mirrors:

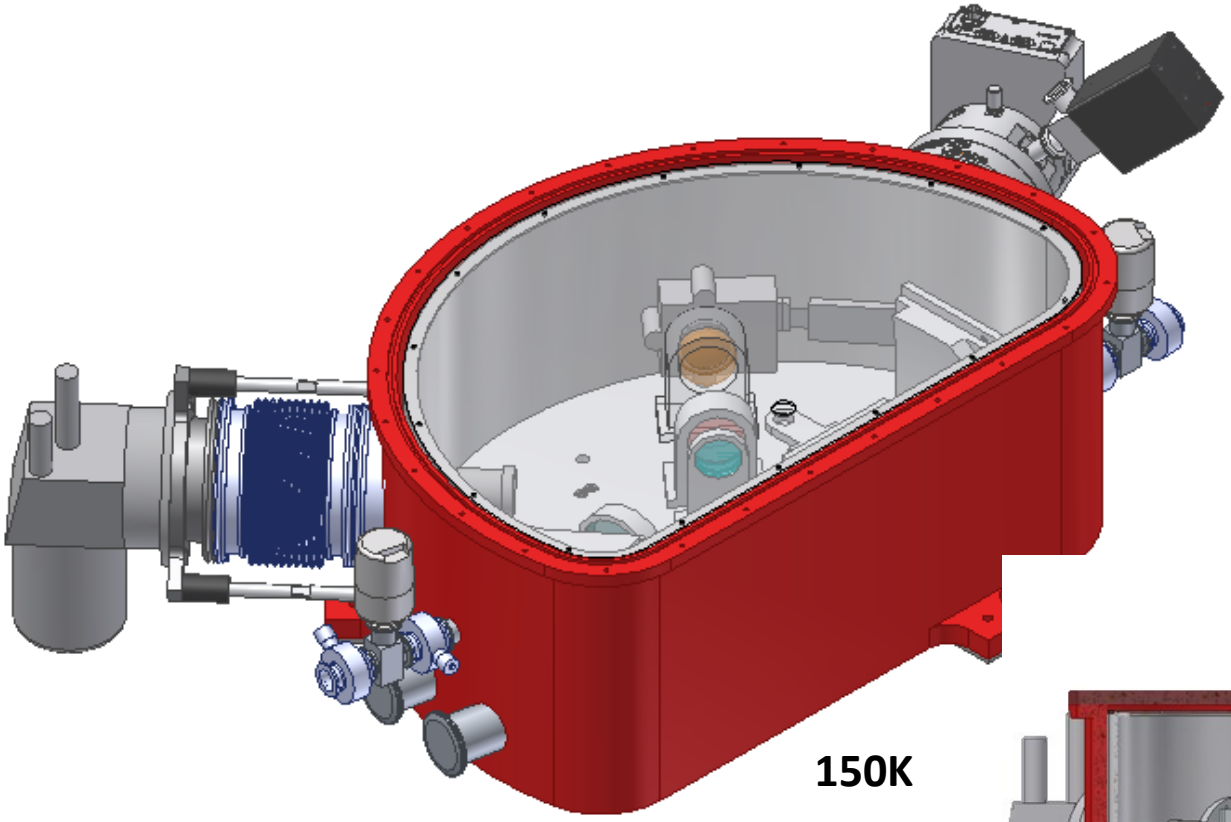
Quote received and order being issued.

- CCD interface
  - Manufactured. Leak test being performed with dummy window.
  - Dummy CCD to be integrated during March/April

Camera and collimator optics:

All substrates have arrived at Winlight and initial shaping has begun

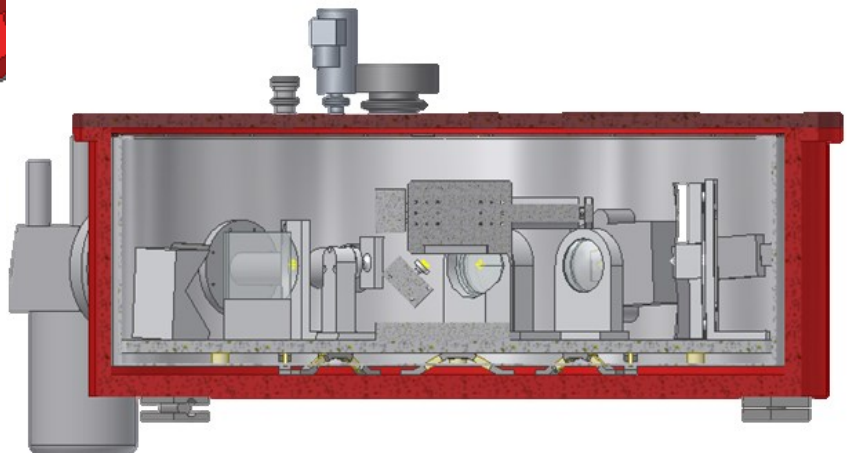
NIR spectrograph



150K

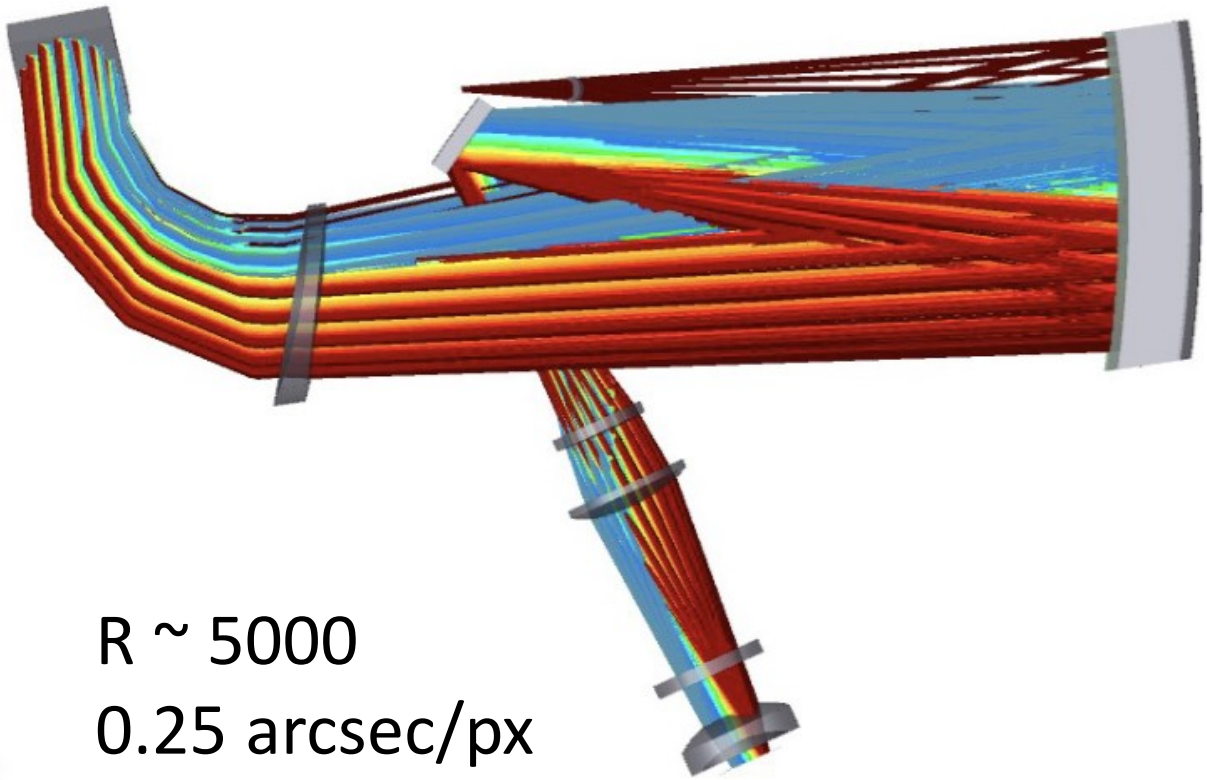
Hawaii H2RG 2K x 2K
Substrate removed

ESO NGC Controller



NIR 4C Design

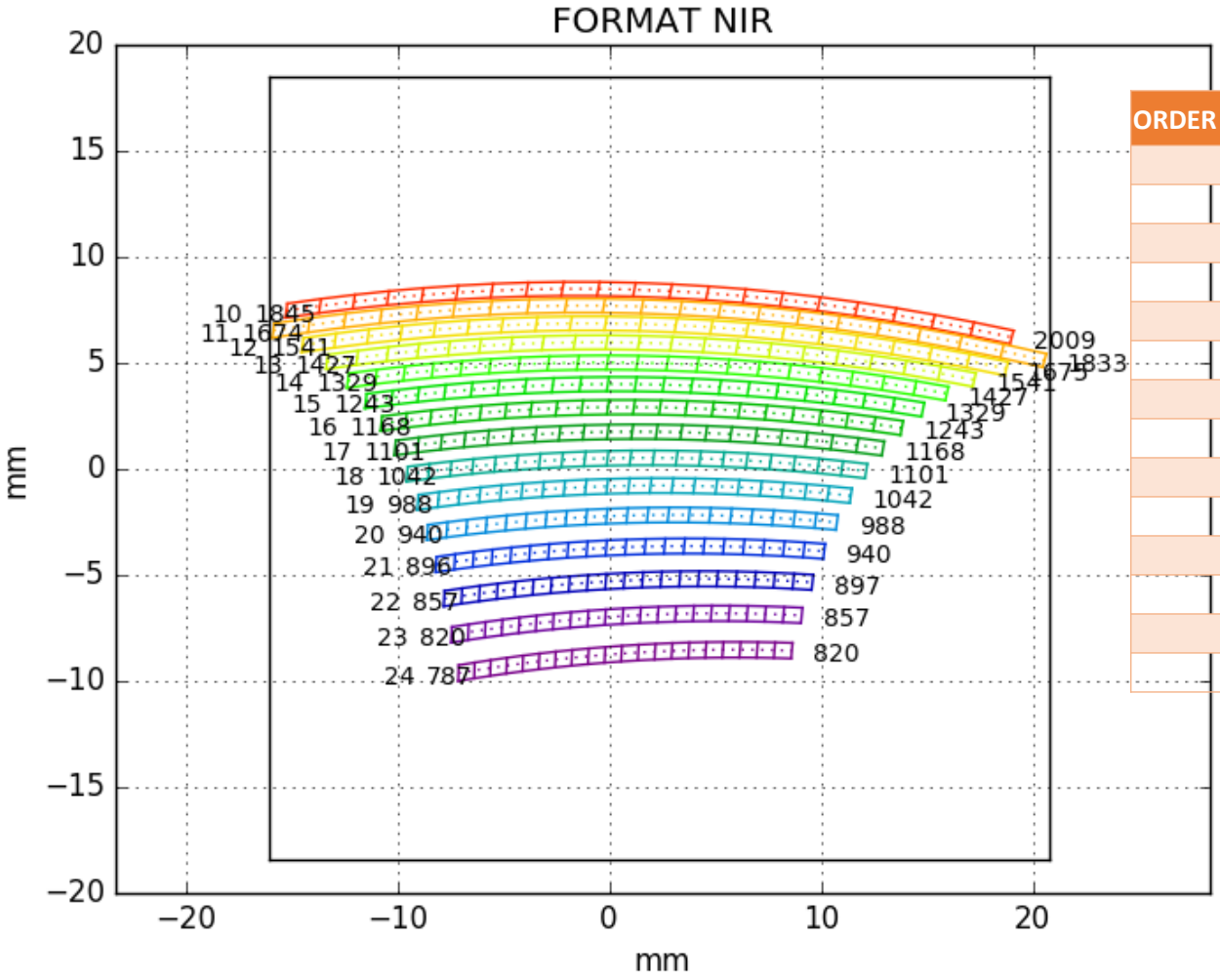
Spectrograph with
Collimator
Compensation of
Camera
Chromatism



Echelle
Cross-Dispersed

R ~ 5000
0.25 arcsec/px
F/3.7 camera

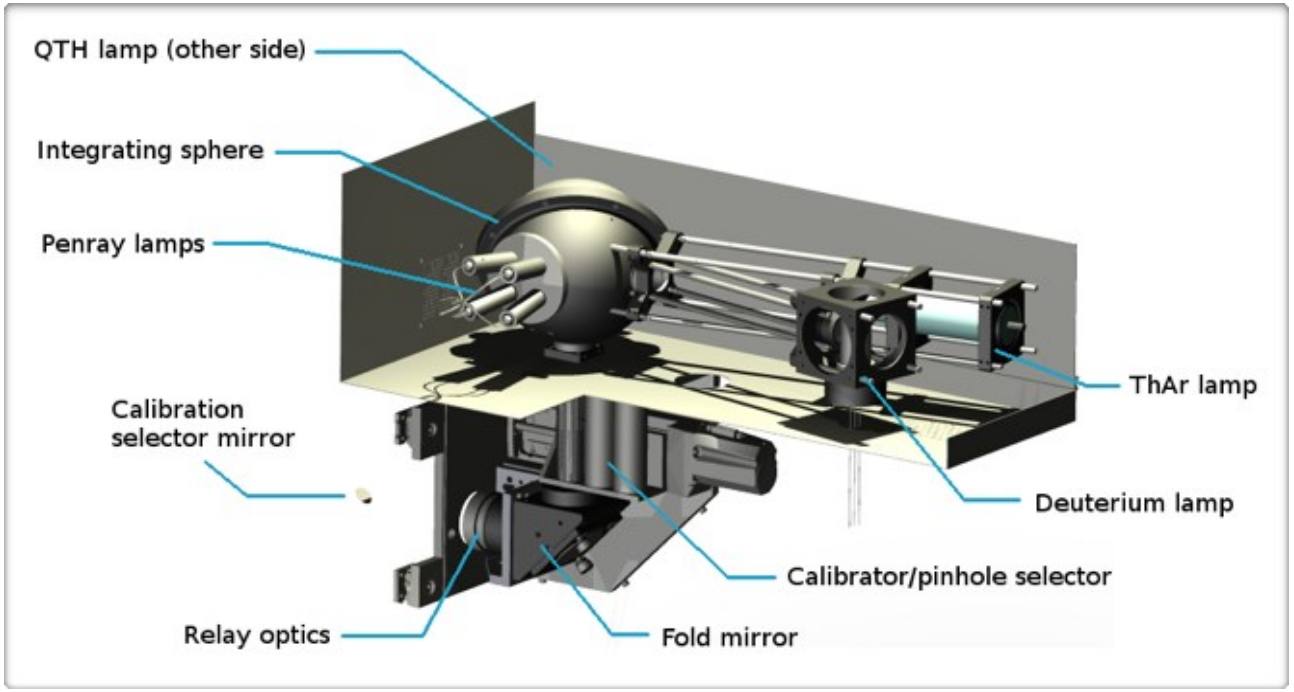
NIR Spectral Format

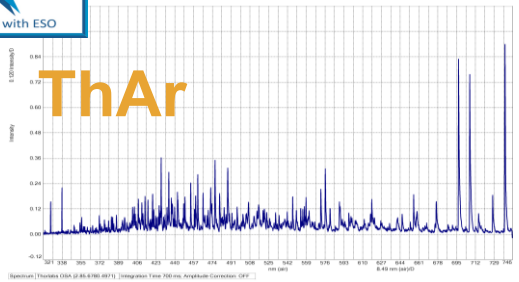


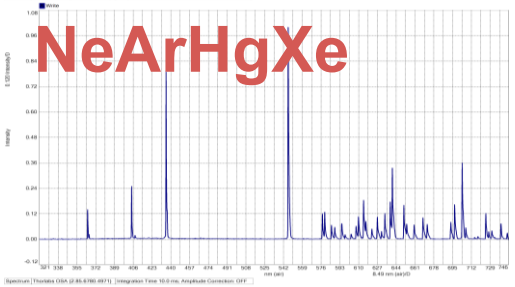
ORDER	FSR	MIN WL	BLAZE WL	MAX WL
11	0.159	1.674	1.754	1.834
12	0.134	1.541	1.608	1.675
13	0.114	1.427	1.484	1.541
14	0.098	1.329	1.378	1.428
15	0.086	1.244	1.286	1.329
16	0.075	1.168	1.206	1.244
17	0.067	1.102	1.135	1.168
18	0.06	1.042	1.072	1.102
19	0.053	0.989	1.016	1.042
20	0.048	0.941	0.965	0.989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

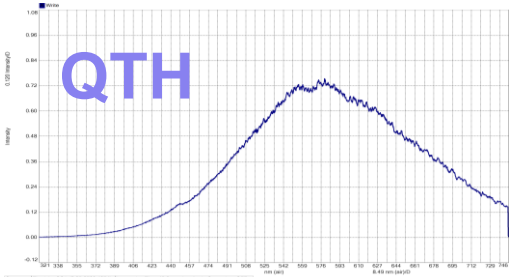
- 15 Orders
- 0.787-2.009 μm

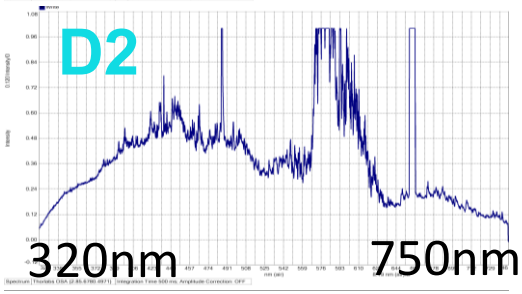
Calibration unit



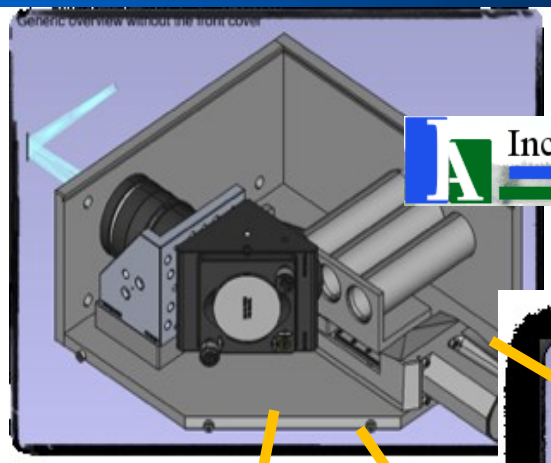


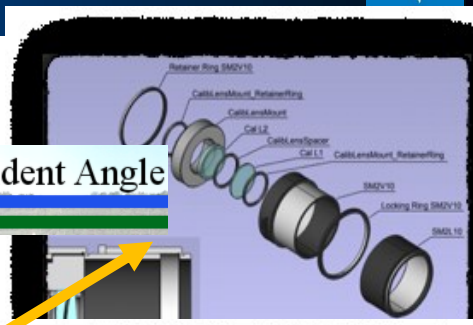


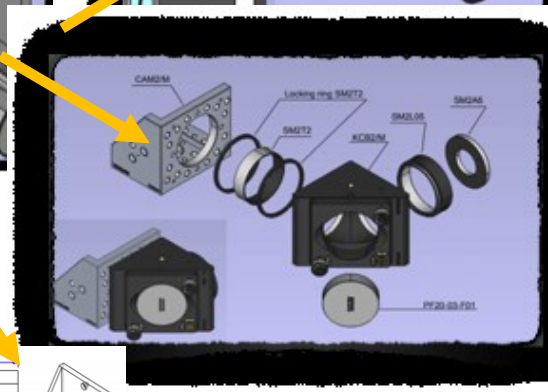


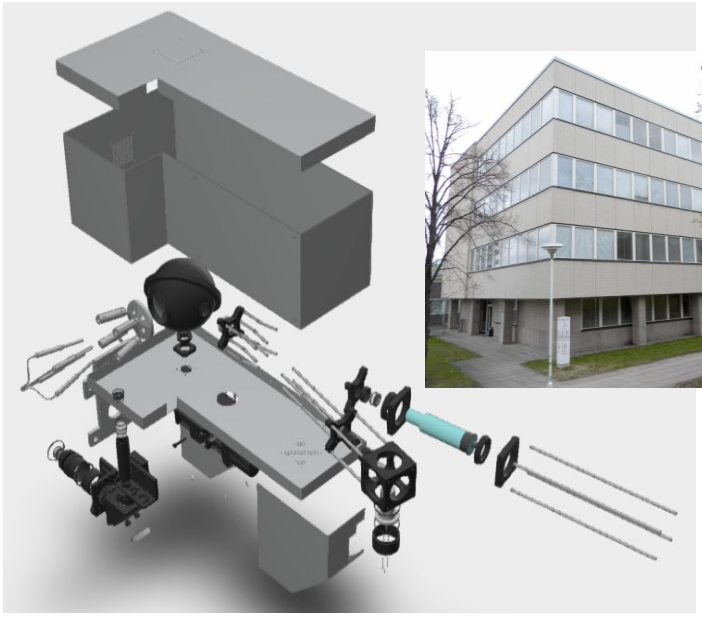


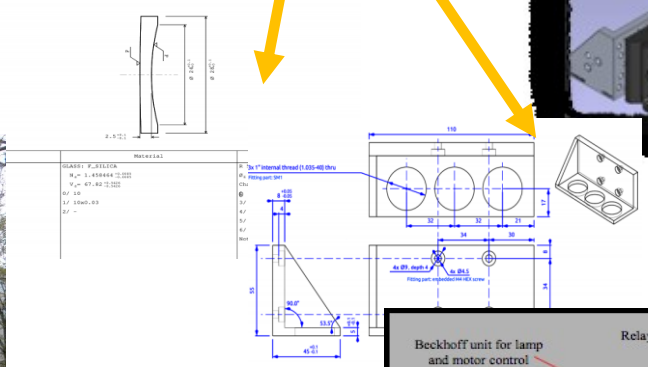
- **FINCA** + 2 local companies
  - **IncidentAngle**: optomechanics
  - **ASRO**: control & electronics
- U. Turku workshop : parts manufacture
- **Currently being built at U. Turku Campus**

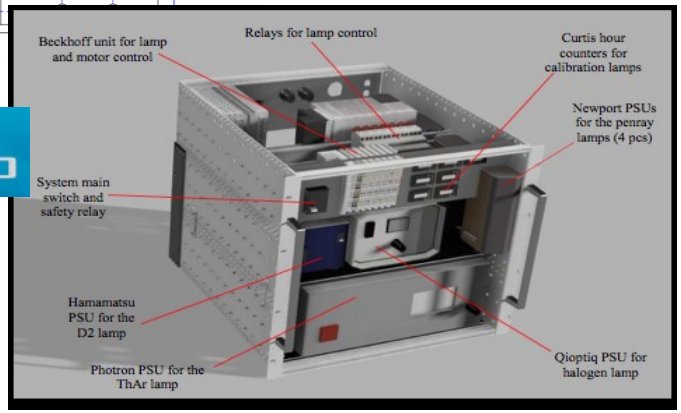












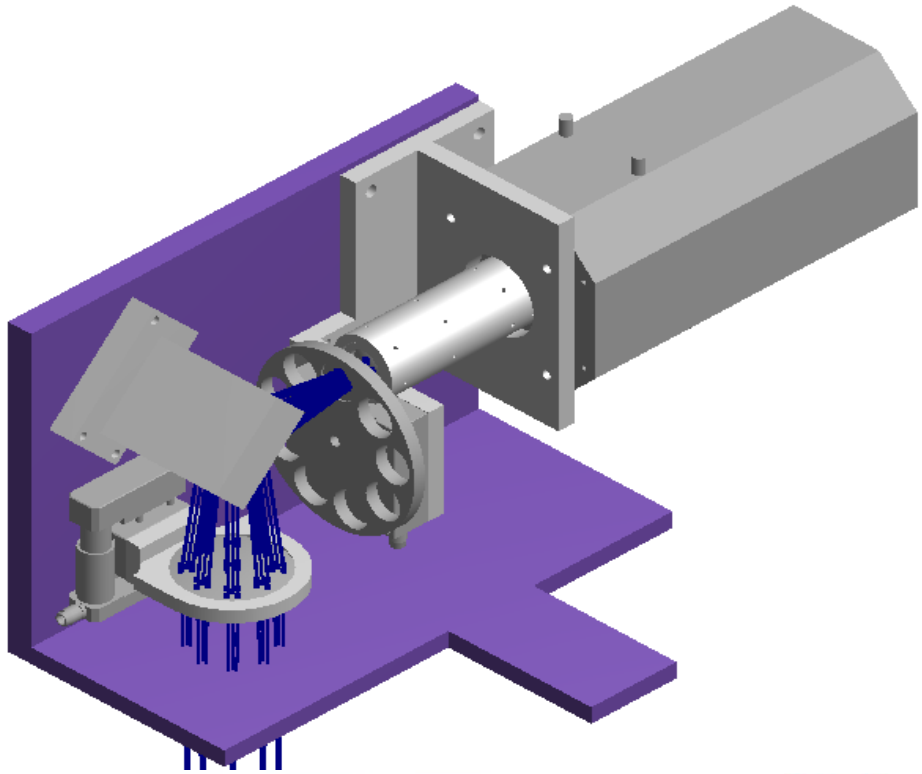
A&G Camera

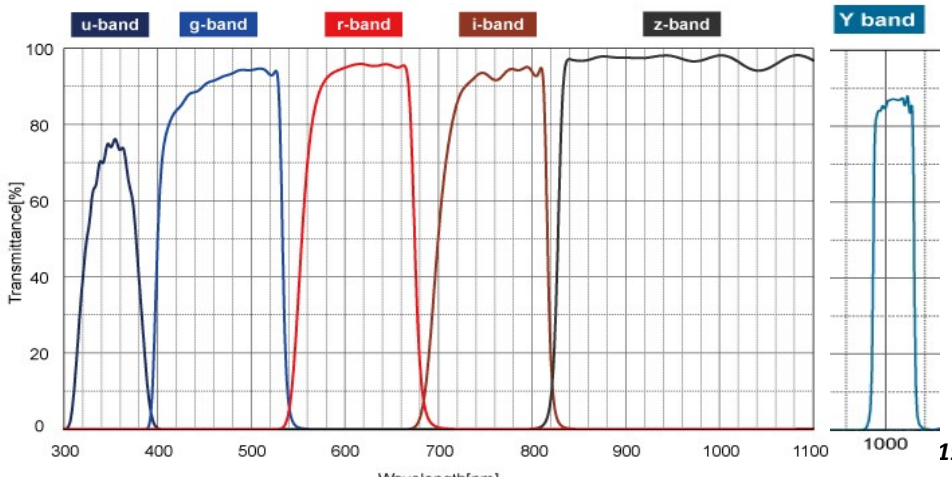
- Target Acquisition
- Secondary guiding
- Photometry

FoW => 3.5'x3.5'

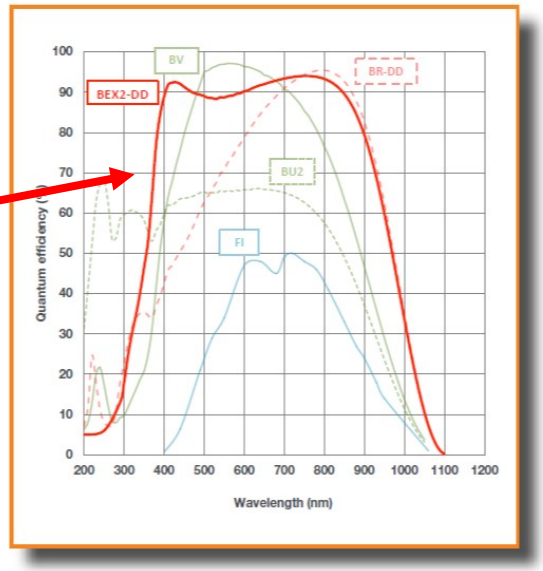
Filters => ugrizy + V

Filters from Asahi Spectra
Very good matching of the SDSS photometric system





BEX2-DD =>
High QE in
a broad
wavelength
range



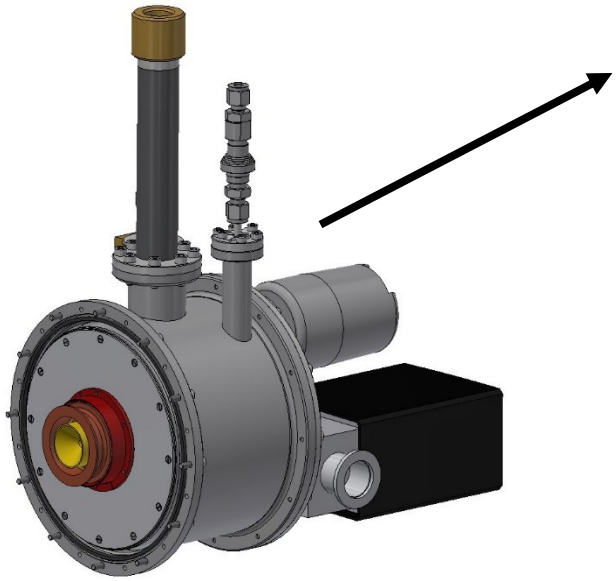
Andor iKon M934
1024x1024
13µm/px 0.205

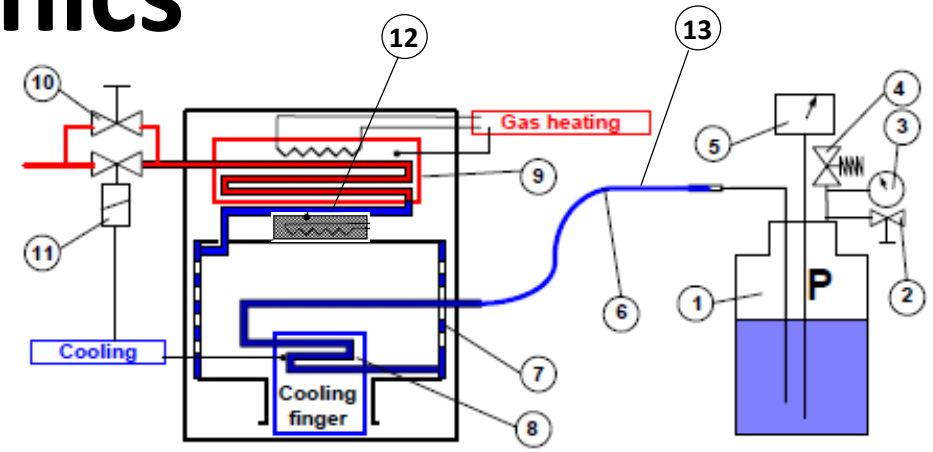
High frame rate
Low RON

Active pixels	1024 x 1024
Sensor size	13.3 x 13.3 mm
Pixel size (W x H)	13 µm x 13 µm
Active area pixel well depth	100,000 e^- (130,000 e^- for BR-DD and BEX2-DD models)
Pixel readout rates (MHz)	5, 3, 1, 0.05
Read noise	2.9 e^-
Maximum cooling	-100°C
Frame rate	4.4 fps (full frame)

UV-VIS Cryogenics

CFC based

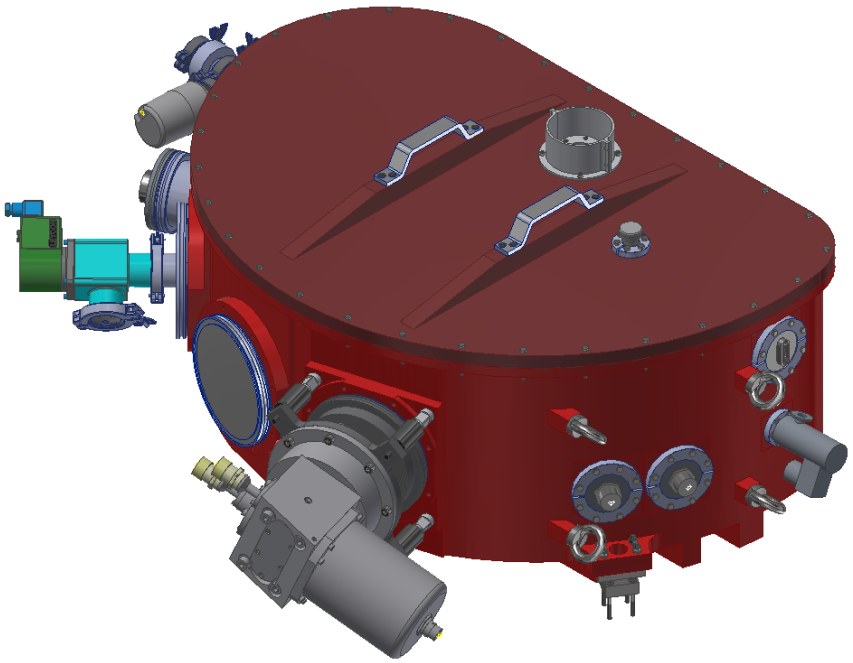


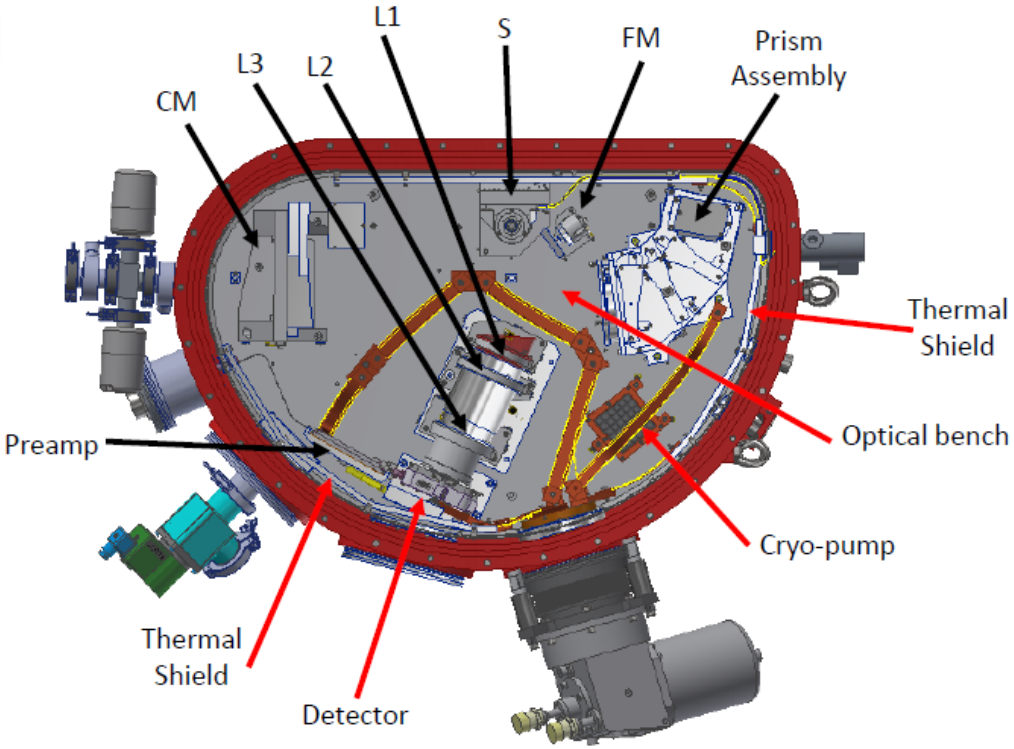


Nr	Component	Reference
1	Liquid nitrogen supply tank	XRP200 S
2	Depressurization Valve	117046 AL
3	Manometer	MS0+1B SP1/4” 117044 AL
4	Over-pressure valve	MS0.5B NPT ¼ M 117033 AL
5	LN2 level measurement	INJC 1
6	LN2 transfer line	
9	Warm heat exchanger	13600-910000-0010
10	Bypass valve	MVSS.ML6-6 Fitock
11	LN2 regulation valve	TVF 010 Pfeiffer
12	Sorption pump	13600-910000-0020
13	Temperature sensor on LN2 line	PT-103-AM
14	Temperature sensors	PT100
15	CFC heaters	5 Ω
16	CCD temperature sensor	DT670
17	CCD heater	MP820 (50 Ω)

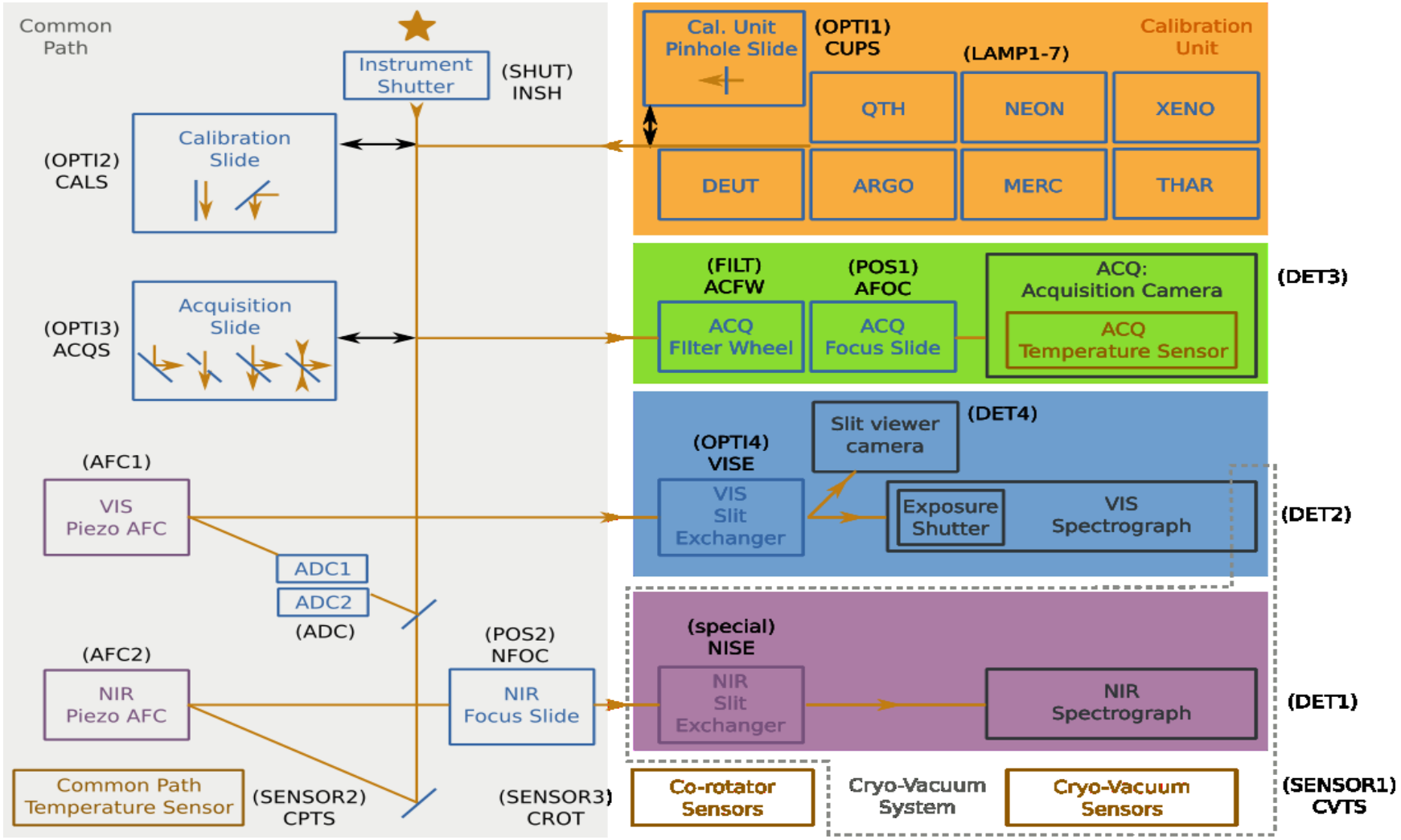
NIR Cryogenics

Nr	Component	Reference	Supplier
1	Compressor COOLPAK 6000 HMD	842015V0001	Leybold
2	Cold Head COOLPOWER 250 MD	840000V6002	Leybold
3	Connecting cable compressor to COOLPOWER 20m	842112	Leybold
4	Temperature sensor PT100	PT-103-AM	Lake Shore
5	Detector temperature sensor	DT670	Lake Shore
6	Heaters (detector & optical bench)	MP820 (50 Ω)	Caddock

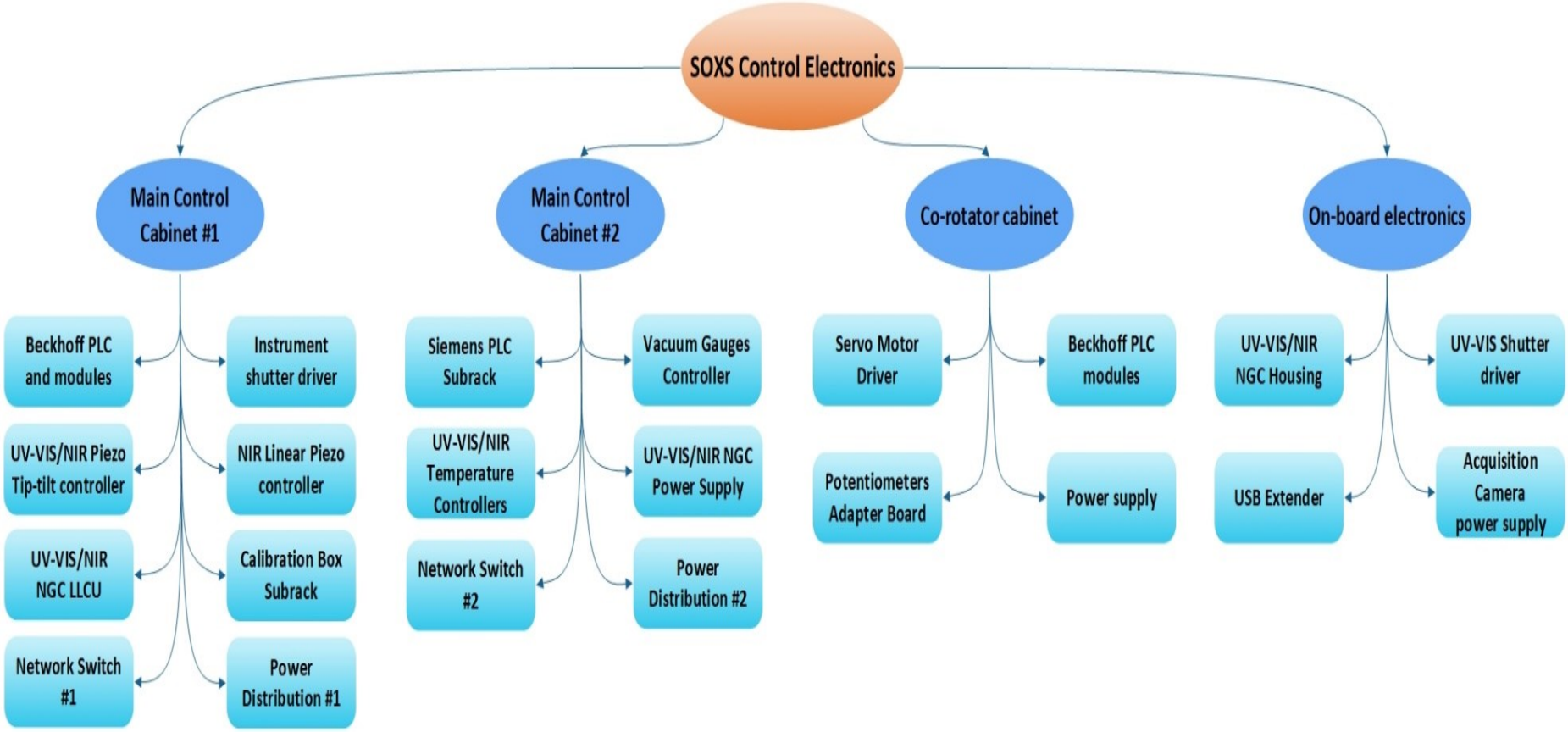




INS - Control Software

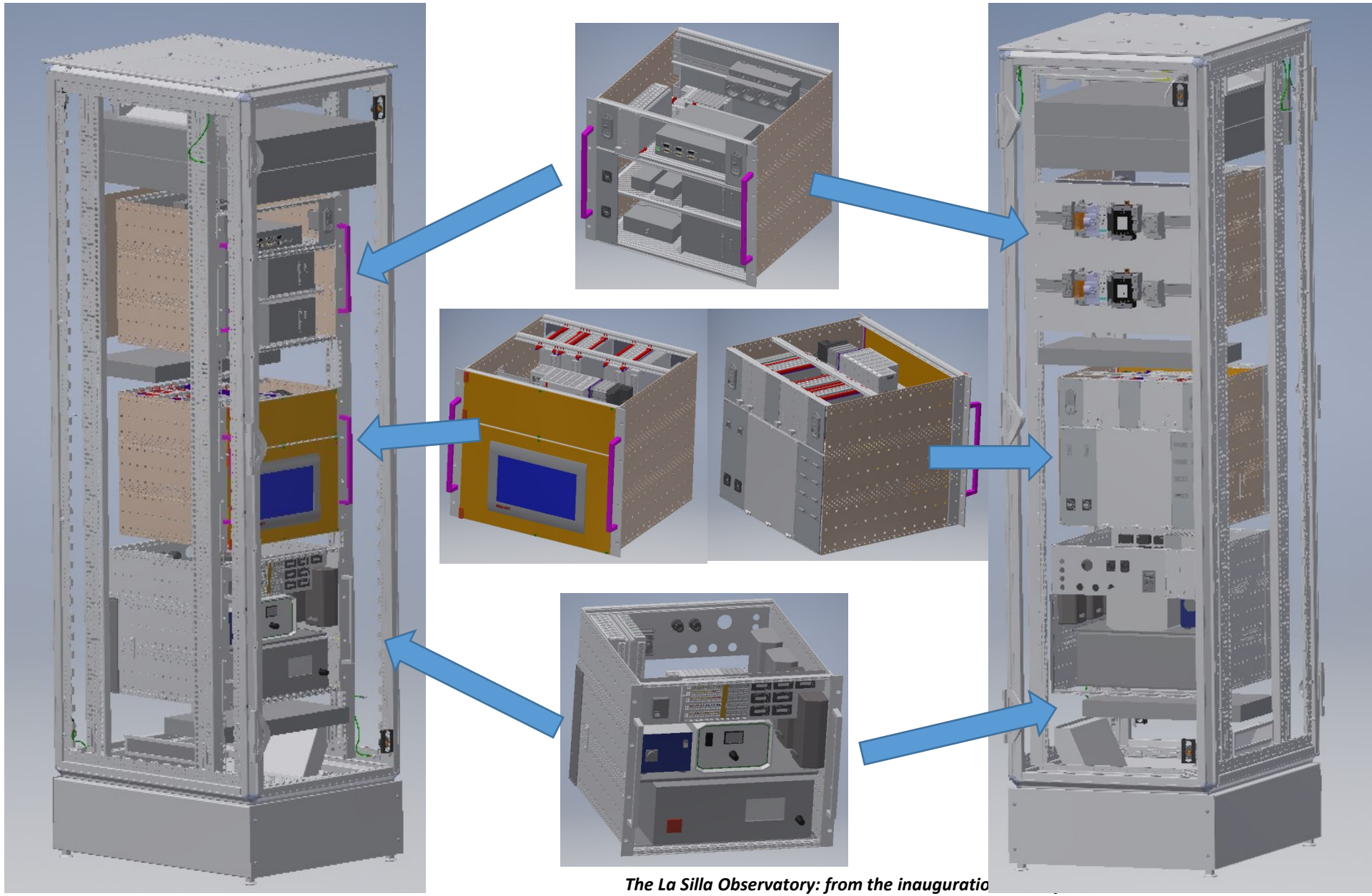


Control Electronics

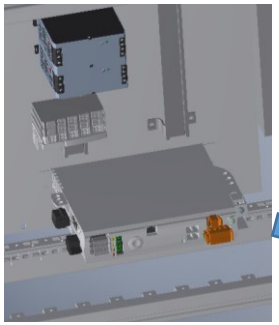


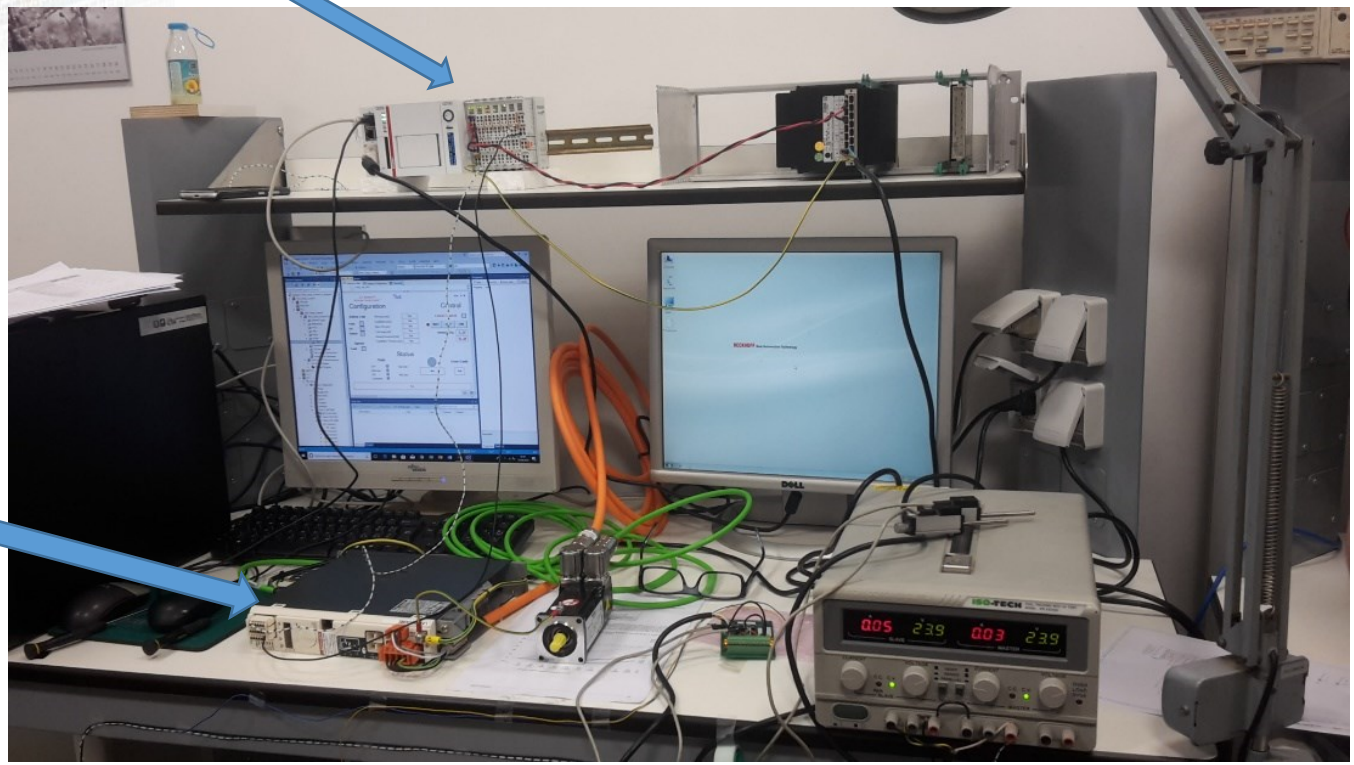
ESO New Standard - Beckhoff PLC based

SOXS



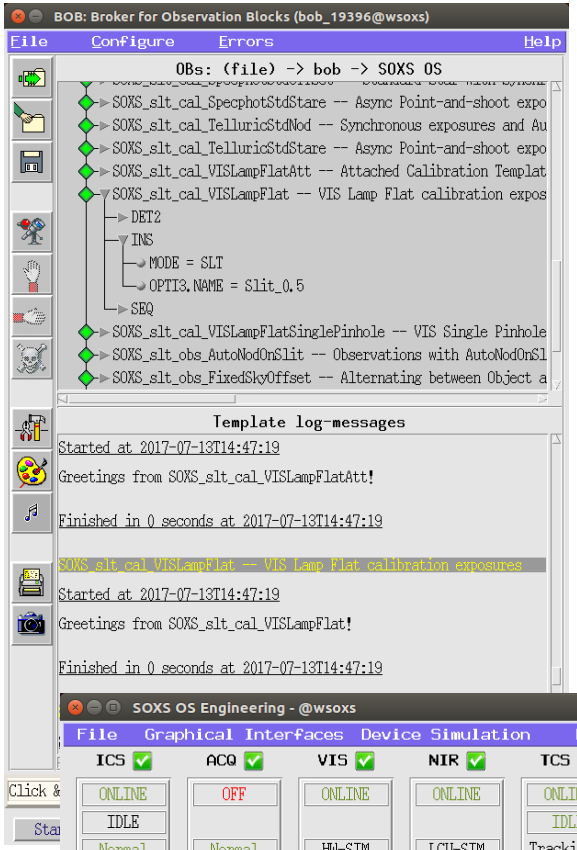
The La Silla Observatory: from the inauguratio

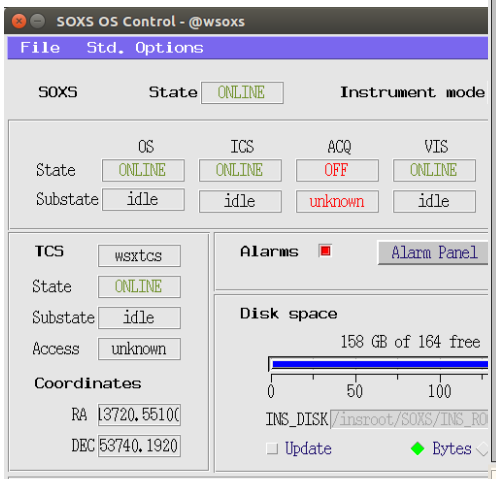


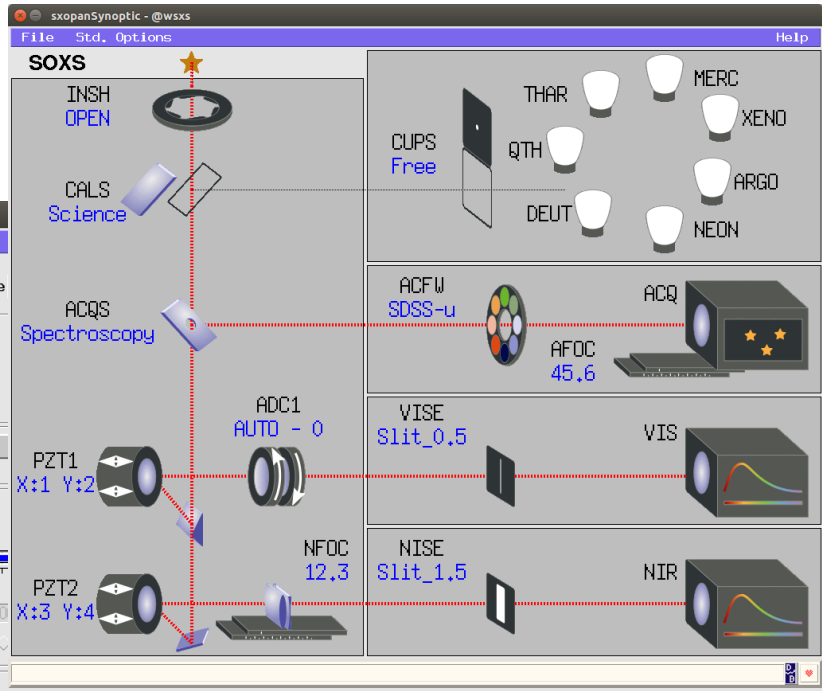


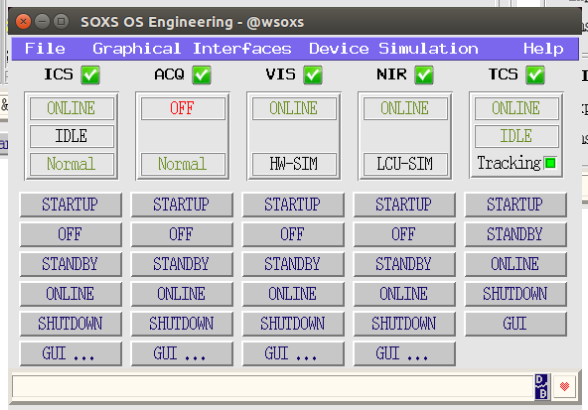
SOXS

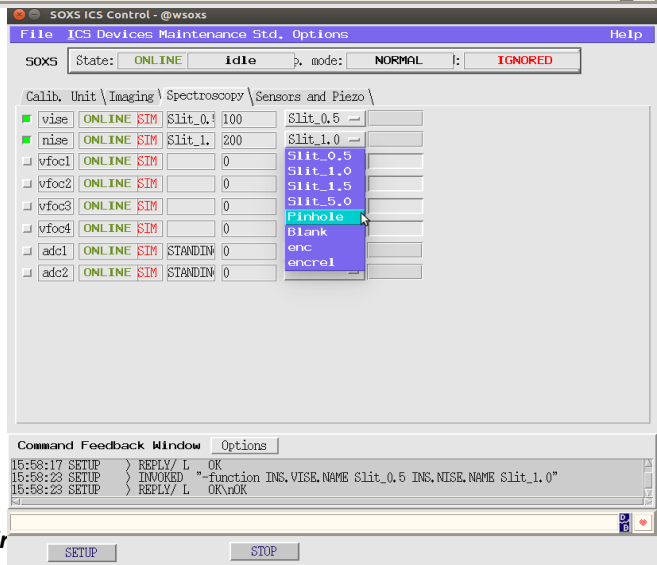
Instrument Software



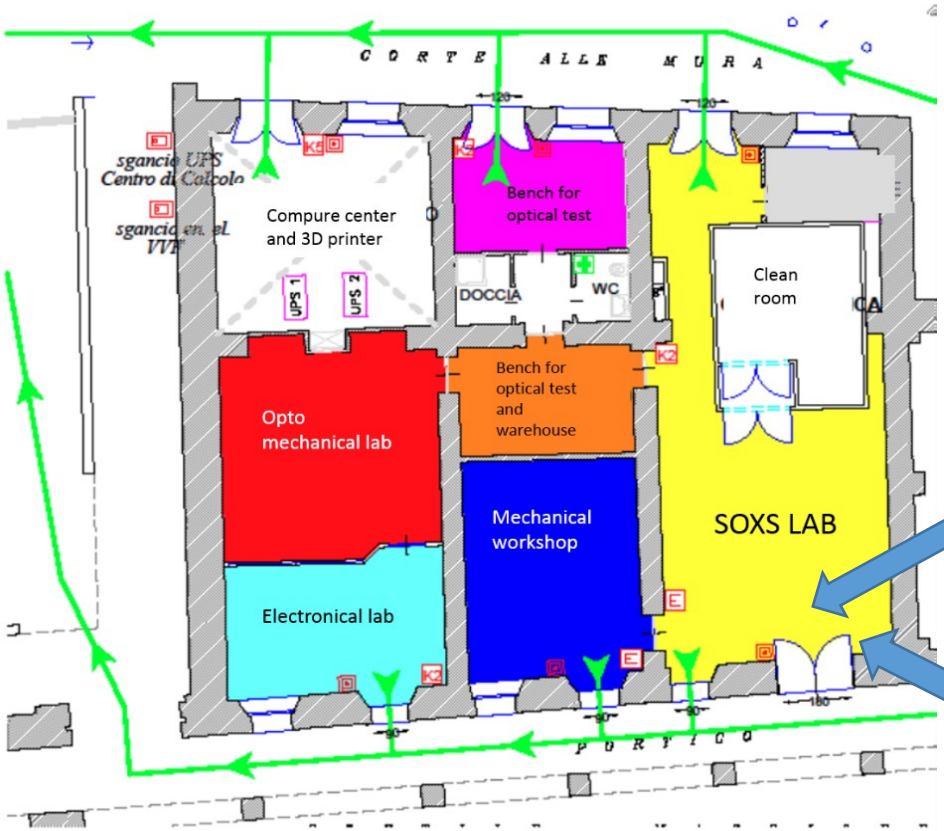








Integration in Europe



The La Silla Observatory: from


SOXS
INAF ISTITUTO NAZIONALE DI ASTROFISICA
מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE
Queen's University Belfast
INSTITUTO MILENIO DE ASTROFÍSICA
Turun yliopisto
University of Turku
TEL AVIV UNIVERSITY
Dark Cosmology Centre
ESO
Thanks