The European Southern Observatory

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This Presentation

ELT construction – latest image

- ELT first light and VLT third generation instruments
- Detector and detector controller developments
- Detector testing and characterization
- ELT 2nd/3rd generation instruments/VLT future needs

MICADO for ELT

MCAO fed imager/spectrometer

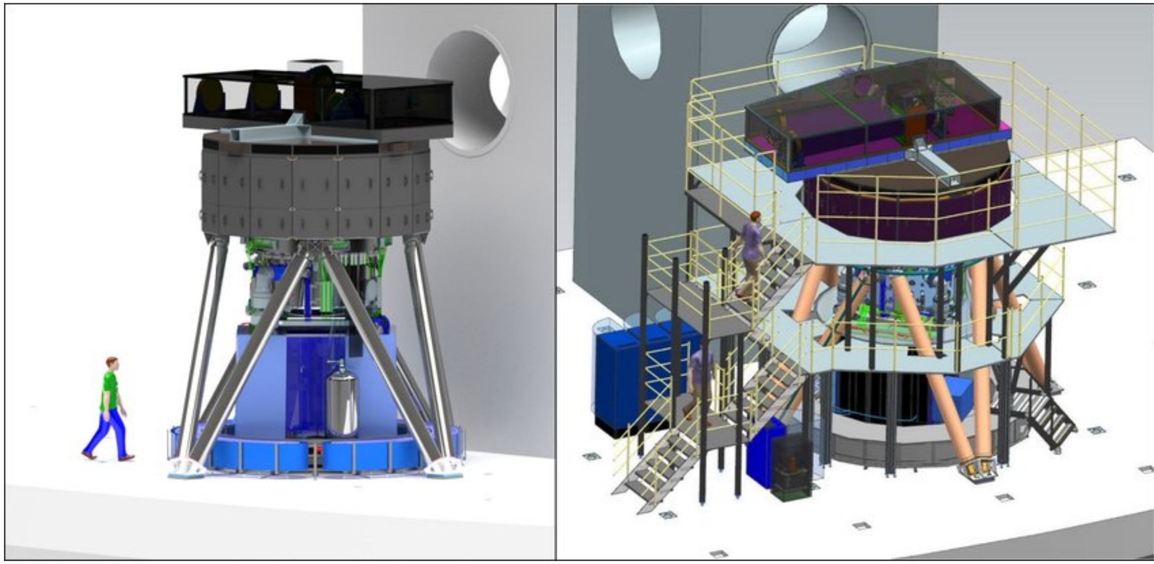
Specification –
“First light” instrument
1 arcmin square FoV, diffraction limited
x30 broad/narrow band filters
Cryostat rotates !
Single slit spectroscopy,
R~ 10k/20k

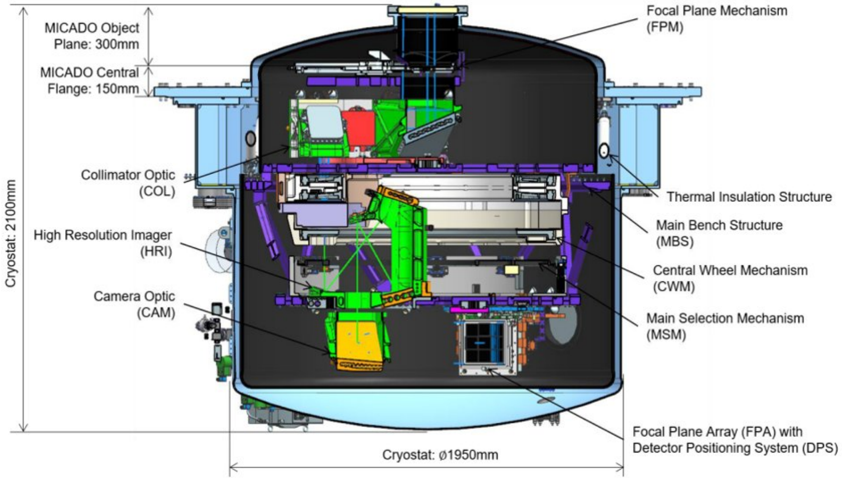
LN2 cooled to 80K, 0.8 – 2.45 um

MCAO/SCAO LGS AO corrected

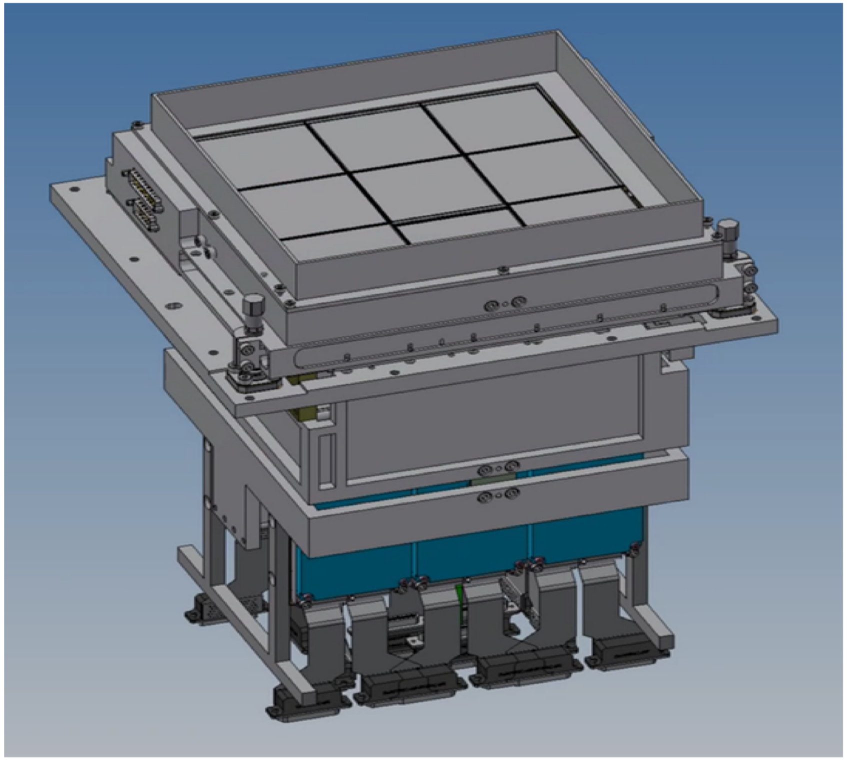
Detectors
9 x H4RG-15 (SWIR)

(+ detectors for AO instrument)



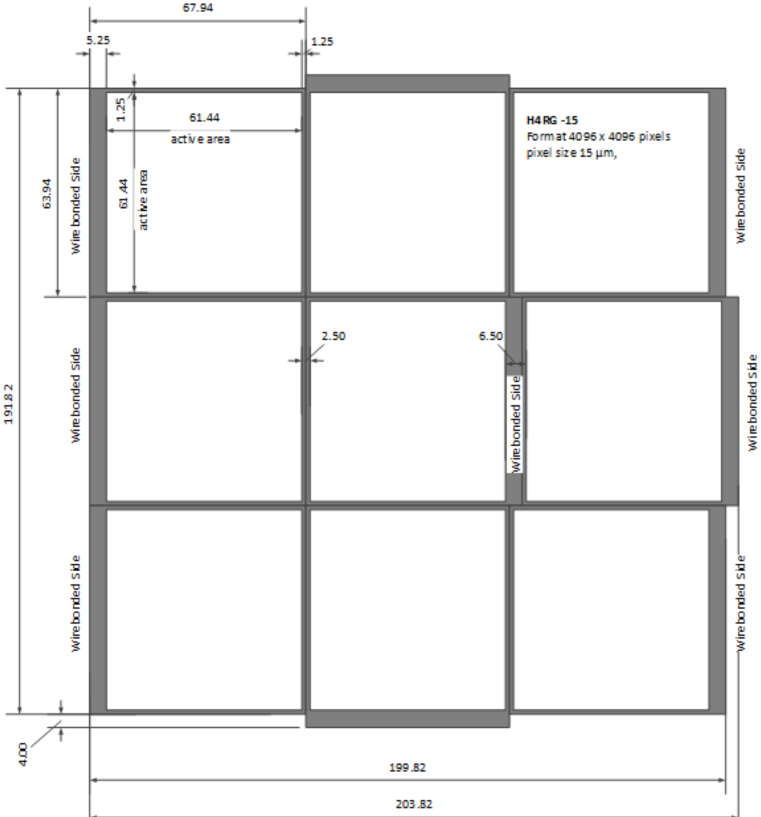


MICADO focal plane



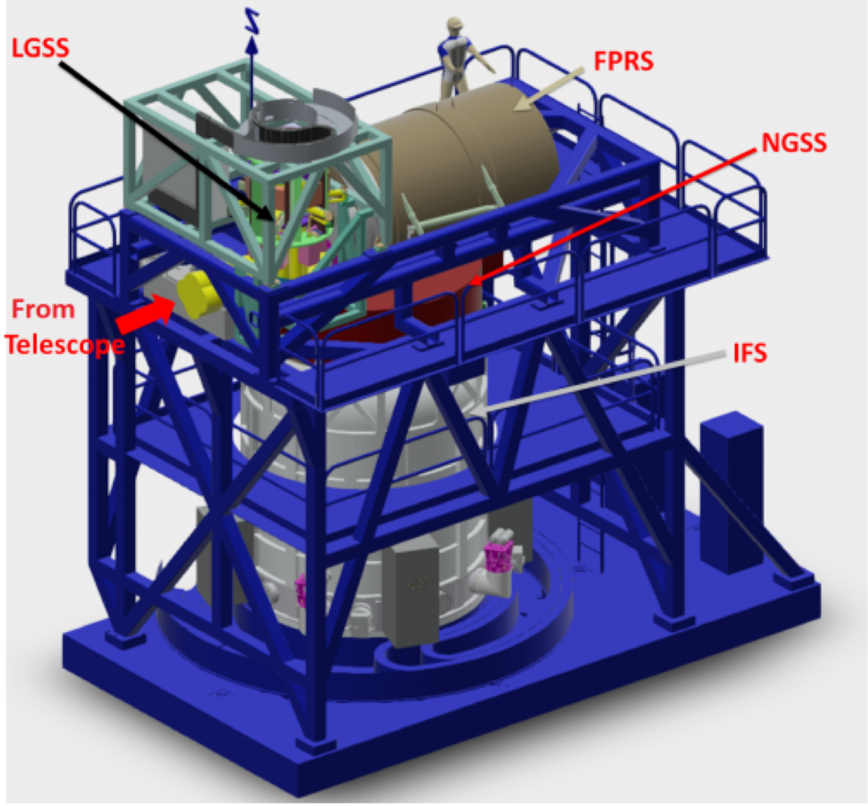
MICADO Focal Plane Design

- 33 channels per detector
- 80K Operation
- 200 kpixels/second => buffered output
- 400 kpixel/s for central detector
- Multiple window resetting bright stars
- Multiple window reading for AO correction



Layout of detectors

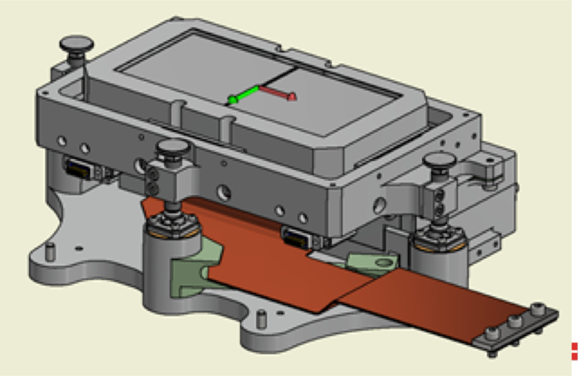
HARMONI



Specification -
3-D spectroscopy
IFU with image slicer to feed spectrographs
Wavelength range 0.47 – 2.45 um
4 different FoV
Both LTAO and SCAO AO corrected
Spectral resolution, 3.5k, 7.5k and 18k

Detectors -
4 x e2v CCD231 from Teledyne e2v
with AR graded coatings

8 x H4RG-15
Mounted as 2 x (2x1) mosaics
65 outputs per detector
40K operation
Lowest Noise, buffered/unbuffered ?

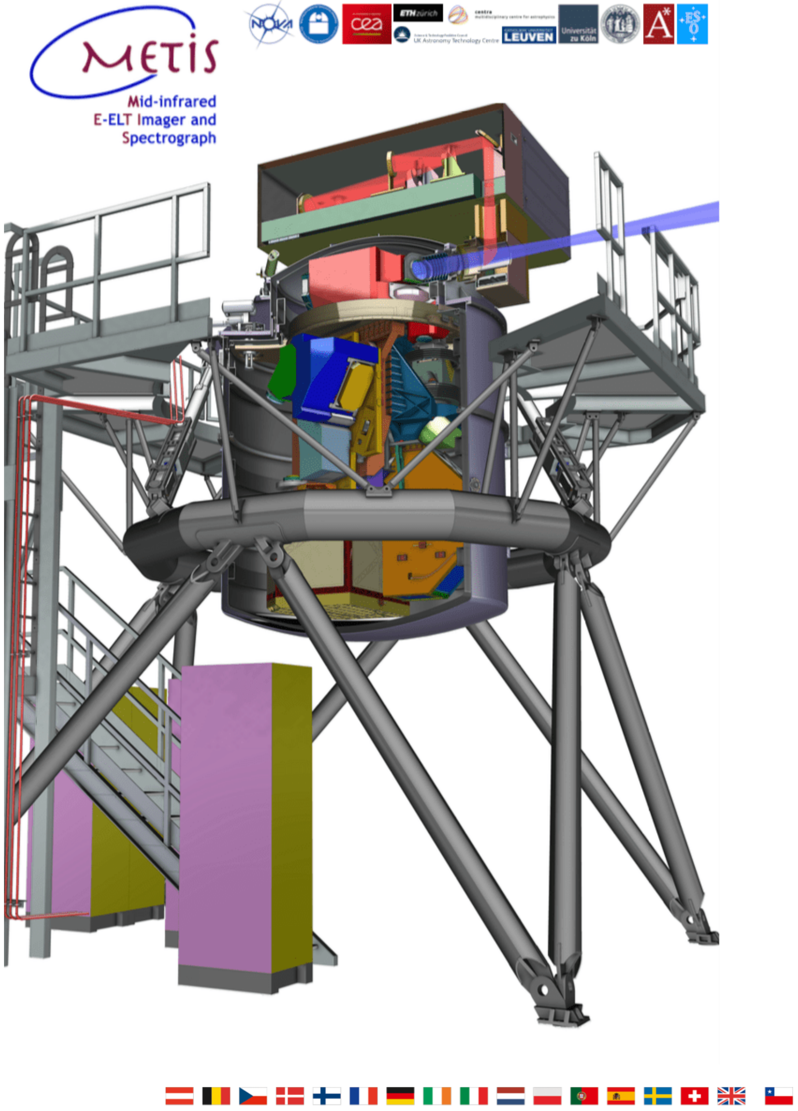


METIS for ELT

Science
Planet formation, proto-planet search
Chemical composition of planet forming gas
Debris disk composition

Specifications
Direct and High contrast Imaging
Long Slit and IFU Spectroscopy
High resolution spectroscopy, R~100k
Imager with 11x11” FoV
SCAO corrected
L,M and N bands, 3-13 um
Cryogenic beam chopper
Cooled to < 40K

Detectors (complicated) -
1 x H2RG, 5.3 um for Imaging
4 x H2RG, 5.3 um for IFU spectroscopy
1 x GeoSnap, 13 um for Imaging/HCI
1 x SAPHIRA detector for SCAO



GeoSnap – the first fully digital science detector at ESO

Use GeoSnap instead of AQUARIUS detector for METIS

2048x2048 pixels, 18 um square

Waveband of 7.5 – 13.5 um, operation at 40K

CTIA circuit, large/small well, < 1W power

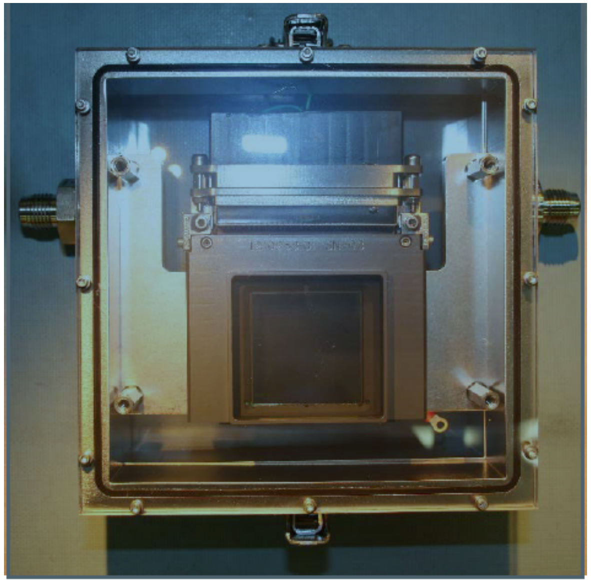
Full well ~ 2Me-/200ke-, noise of 400/40 e- rms

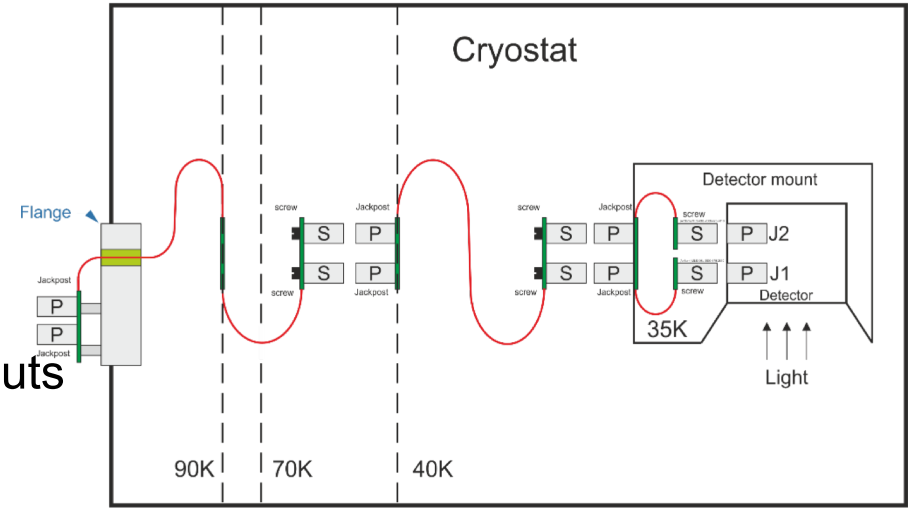
Frame rate > 100 Hz

Fully digital device, 8 differential transmitters operation at 1.6 Gbits

Engineering challenges

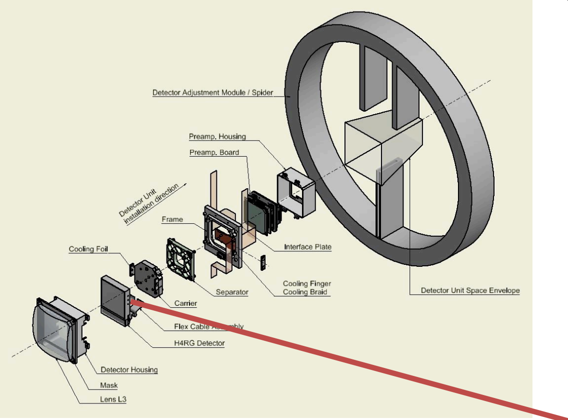
- New controller design, digital detector outputs
- - 3 metres of cables

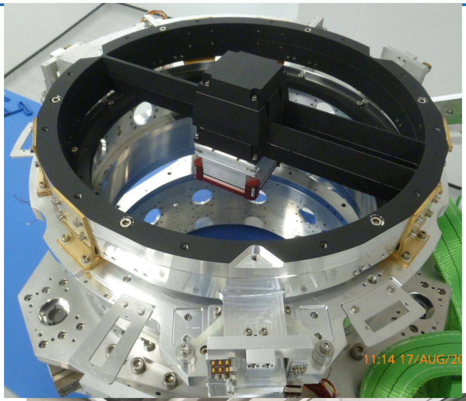




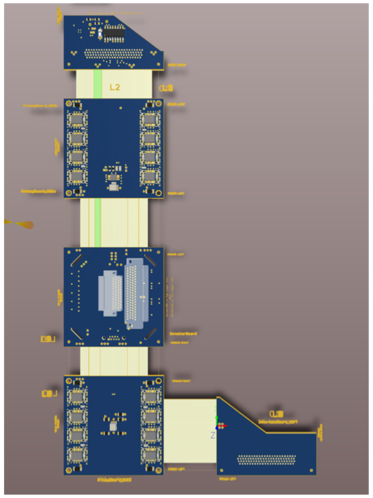
3rd generation - MOONS at the VLT

Detector Mount Design – minimize footprint

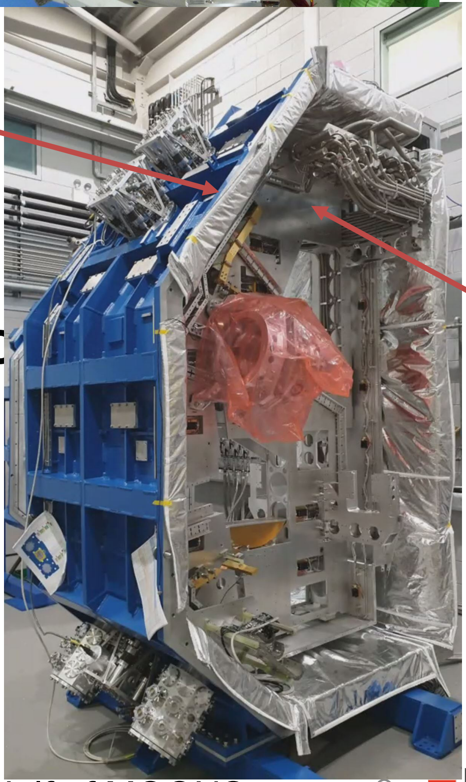


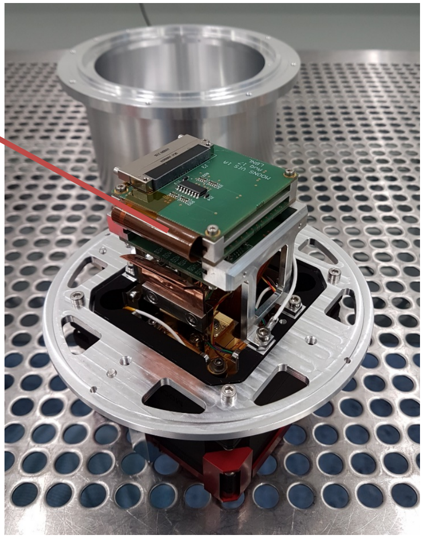


Preamp design – 65 channels



4 x H4RG detectors
2 x LBNL thick, fully depleted CCD

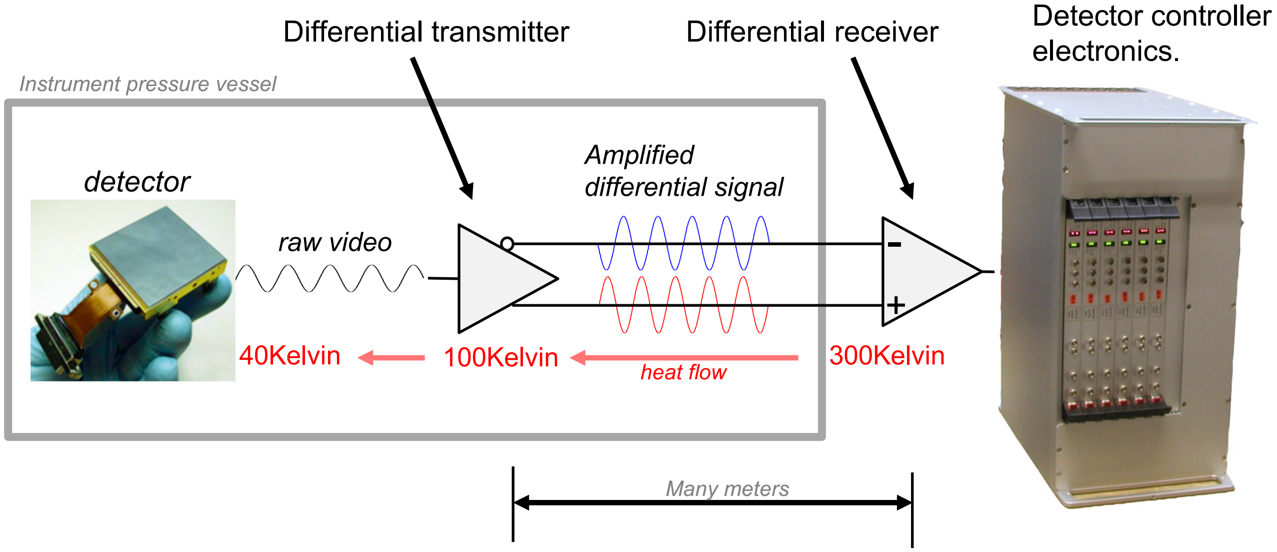




Half of MOONS cryostat

Detector Operation: Cabling

Differential transmission of low-level video signal used to reduce noise and minimise cross-talk between channels.



Differential transmitter

Differential receiver

Detector controller electronics.

Instrument pressure vessel

detector

raw video

Amplified differential signal

40Kelvin

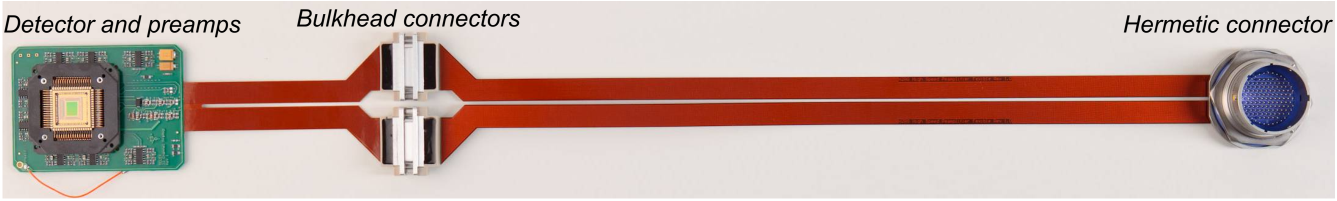
100Kelvin

heat flow

300Kelvin

Many meters

A rigiflex cable



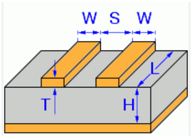
Detector and preamps

Bulkhead connectors

Hermetic connector

Shielded twisted pair cable
(expensive to assemble, high heat load, unlimited length)

PCB rigi-flex technology
(easy to assemble, low heat load, limited length)

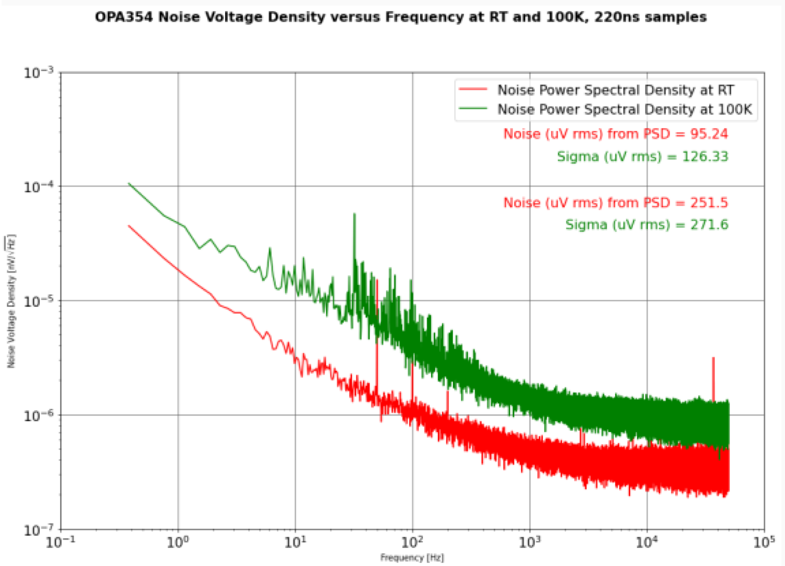


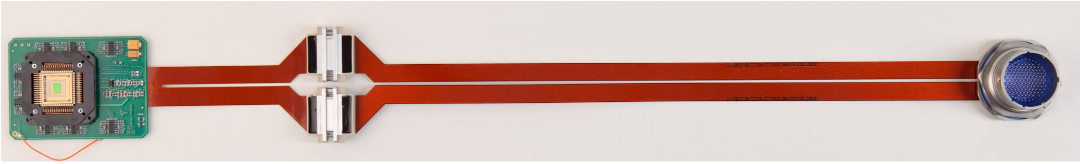
Cryogenic Preamplifier design

For many years settled on TLC 2274 opamp for preamplifier.
Requirements for preamplifier driven by slow/fast mode of H*RG detectors, new controller input video circuit and instrument needs

Slow, 200 kpixel/second, low noise, long exposures
- OPA4192, 10 MHz GBW, 5.5 nV/√Hz, low offset voltage drift, operation at 70K

Slow/Fast, 5Mpixel/second, >30 frames/second
- OPA354, 100 MHz GBW, 6.5 nV/√Hz, operation at 70K





ESO detector connectivity model

Issues

- performance of some op-amps changes with temperature

- Require Slow and Fast from same detector

The new ESO controller development - NGCII

NGC ~ 10 years since first delivery, continuous development but issues with obsolescence, particularly FPGAs.

NGCII Specifications –

COTS based, uTCA architecture

Zynq Ultrascale+ FPGAs – Arm cortex-A53, many logic cells, 10 Gbit interface etc

Integrated PSU

2U form factor for H4RG 64 channel operation (3 x AQ22 + 1 x C20B20 modules)

Multiple 10 Gbit ethernet links

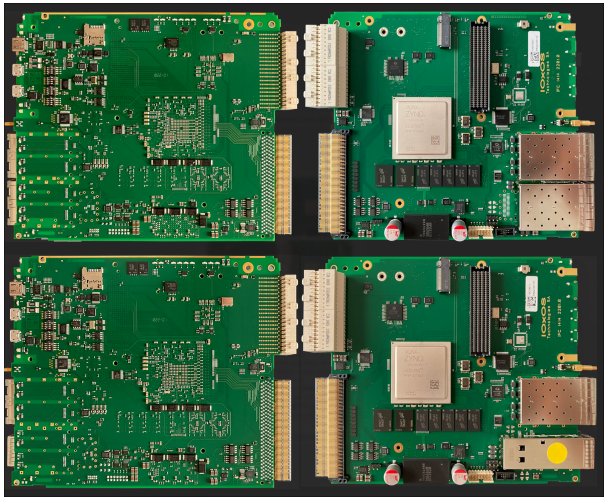
PPE for absolute time stamping

“White Rabbit” for multi-controller synchronization

Bespoke board design only required for detector biases/clocks/ADC

Very stable reference source for biases etc – limiting factor of NGC !

EN4165 connector system



COTS FPGA modules

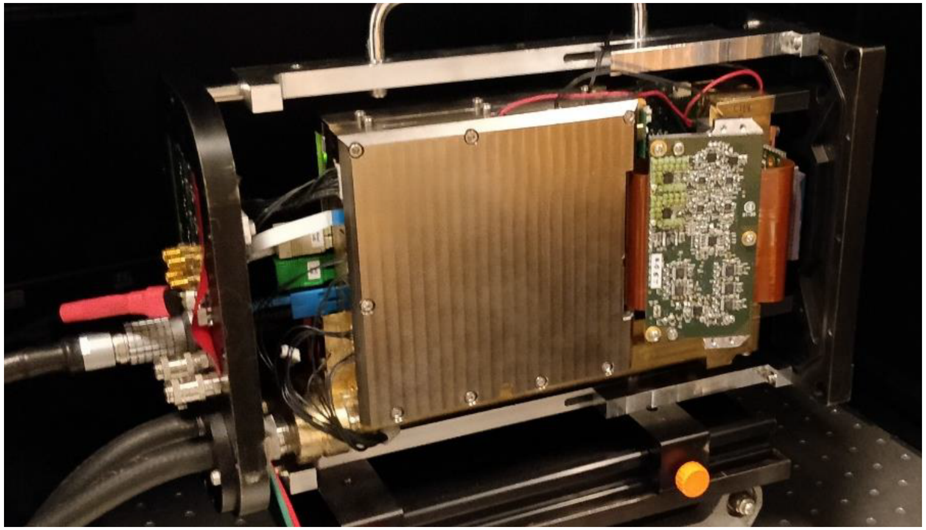
Typical 2U uTCA chassis

New AO Camera developments

3 x different AO cameras required for ELT
Detectors – SAPHIRA, L3CCD and LVSM

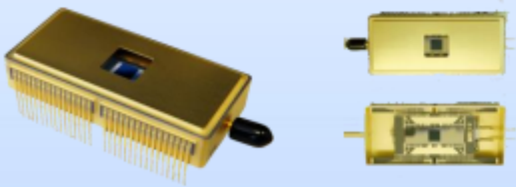
For SAPHIRA, FLI Camera, re-purposed with 10 Gbit ethernet link

For NGS and laser AO, CCD220 (ALICE) and LVSM (LISA) controller development
10 Gbit ethernet + 1 Gbit for PPE
Again, Zynq Ultrascale+ FPGAs, running LINUX on Arm processors
Commonality of design for CCD220 and LVSM, difference in interface board
Water and Peltier cooled , modest camera volume !



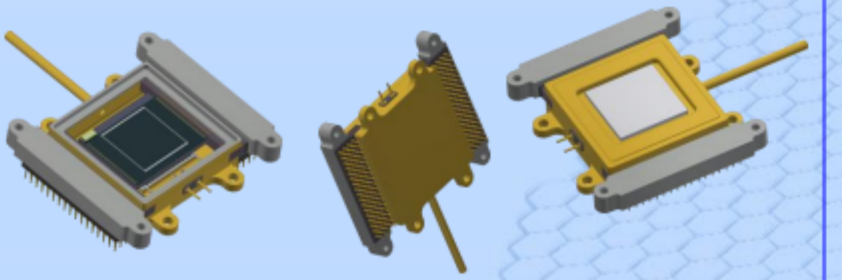
3 different detectors for AO applications

**1) Extremely low noise (0.1e-)
small format (240x240) → CCD220**



TELEDYNE e2v
Everywhereyoulook™

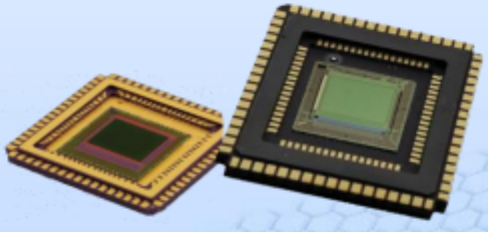
**2) Large format (>800x800)
modest noise (3e-) → LVSM**

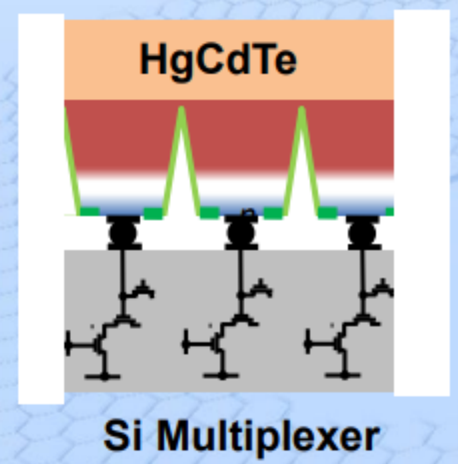


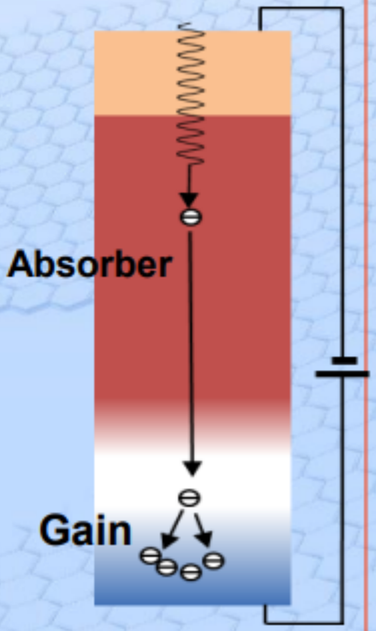
Visible

**3) Low noise (1e-)
small format (320x256) → SAPHIRA**

LEONARDO
LAND & NAVAL DEFENCE ELECTRONICS







NIR

(Josh has poster on the cameras)

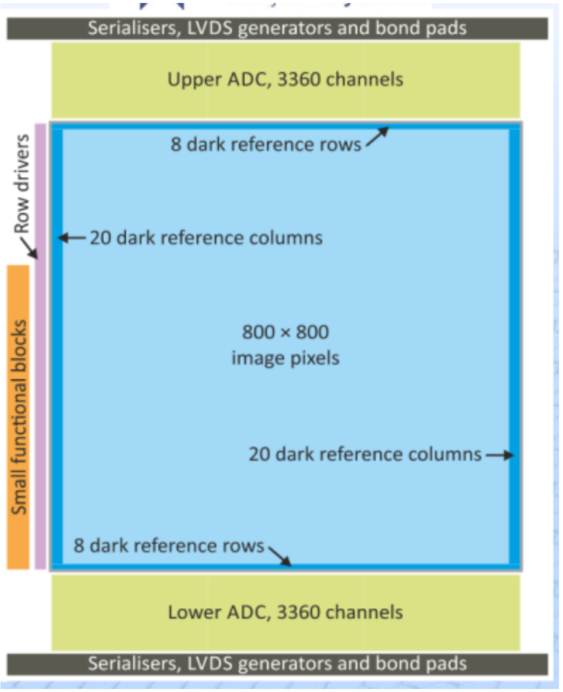
LVSM development – Teledyne e2v – fully digital AO detector

Sampling spot elongation from Laser guide star
80x80 sub-apertures of 10x10 pixels, 24 um
CCD220 not scalable, so CMOS Imager development

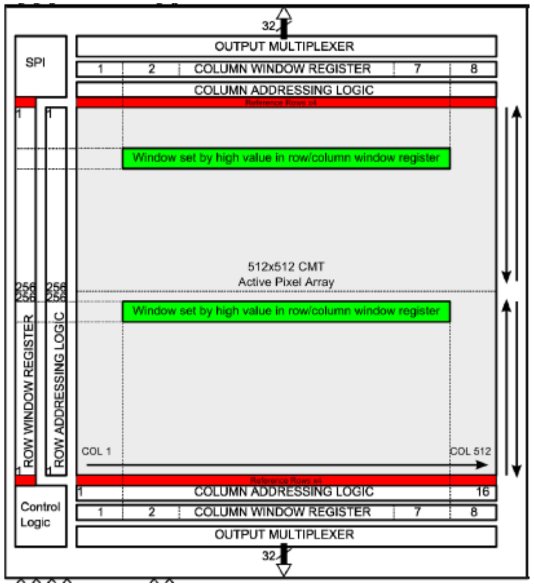
700 frames/second at < 3e- rms noise
Back-side illuminated, QE ~ 90% at 589 nm
Full well > 4000 e-
Cooling to -10C using integral Peltier

All analogue processing on chip, including CDS
Programmable gain
9/10 bit ADCs at 14 us, 6720 channels
4 rows top/bottom in parallel

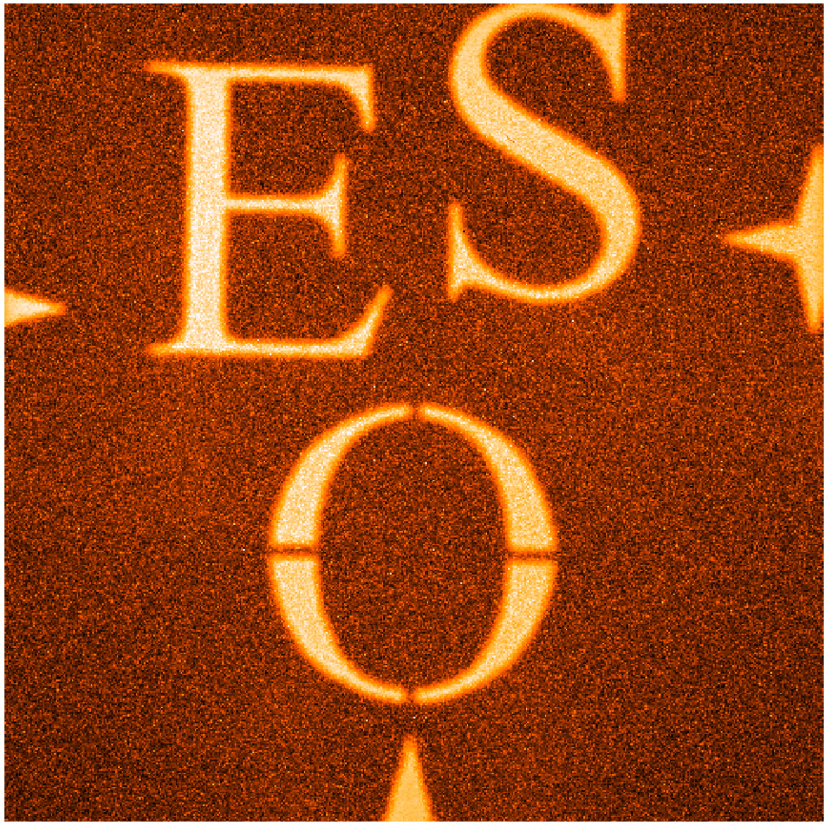
24 lines at 256 Mbit/s LVDS serial interface



Large SAPHIRA detector developments



- New ROIC, the ME1120
- Simple operation, few clocks/biases
- 64 channels at ~10 MHz
- ROIC operational now at 3 MHz
- NGCII development for all present/new detectors



First Light image – warm ROIC only

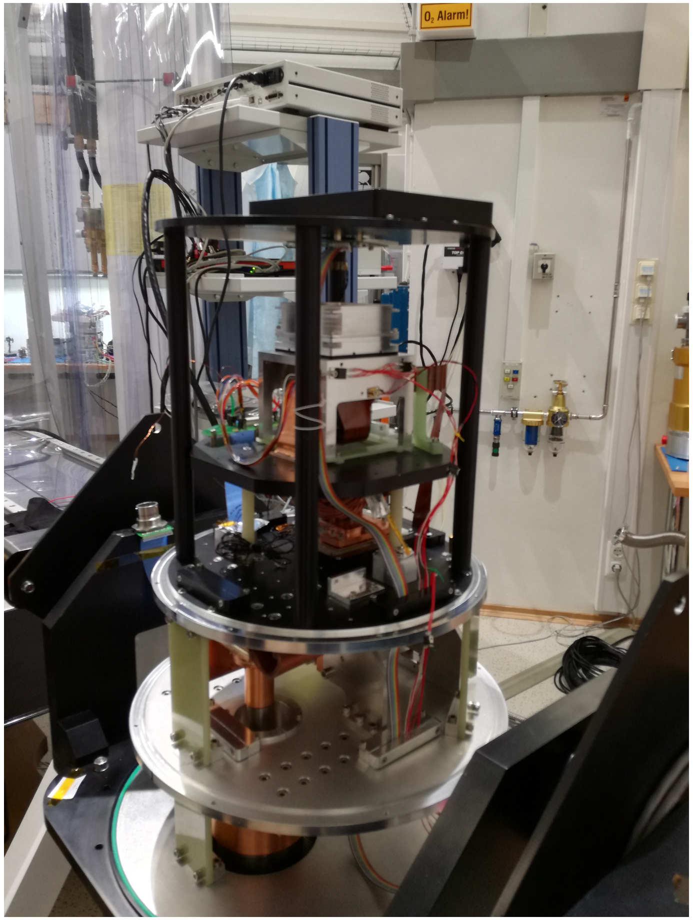
Detector characterisation

3 new facilities for detector testing, CRISLER, CEAT and FIAT

CRISLER – designed for MOONS H4RG testing

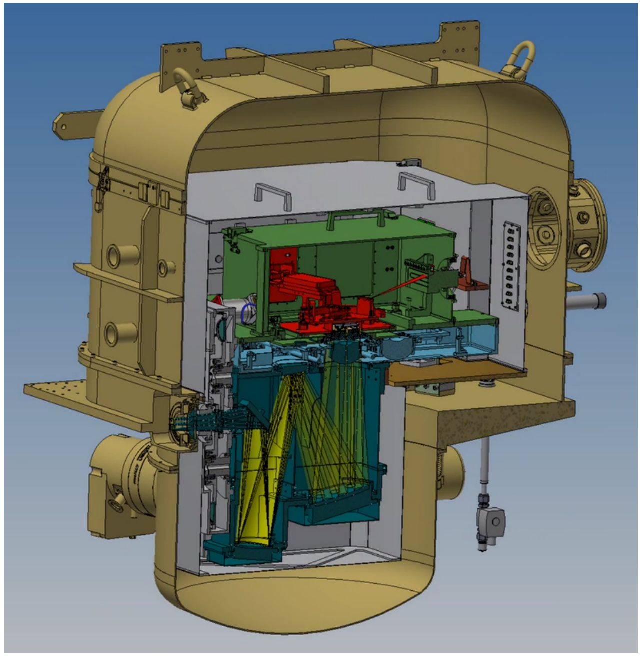
Universal Cryogenics, Tucson
2 stage CCC, < 40K for detector
5 position motorized filter wheel
Pymont monitoring
Window for external calibration sources etc
Detector 40K/80K possible and used

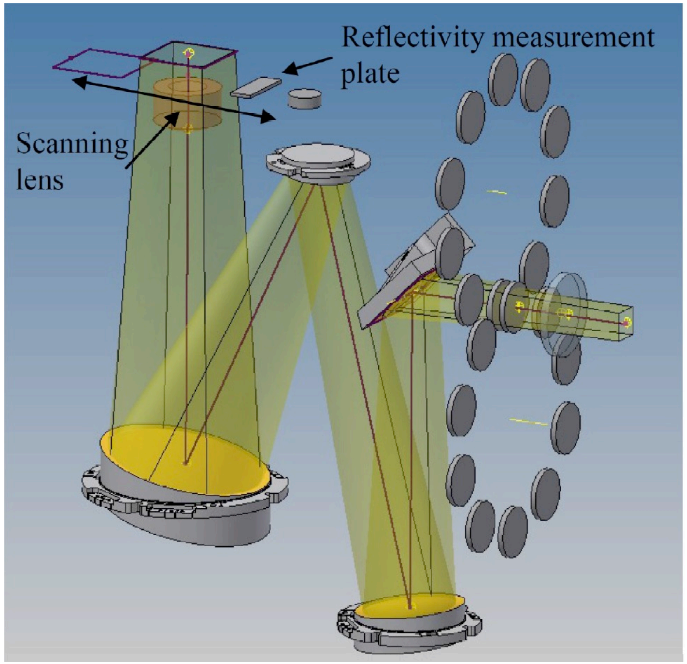
Second system, CEAT
Single stage cooler ~ 70K
No filter wheel or window
Used for testing cables cold/CCD operation



FIAT

- Facility for Infrared Array Testing
  - Conjugated object image focal plane, field of view ~66mm square
  - Low background, QE measurements, Intra-pixel scan
  - Detector operating temperature range 40K to 110K, Cold copper mass
  - Easy access to the detector area



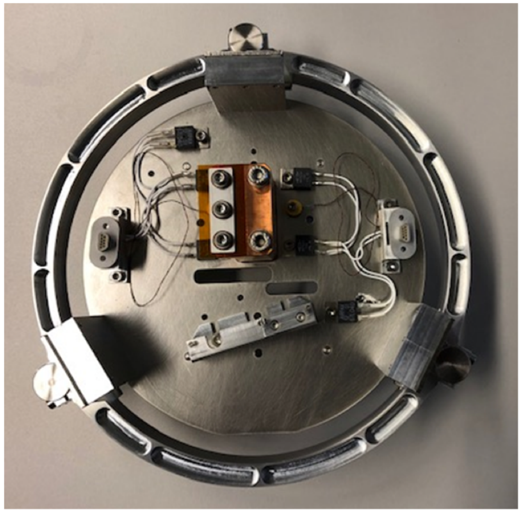


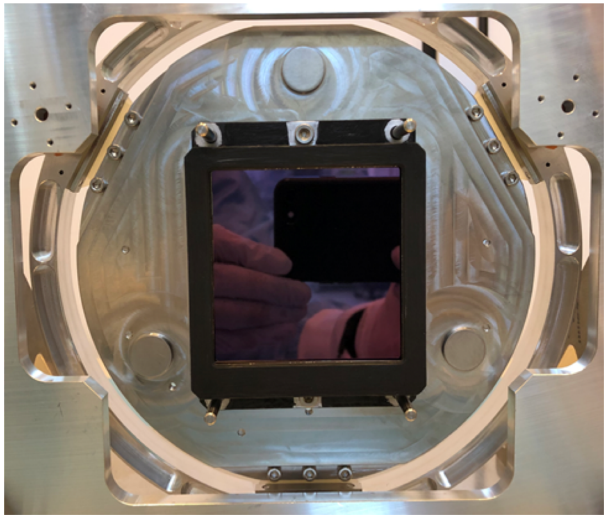
FIAT Illumination

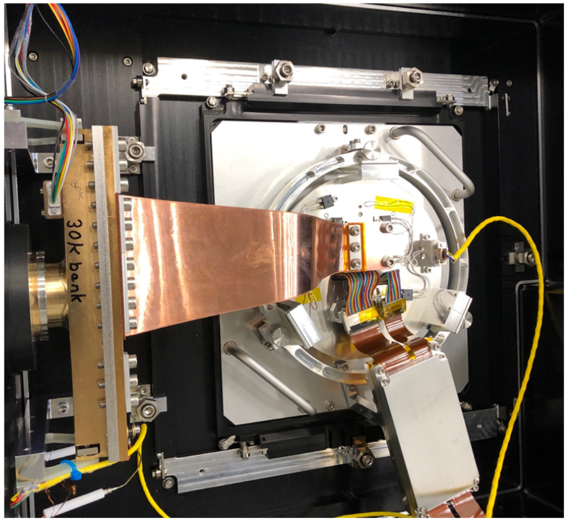
- Extended blackbody source at the object focal plane

Test Setup for H4RG

- 33-ch Preamp for H4RG
- H4RG detector in FIAT
  - PMOS buffer mode, 200kHz pixel rate







H4RG characterization

Excellent QE, noise, dark current, cosmetics and flatness

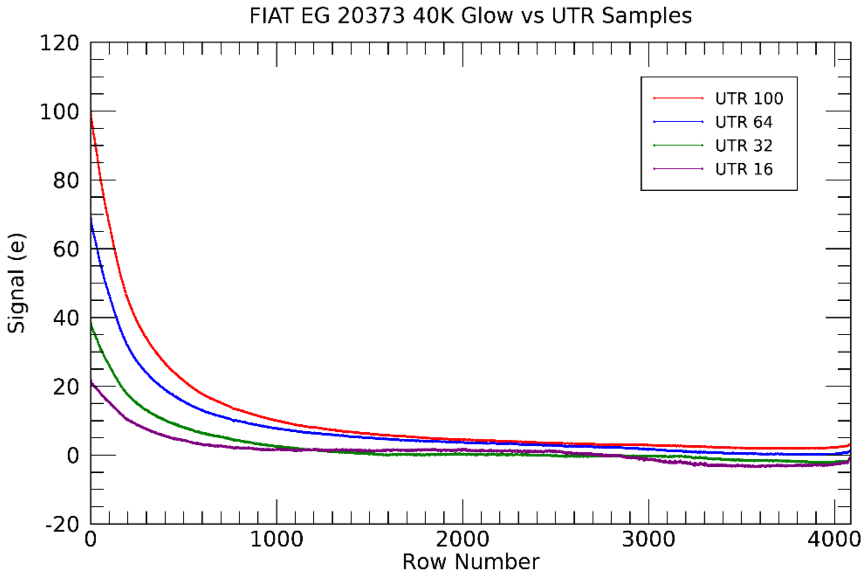
Operated in Unbuffered/Buffered mode – Buffers preferred, glow seen from buffers

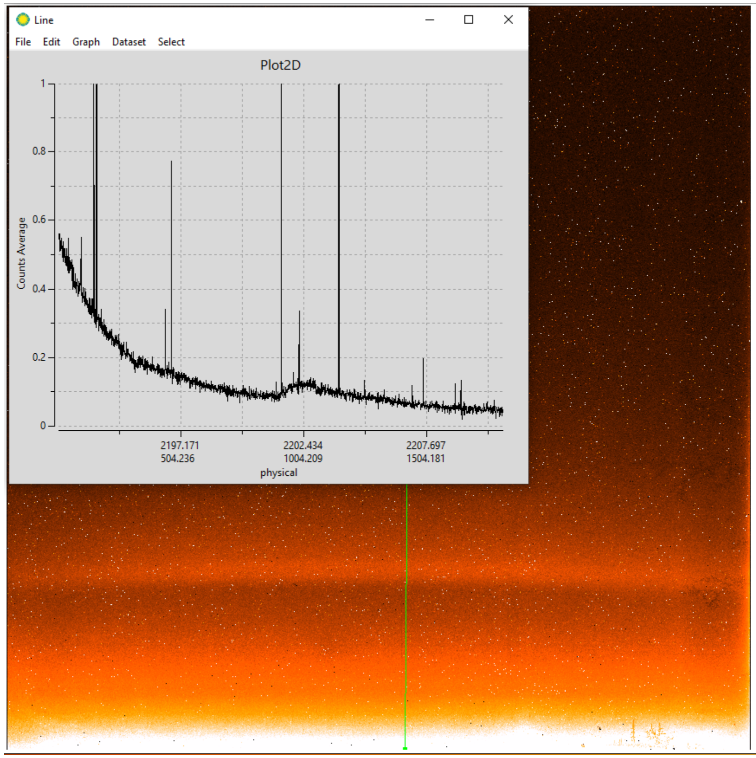
New version of ROIC in preparation, after ESO testing

Persistence quantified for pipeline correction

80K/40K quantified for different instruments

X 5 detectors tested

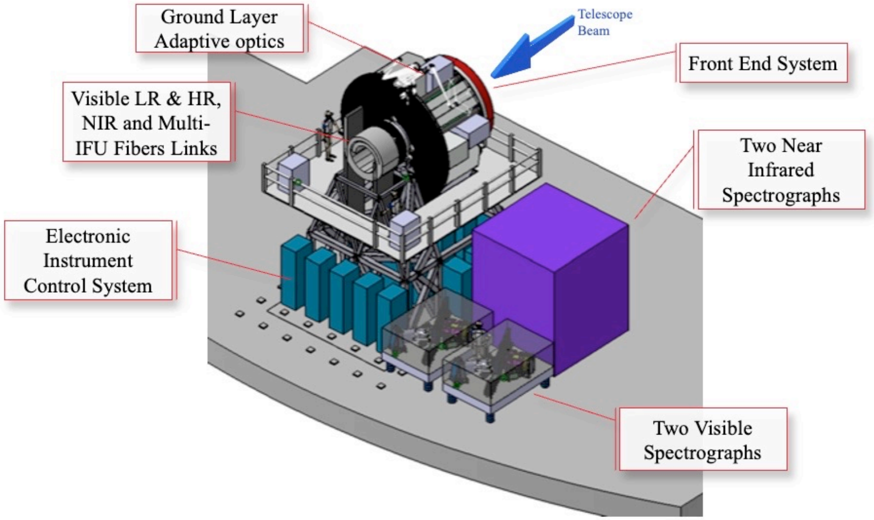




2nd generation ELT instruments - MOSAIC

MOSAIC – multi-object spectrograph for the ELT

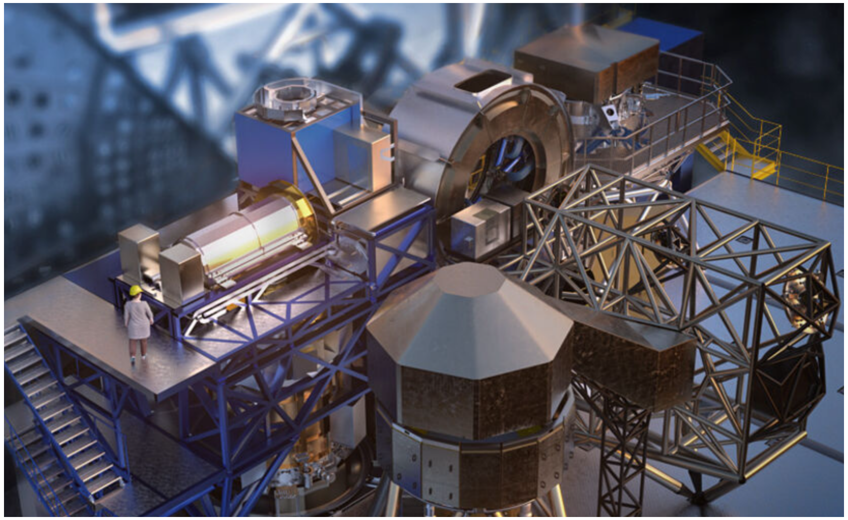
High multiplex capability in optical –
- 0.45 to 0.80 um
- 200 objects at R~5000
- 80 objects at R~20000
- Fibre fed spectrographs



High multiplex capability and Mini-IFUs in the IR –
- 0.80 – 1.80 um
- 200 objects at R~5000
- 8 x mini-IFUs with 200 mas pixel scale

- Led by Lidia Tasca at LAM + 13 countries
- Instrument cost < 50 M Euros (including contingency)
- Fully funded by consortium, no ESO funding
- 6 x 4kx4k IR detectors

2nd generation ELT instruments - ANDES



ANDES – high resolution spectrograph
Two wavelength channels using dichroic
Fibre fed, fixed configuration

Wavelength -

- 0.40—1.80 µm (baseline),
- 0.35—2.40 µm (goal)

Spectral resolution, R ~ 100,000
Wavelength precision ~ 1 m/s (baseline), 0.1 m/s (goal)
Wavelength calibration stability ~ 1 m/s over 24 hours (baseline), 0.02 m/s over 10 years (goal)

Detectors

- U (goal): 1x e2v CCD290-99, 9kx9k, 10micron pixel, CH (Geneva)
- B V: 2x e2v CCD290-99, 9kx9k, 10 micron pixel, CH (Geneva)
- R IZ: 2x e2v CCD231-84, 4kx4k, 15 micron pixel, CH (Geneva)
- Y J H: 3x H4RG, 4kx4k, 15 micron pixel, CAN (Montreal)
- K (goal): 1x H4RG, 4kx4k, 15 micron pixel, D (MPIA)

PI - Alessandro Marconi, University of Florence

Detector Purchases

21 x H4RGs already purchased

Probably too ambitious

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
VLT/I	4 moons				2? new		2? new		2? new		
ELT		17 1st light					3 ANDES	6 MOSAIC		4 pcs	
total	4	17			2		5	6	2	4	

Other Science Detectors recently delivered

3 x H2RGs, 5.3 um (MWIR) for CRIRES+

1 x H2RG, 5,3um for ERIS

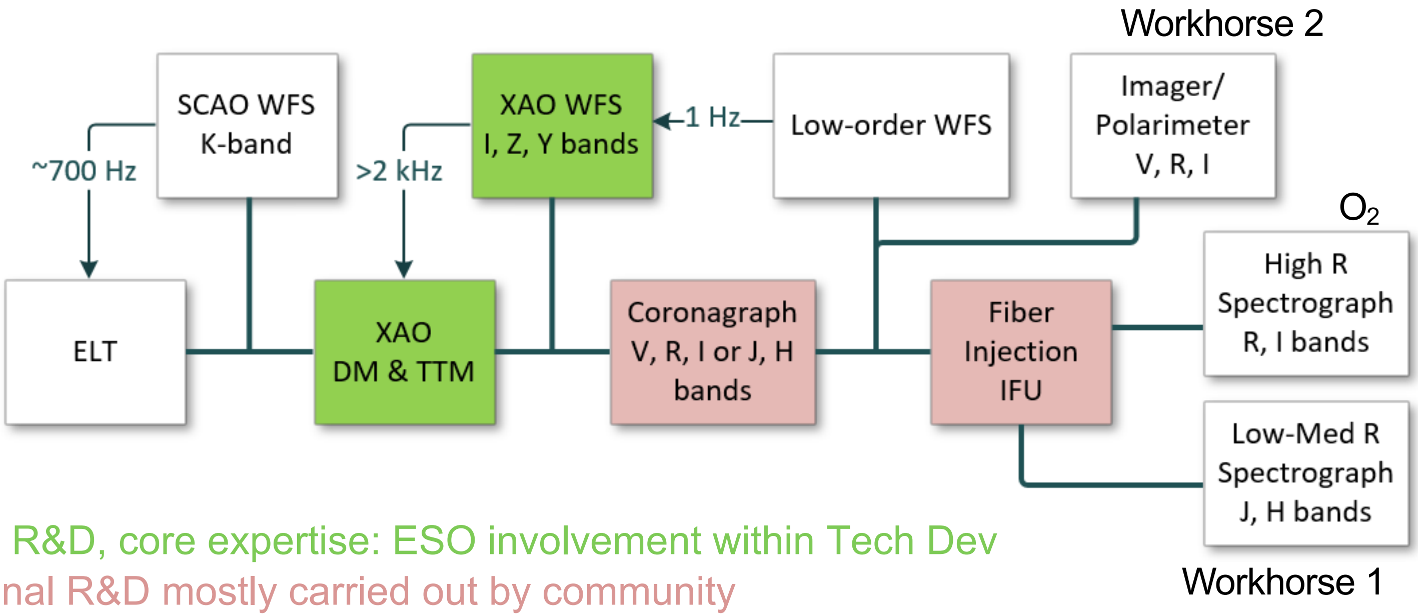
ELT AO detector needs

11 x LVSM – see later

11 x L3CCD

3 x FLI C-Red One Cameras, with SAPHIRA detectors

ELT Planet Coronagraphy Spectrograph instrument concept

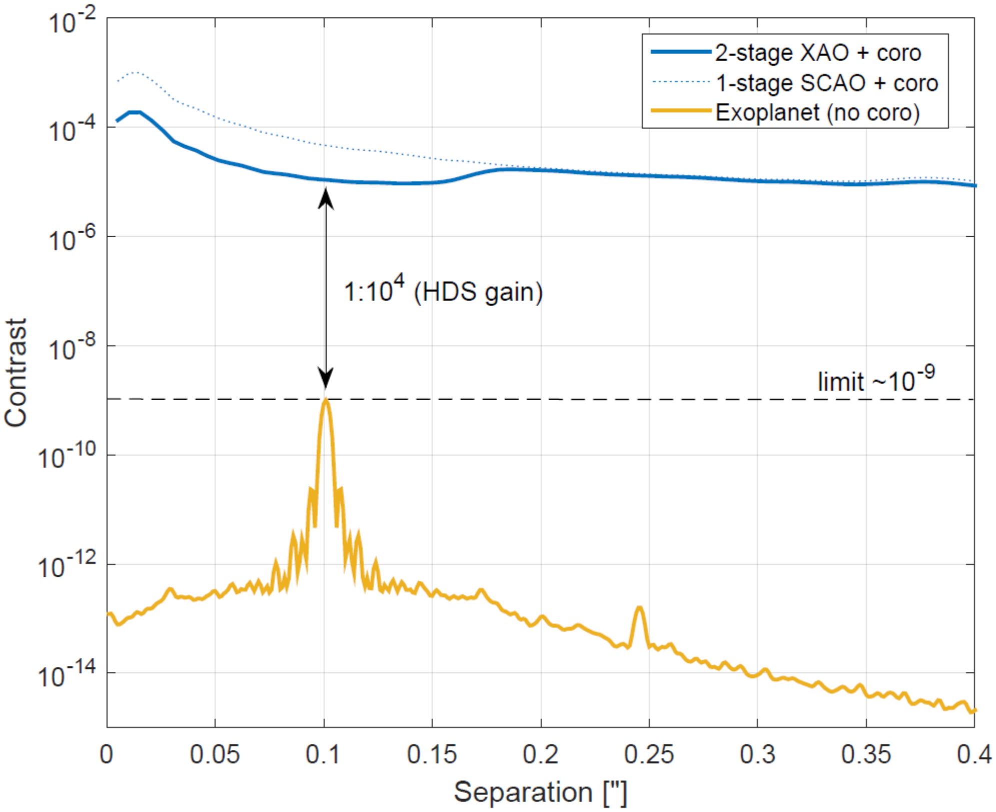


Green: XAO R&D, core expertise: ESO involvement within Tech Dev

Red: Additional R&D mostly carried out by community

- 2x 4K IR detectors for the spectrograph (H4RG or any other competitive IR detector)
- 1x 2K IR detectors for the imager (H2RG or any other competitive IR detector)
- wavelength range 1-2 um for the spectro, low dark current is very important.

How ELT PCS achieves high contrast and high sensitivity



Concept validation on-sky: HiRISE, KPIC, MagAO-X, SCExAO….

The challenge is then **sensitivity before contrast!**

1. Maximize signal: Strehl, spectrograph throughput
2. Minimize noise:
   XAO residual halo

-> **push XAO and possibly fiber spectroscopy**

VLT instruments

- Current FORS upgrade, CUBES and MAVIS are all visible-UV instruments➔ CCD or CMOS detectors
- Next instrument in the roadmap to start phase A end of 2023: BlueMUSE: visible/ UV➔ CCD/ CMOS
- VLT 2030+ workshop to define instruments for VLT in 2024

Conclusions

- New controller development – “first light” expected Q4 2022
  NGCII fanless design done externally at ANU
  Allows for operation of both analogue and fully digital detectors

- Stronger collaborations with external groups, many using NGC,
  e.g. ESA, ANU, UoCambridge, UoSheffield, CEA, Saclay for ALFA detector development etc.

- New updated test facilities

- New test and characterization processes

- Future needs