Astrophysical Technology Group

INAF-OAT

The commissioning of X-shooter: a new spectrograph @ VLT

P. Di Marcantonio – *INAF-OAT (on behalf of the X-shooter consortium)*

X-shooter has been built by a Consortium of European Institutes comprising:

- ESO (*PI S. D'Odorico, PM H. Dekker*)
- Denmark (*PI/PM P. Kjærgaard-Rasmussen*)
- France (*PI F. Hammer, PM I. Guinouard*)
- The Netherlands (*PI L. Kaper, PM R. Navarro*)
- Italy (***PI R. Pallavicini***, *PM F. Zerbi*)

ATG has been responsible for the design, development, integration and commissioning for the control software of the whole instrument.

People involved @ OAT:

- Paolo Di Marcantonio, Paolo Santin, Marzio Vidali (till end 2006)
- Andrea Zacchei, Claudio Zamberlan (thesis), Roberto Cirami
- continuous support of the OATs electronic group

The X-shooter Consortium

Astron

University of Amsterdam

University of Nijmegen

Observatory of Paris/Meudon

Copenhagen University Observatory

European Southern Observatory

Trieste Observatory

Merate Observatory

Palermo Observatory

Catania Observatory

11 institutes
in 5 countries

X-shooter resources

	effort (FTE)	Cost (k€)	Contribution
Denmark	19	850	Control electronics, Backbone unit, FEA, system test of UVB spectrograph
ESO	15	1510	Overall ProjMan.& SysEng, detectors, final system integration and commissioning, logistics
France	12	140	IFU, DRS
Italy	**19**	**800**	**Optomechanical design and integration of UVB and VIS, system test of VIS spectrograph, Control Software**
Netherlands	1.8	2044	NIR spectrograph, contribution to DRS
Total	**66.8**	**5344**	

	Guaranteed Nights
Italy	**44.5**
Denmark	45.5
France	20.8
Holland	43.5
Total	**154.3**

INAF-OATs (only) GTO involvement:

- Abundances and Dust in high redshift (z>4.0) Damped Lyman α galaxies (PI: Paolo M., CoI: Giovanni V., Valentina D'O. …)
- Optical-NIR spectra of quasars close to re-ionization (z~6) (PI: Valentina D'O., CoI: Paolo M., Stefano C., Matteo V., Giovanni V….)
- Extremely metal-poor stars in SDSS fields (PI: Piercarlo B., CoI: Paolo M., …)
- Tomography of the Intergalactic Medium with multiple QSO lines of sight (PI: Stefano C., CoI: F. Calura, E. Vanzella, V. D'Odorico, M. Viel, P. Monaco, …)
- A 100 burst X-Shooter/Swift GRB afterglow legacy survey (CoI: Elena P.)
- X-Shooting Supernovae (CoI: Elena P.)
- Study in situ of GRB progenitors and their host galaxies with X-Shooter : from z = 0.1 to 2.3 (CoI: Elena P.)

X-shooter time schedule

STC 56	Dec 2003
PDR	Dec 2004
FDR	Feb – Jul 2006
Integration@ESO	2008
PAE	Sept 2008
Comm #1	Nov 2008
Comm #2	Jan 2009
Comm #3	Mar 2009
Comm #4	May 2009
SV or GTO (several periods)	Jul – Sept 2009
Start of Operations	1.10.2009

X-shooter comm. team

Instrument characteristics

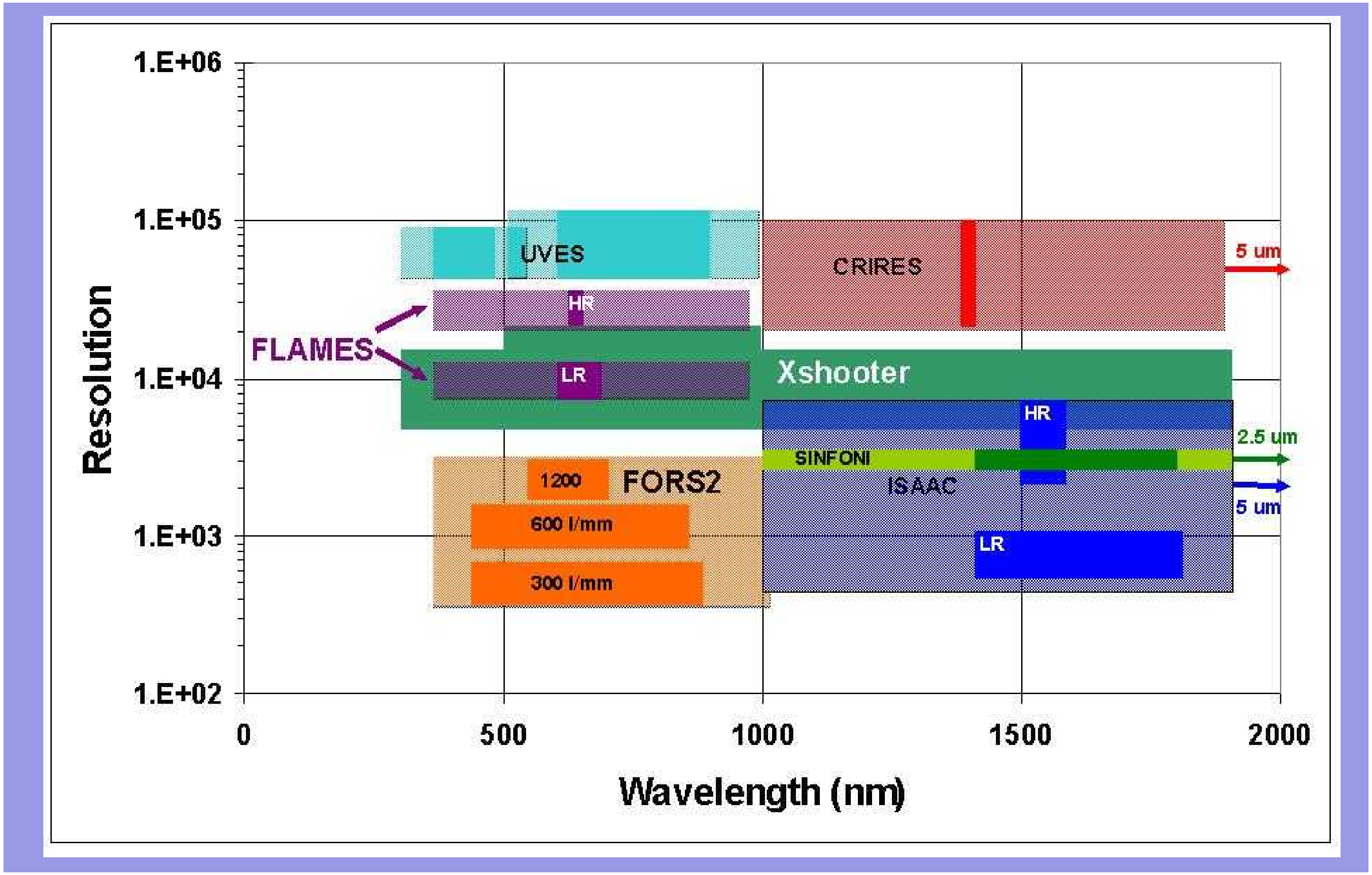
- Wavelength range: three arms covering from 300 nm to 2500 nm
- Fixed prism cross-dispersed echelle format (slit length 11")
- Detectors:
  - 2K x 4K 15μ CCDs (UVB and VIS arms)
  - 2K x 1K segment of a 2K x 2K 18μ Hawaii 2RG MBE (NIR arm)
- IFU (1.8" x 4"), ADC for UVB and VIS arms, calibration unit and A&G unit
- Spectral resolution: ~7000 to 12000 for 0.6" slit or IFU
- High Detective Quantum Efficiency
- Pipeline delivering sky-subtracted, wav cal 2D spectra and 3D data cube for the IFU

X-shooter science II

- ***High-redshift emission-line galaxies***
- ***AGNs at intermediate and high redshifts***
- ***Absorption lines in QSO spectra***
- ***Tomography of the intergalactic medium***
- ***Supernovae***
- ***GRB afterglows***
- ***Brown dwarfs and T-Tauri stars***
- ***Stellar remnants and compact binaries***

The instrument will be released on 01/10/09 and is already in high demand (120 proposals were received for P84 – for comparison: FORS 1+2: 180, UVES: 90).

Comparison with other VLT spectrograph

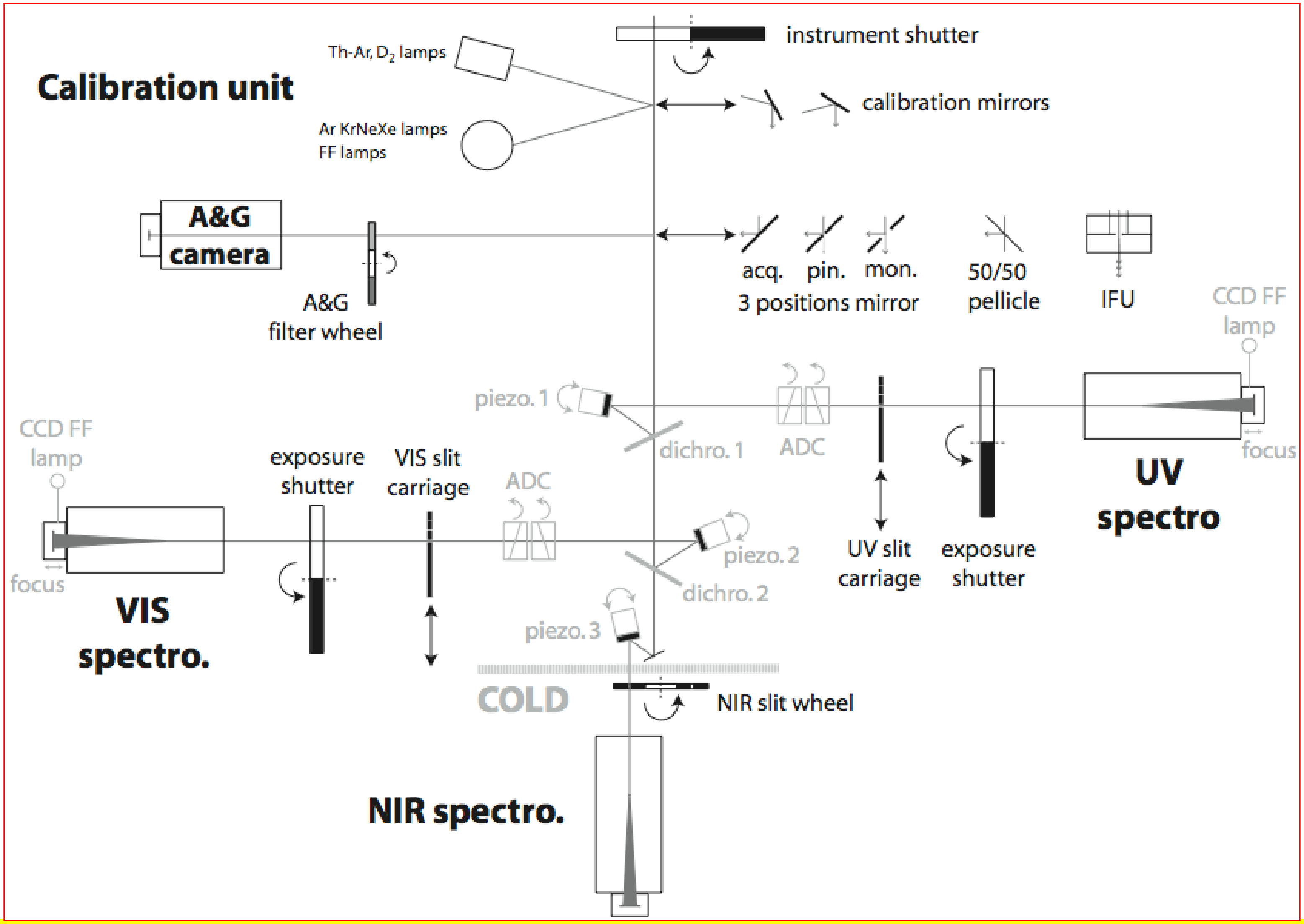


Note: Widths of the darker strips identify the spectral coverage in a single exposure. VIMOS (not shown) approximately overlaps with FORS and both have poor response in the UV. FORSes and ISAAC are expected to be decommissioned by the time when X-shooter will become operational.

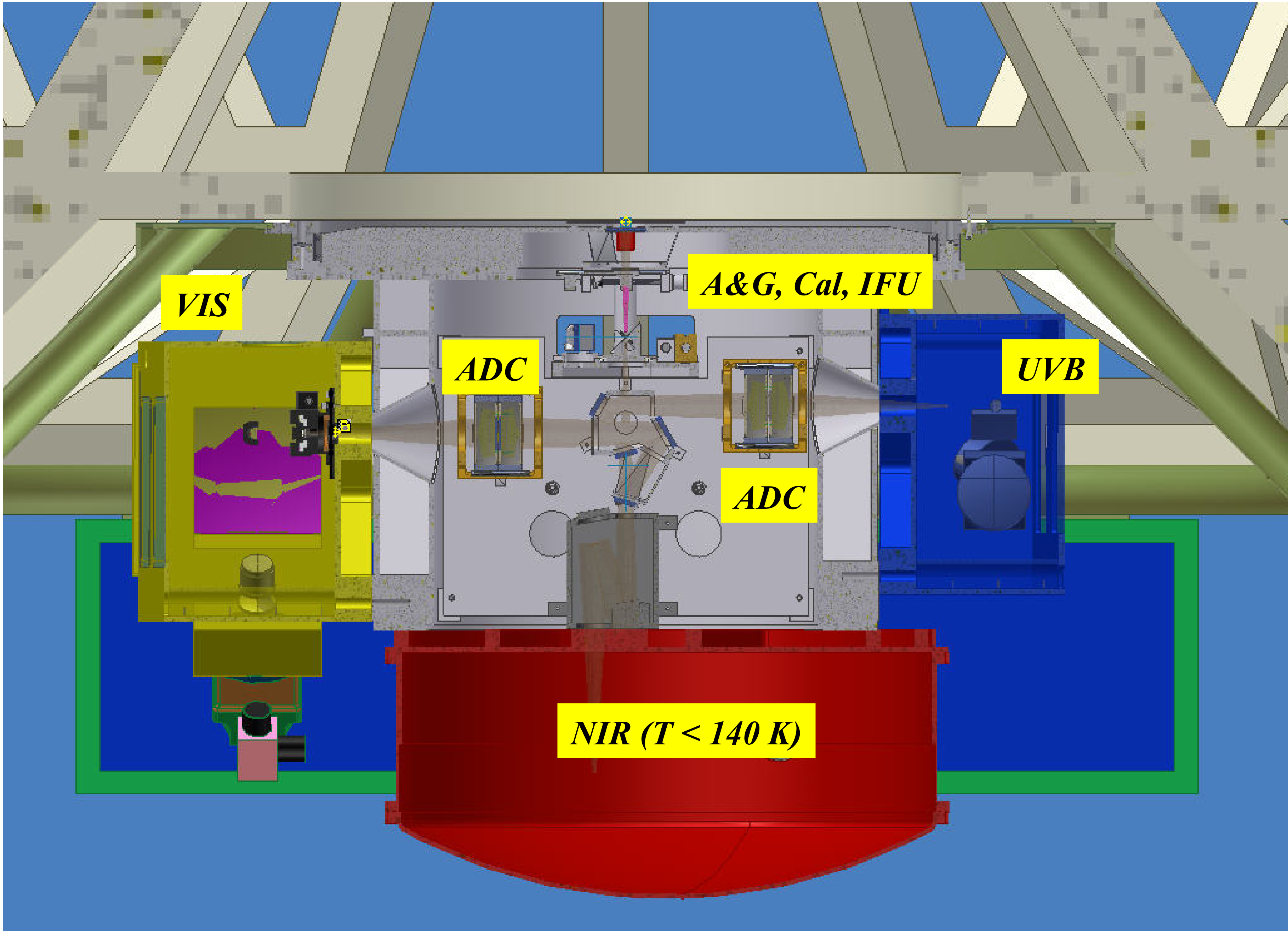
Arms obseving capabilities

- **UV-blue arm Range: 300-550 nm in 12 orders**
  - Resolution: 5100 (1" slit)
  - Slit width: 0.5”, 0.8”, 1.0”, 1.3”, 1.6”, 5.0”
  - Detector: 4k x 2k E2V CCD
- **Visual-red arm Range: 550-1000 nm in 14 orders**
  - Resolution: 8800 (0.9" slit)
  - Slit width: 0.4”, 0.7”, 0.9”, 1.2”, 1.5”, 5.0”
  - Detector: 4k x 2k MIT/LL CCD
- **Near-IR arm Range: 1000-2500 nm in 16 orders**
  - Resolution: 5100 (0.9" slit)
  - Slit width: 0.4”, 0.6”, 0.9”, 1.2”, 1.5”, 5.0”
  - Detector: 2k x 1k Hawaii 2RG

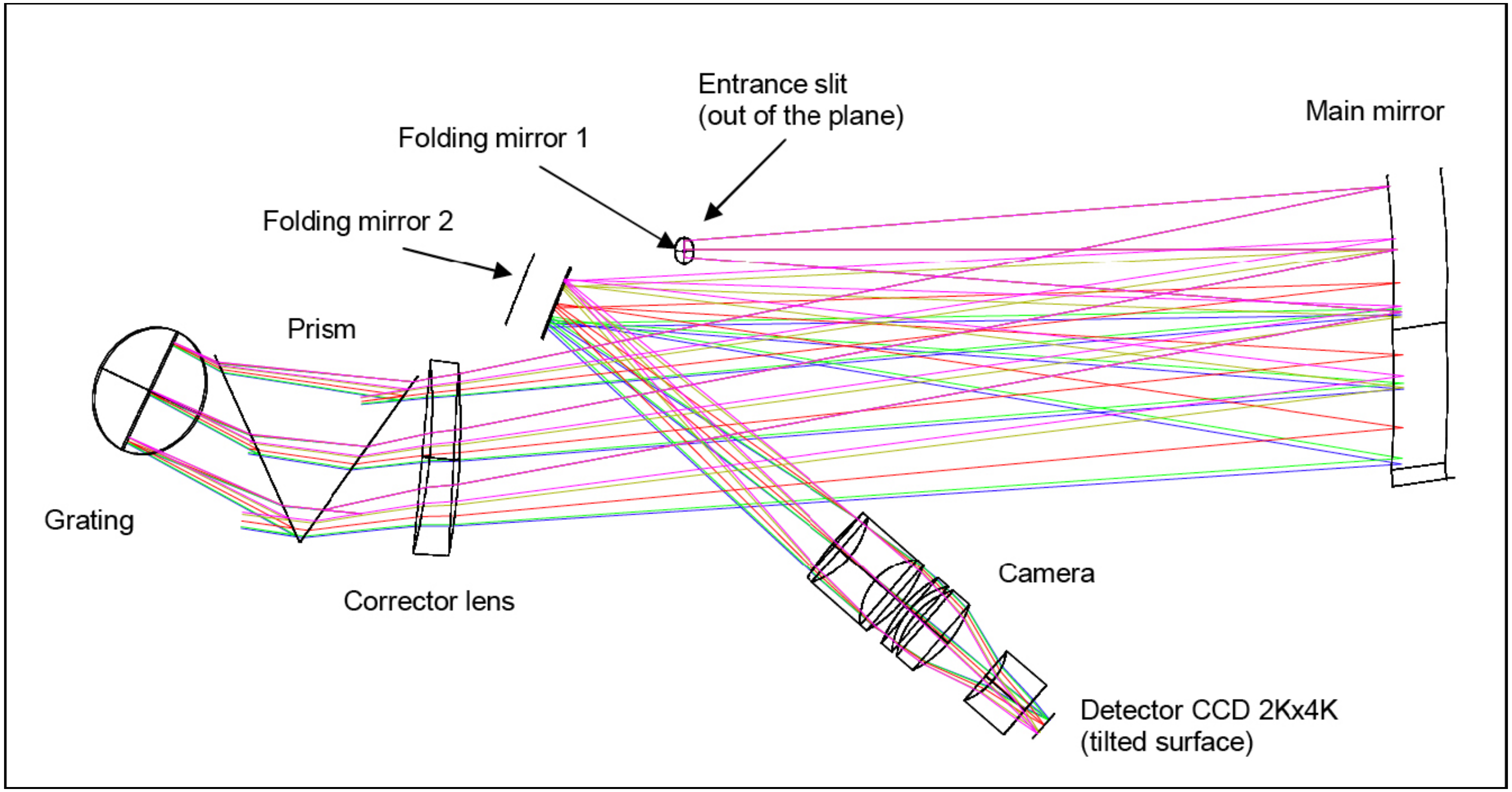
Instrument layout I



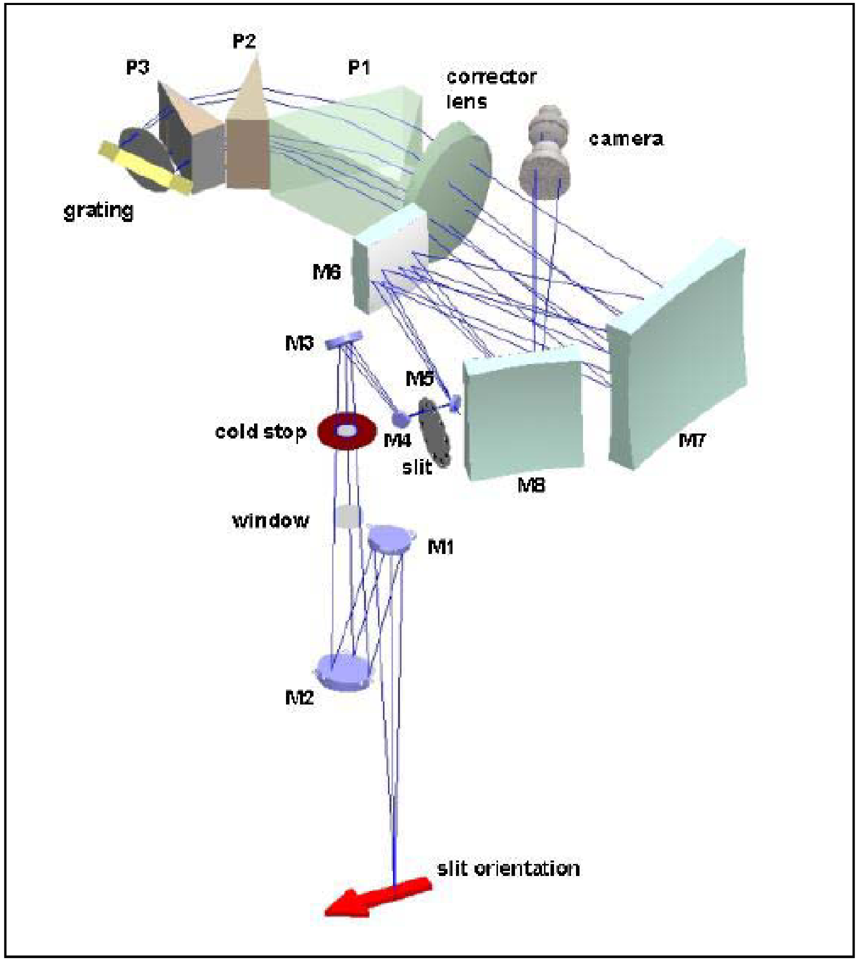
Instrument layout II

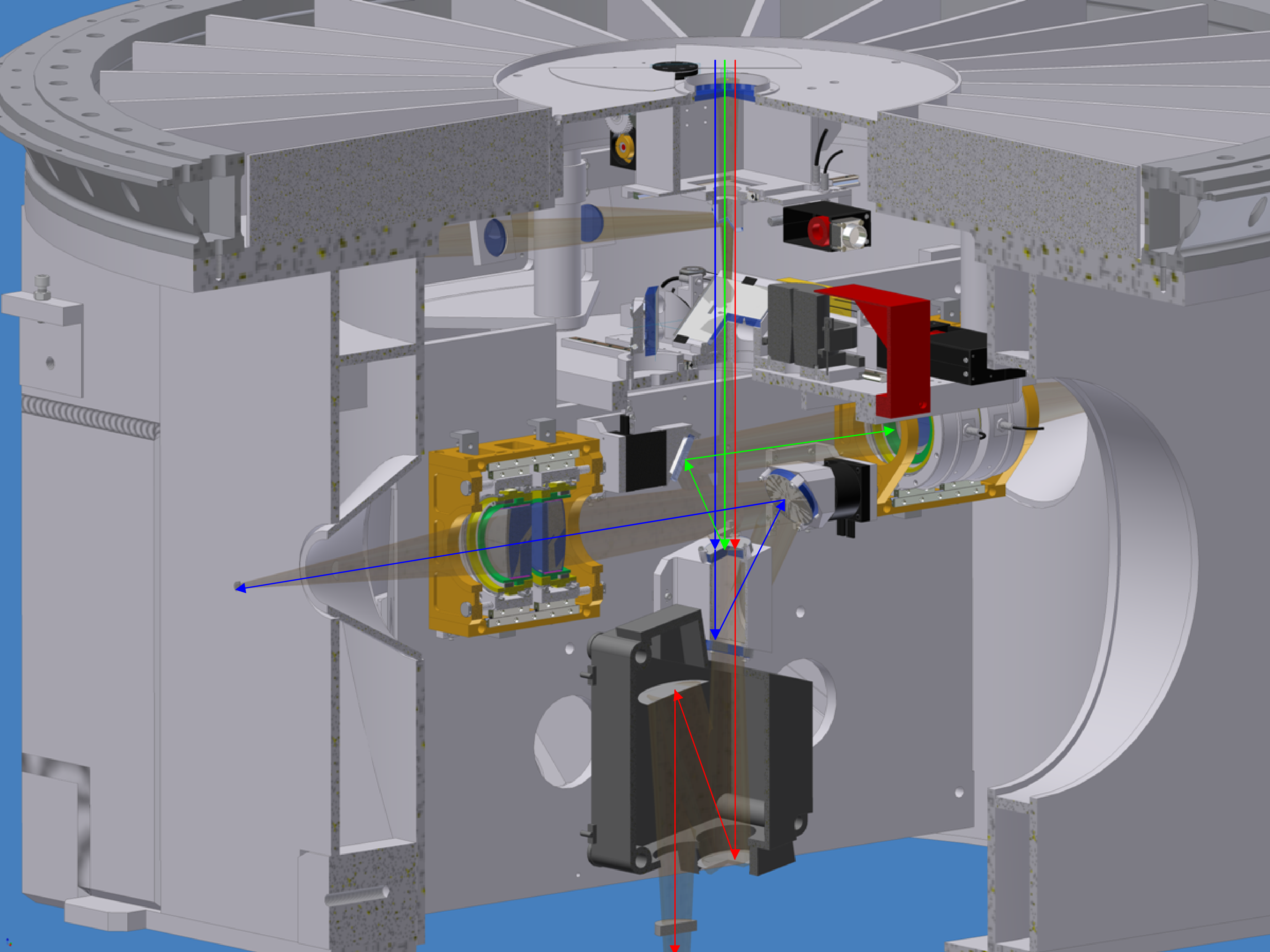


UVB-VIS optical layout



NIR optical layout





Calibration unit

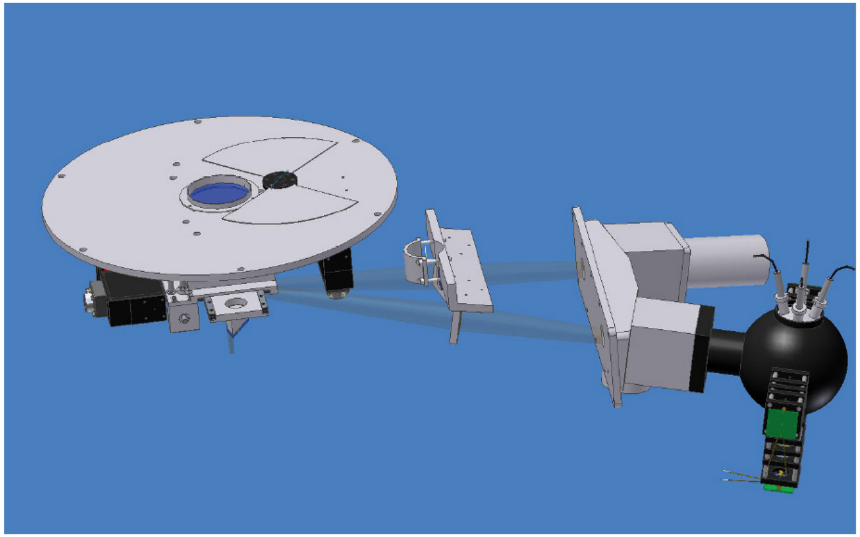


Figure 18 *ISH & Calibration Lamps Unit, View from above*

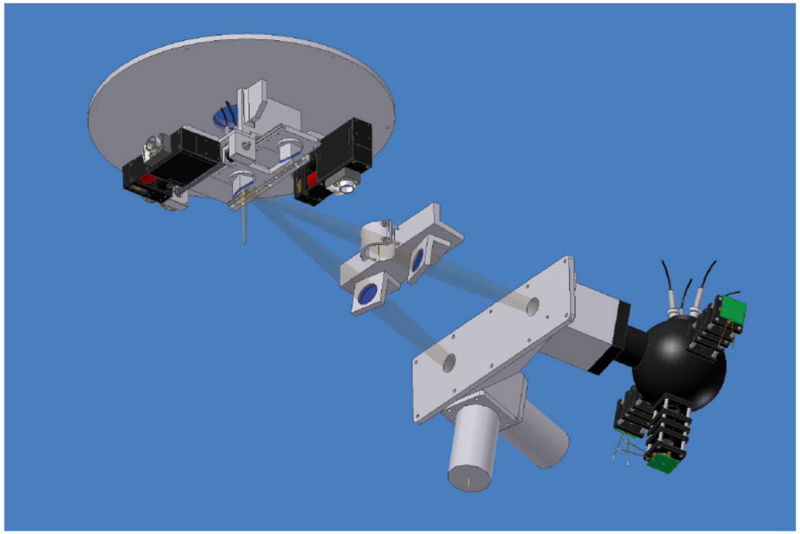
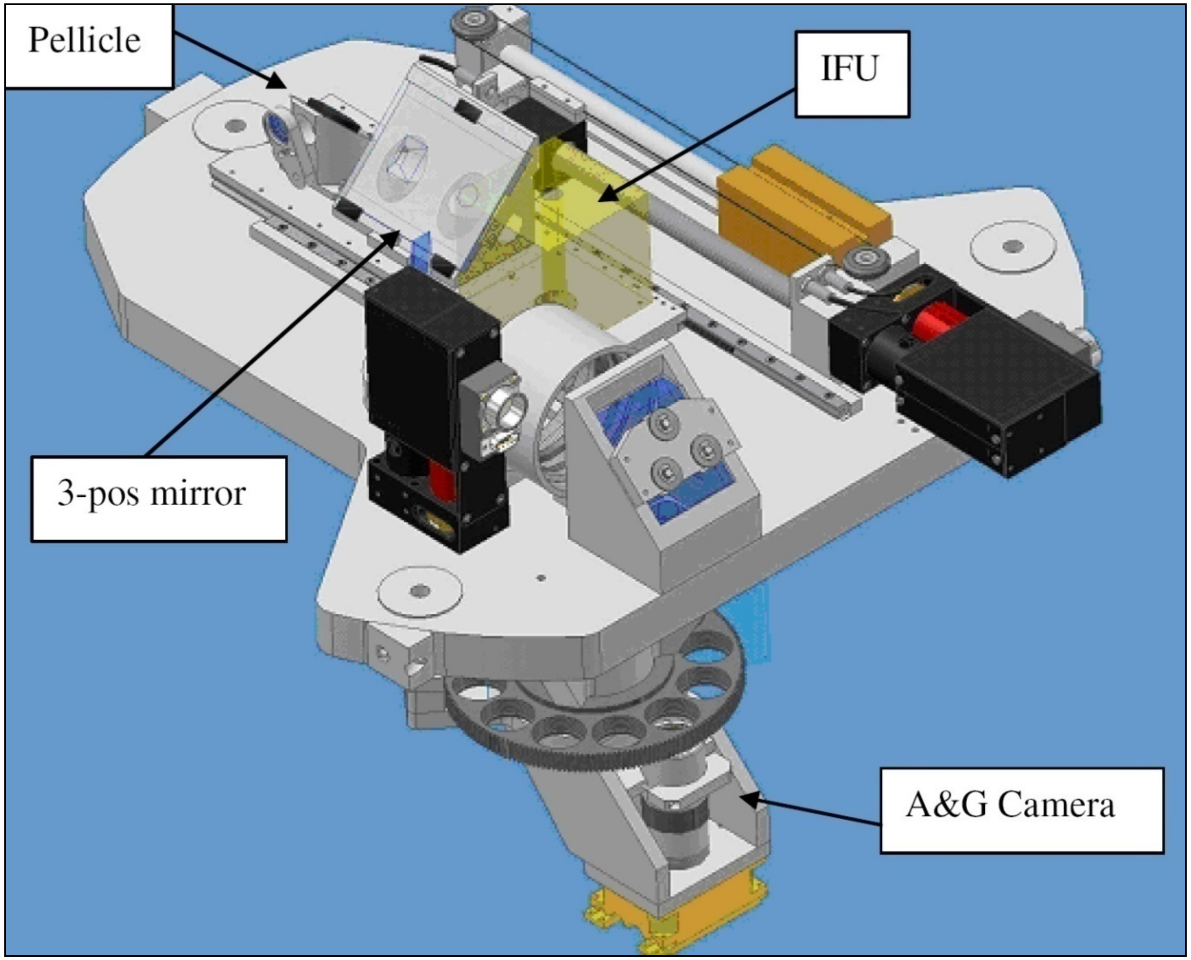
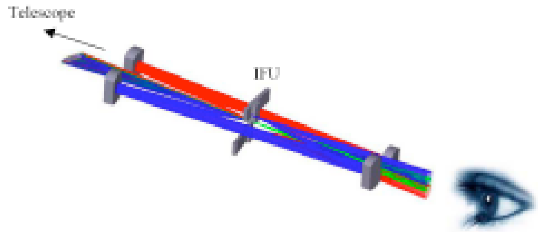
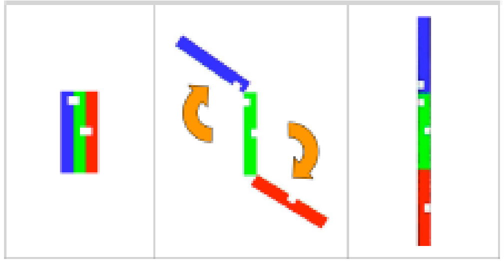


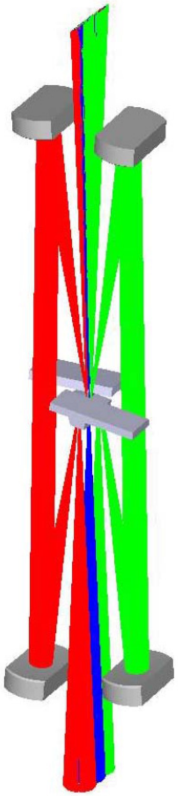
Figure 19 *View from below*

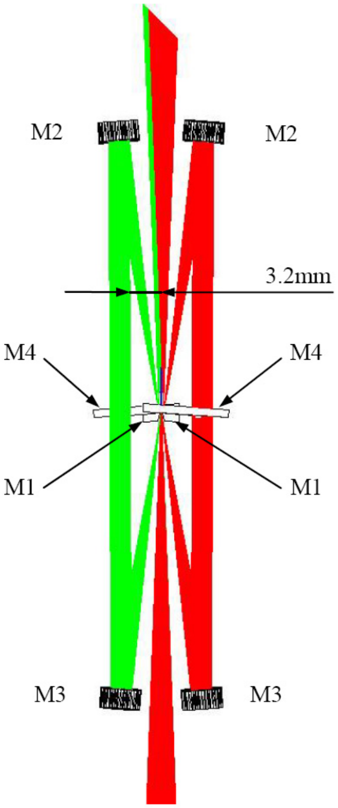
A&G unit



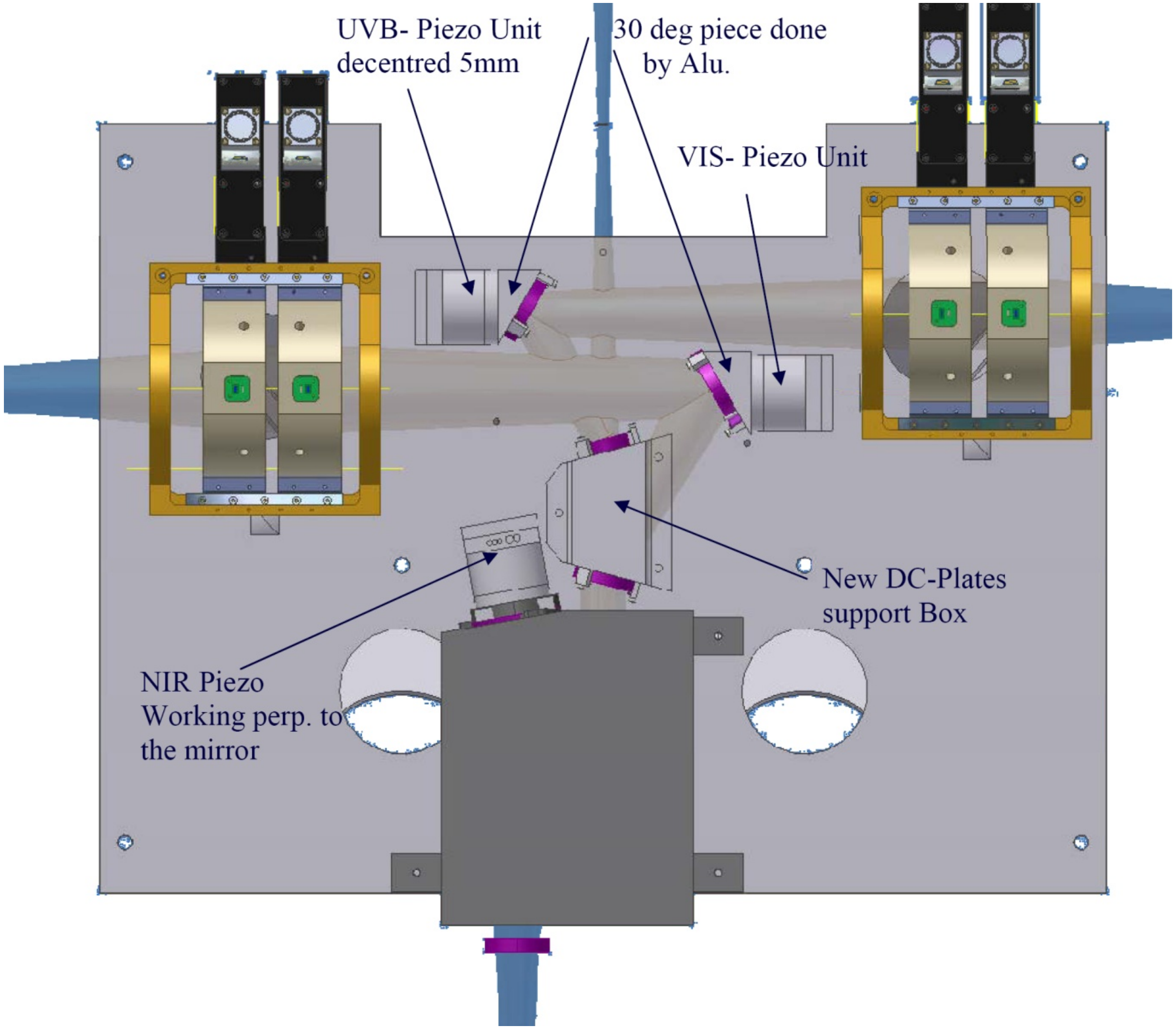

Telescope
IFU






M2
M2
3.2mm
M4
M4
M1
M1
M3
M3

ADCs & Piezo's


UVB- Piezo Unit
decentred 5mm
30 deg piece done
by Alu.
VIS- Piezo Unit
New DC-Plates
support Box
NIR Piezo
Working perp. to
the mirror

NIR cryostat

The vacuum containment as designed consists of three major elements, viz.

A stiff aluminum top plate (red part)
An aluminum cylindrical shell (green part)
A stainless steel cryogenic service unit (CSU)(blue part)

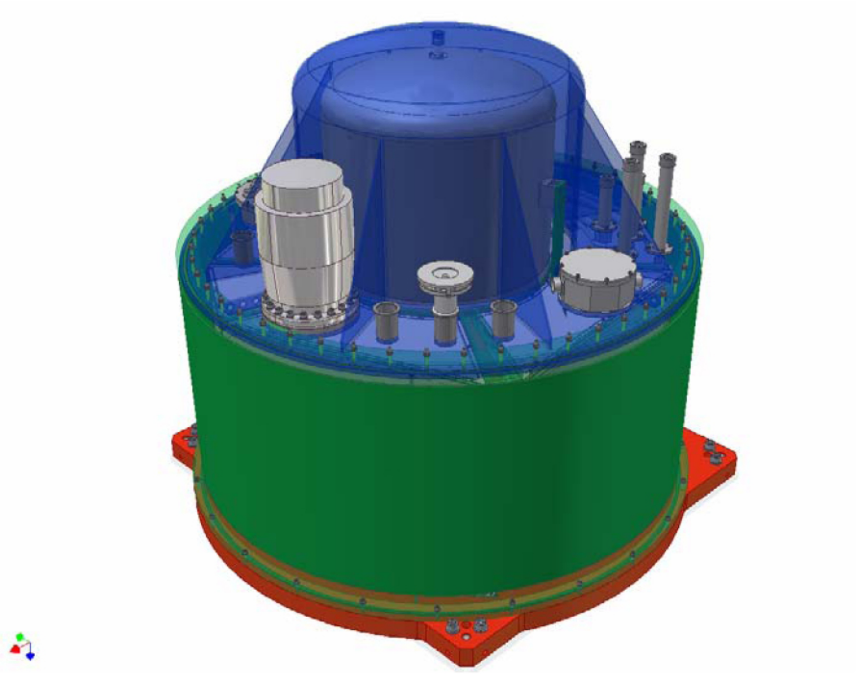
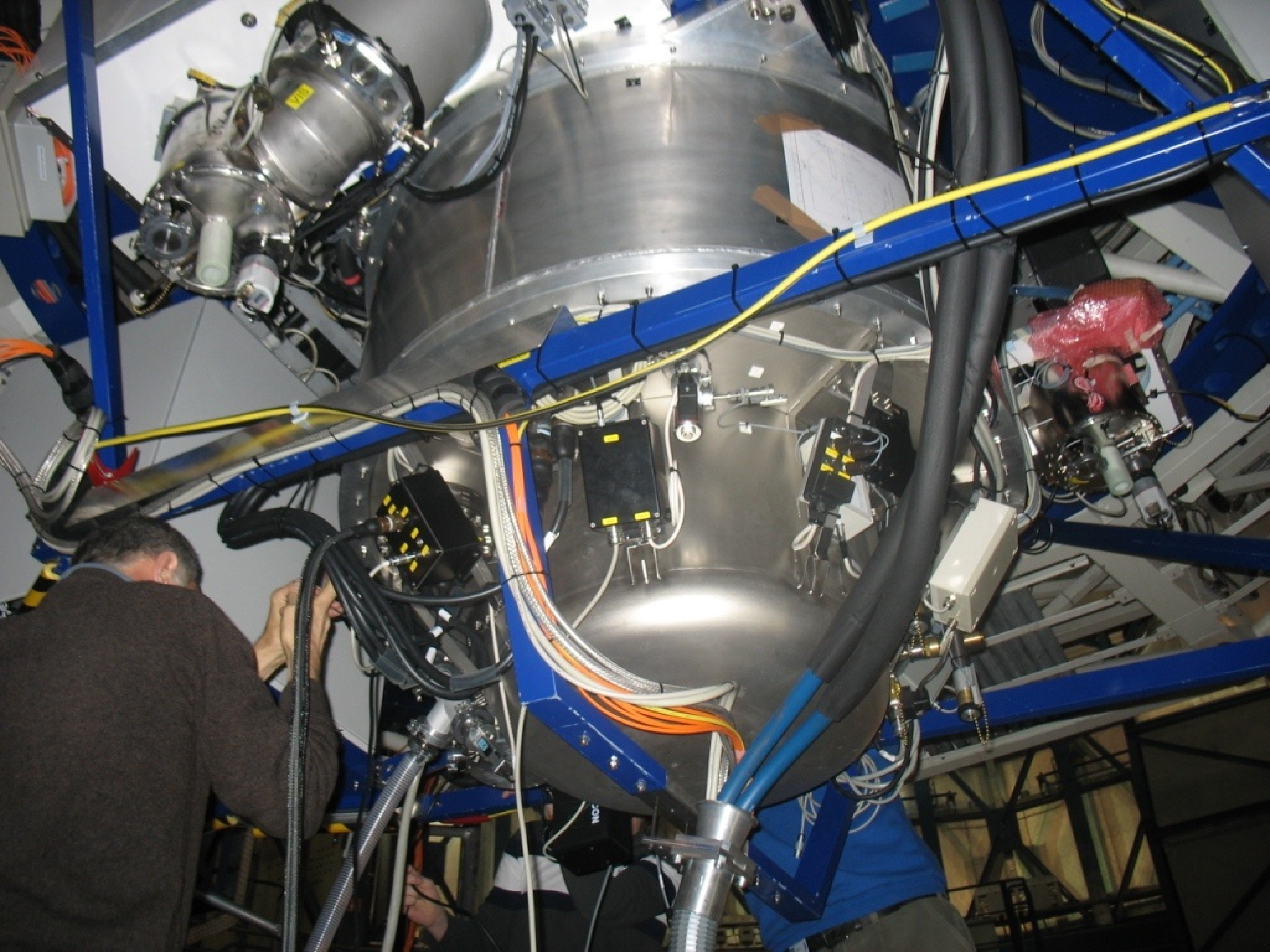
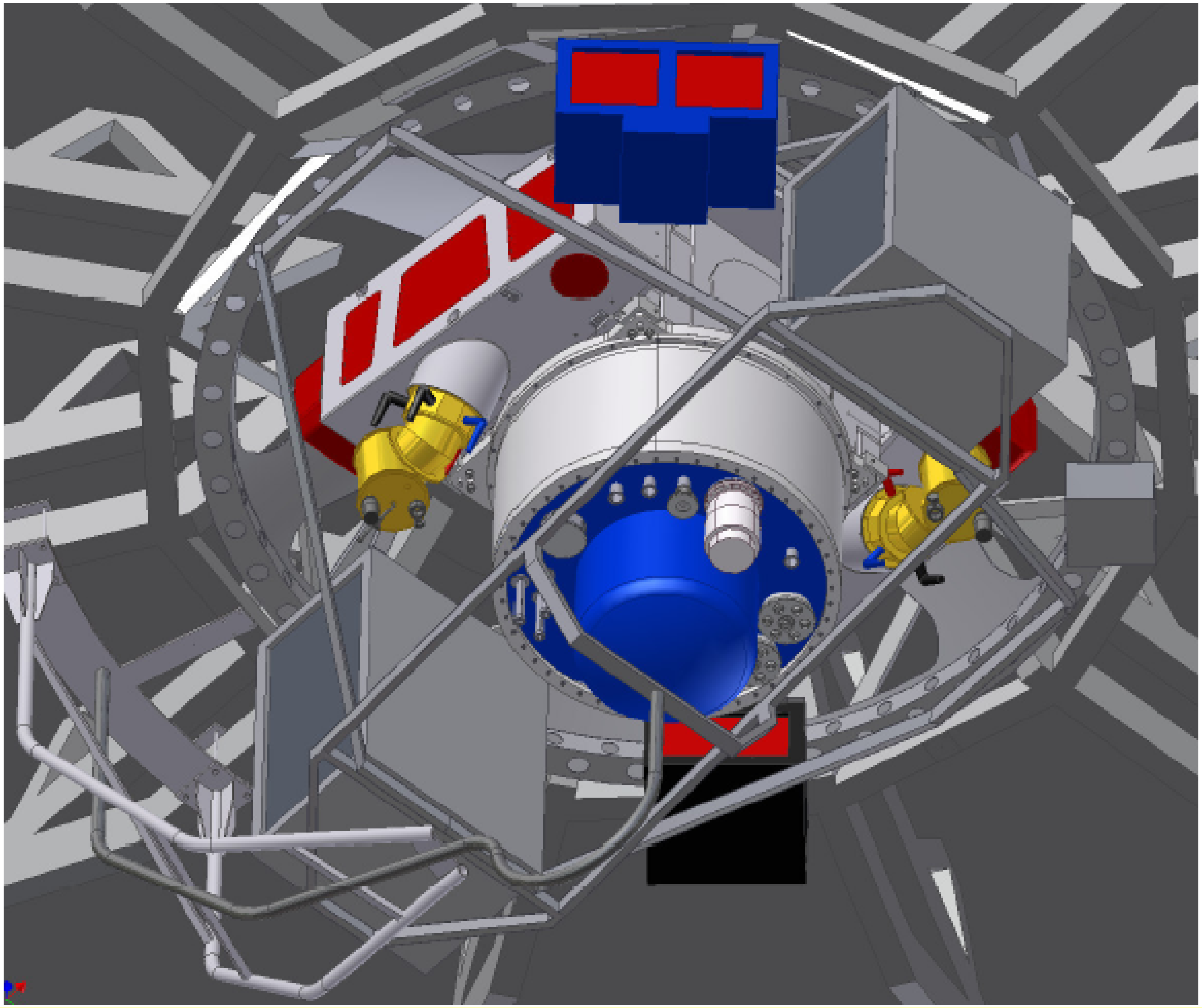


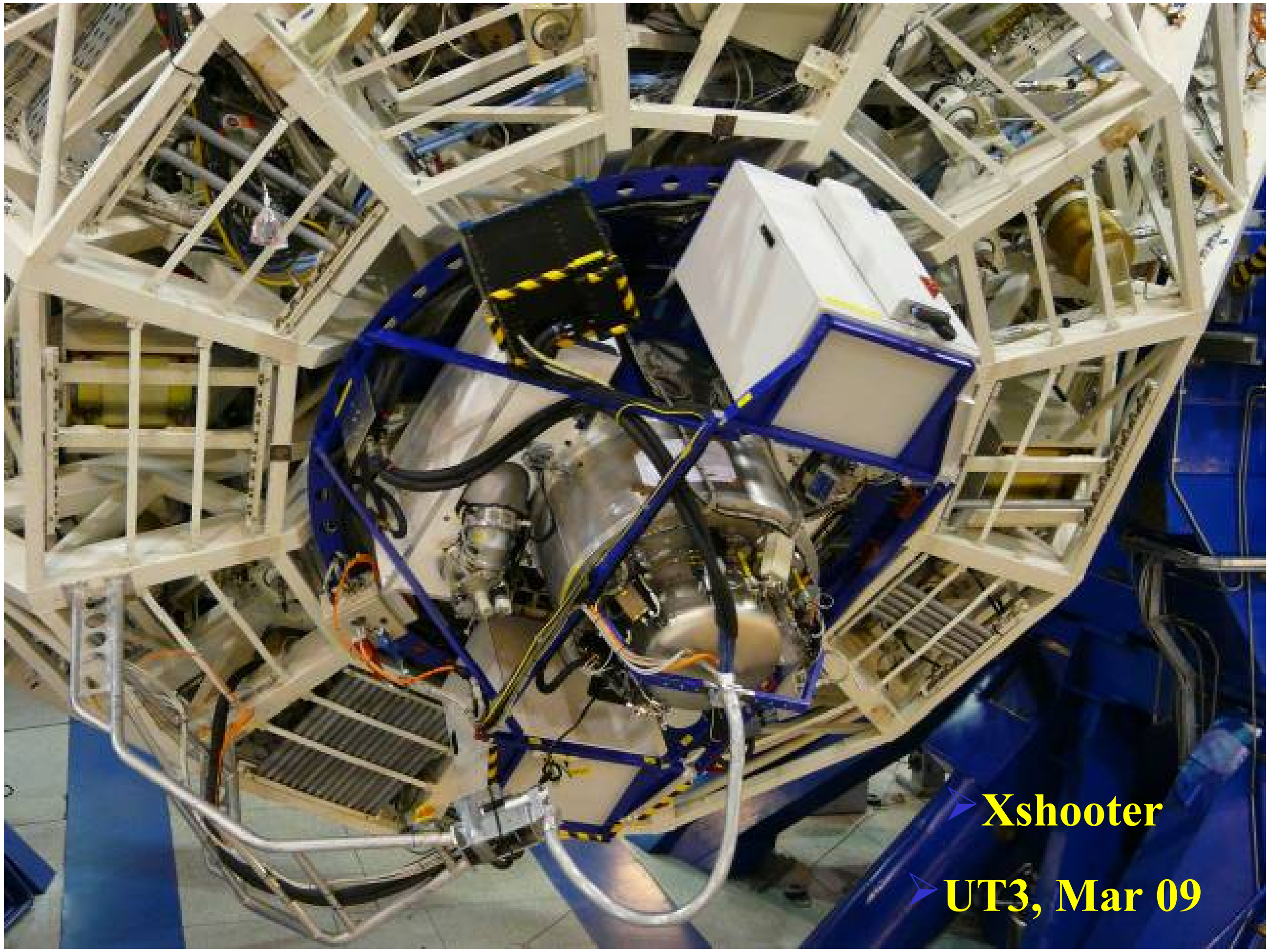
Figure 6 Major Elements Cryostat



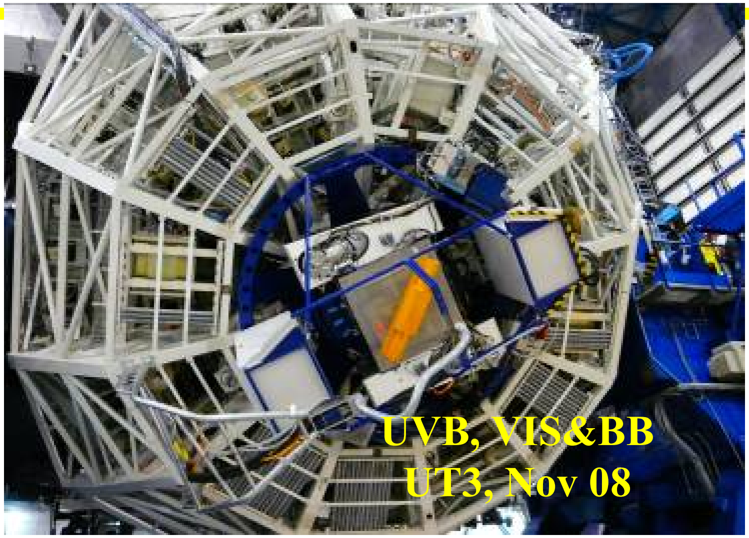
FDR CAD design

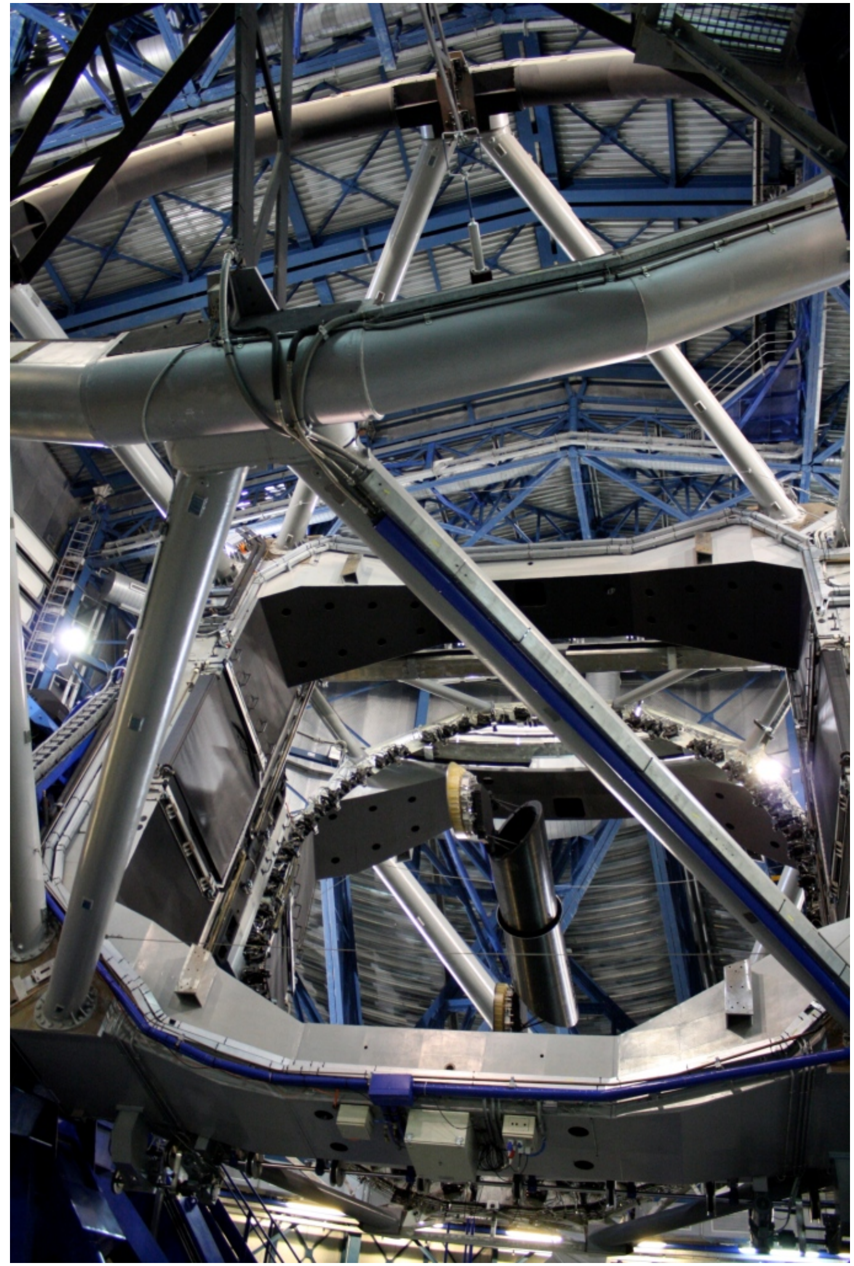


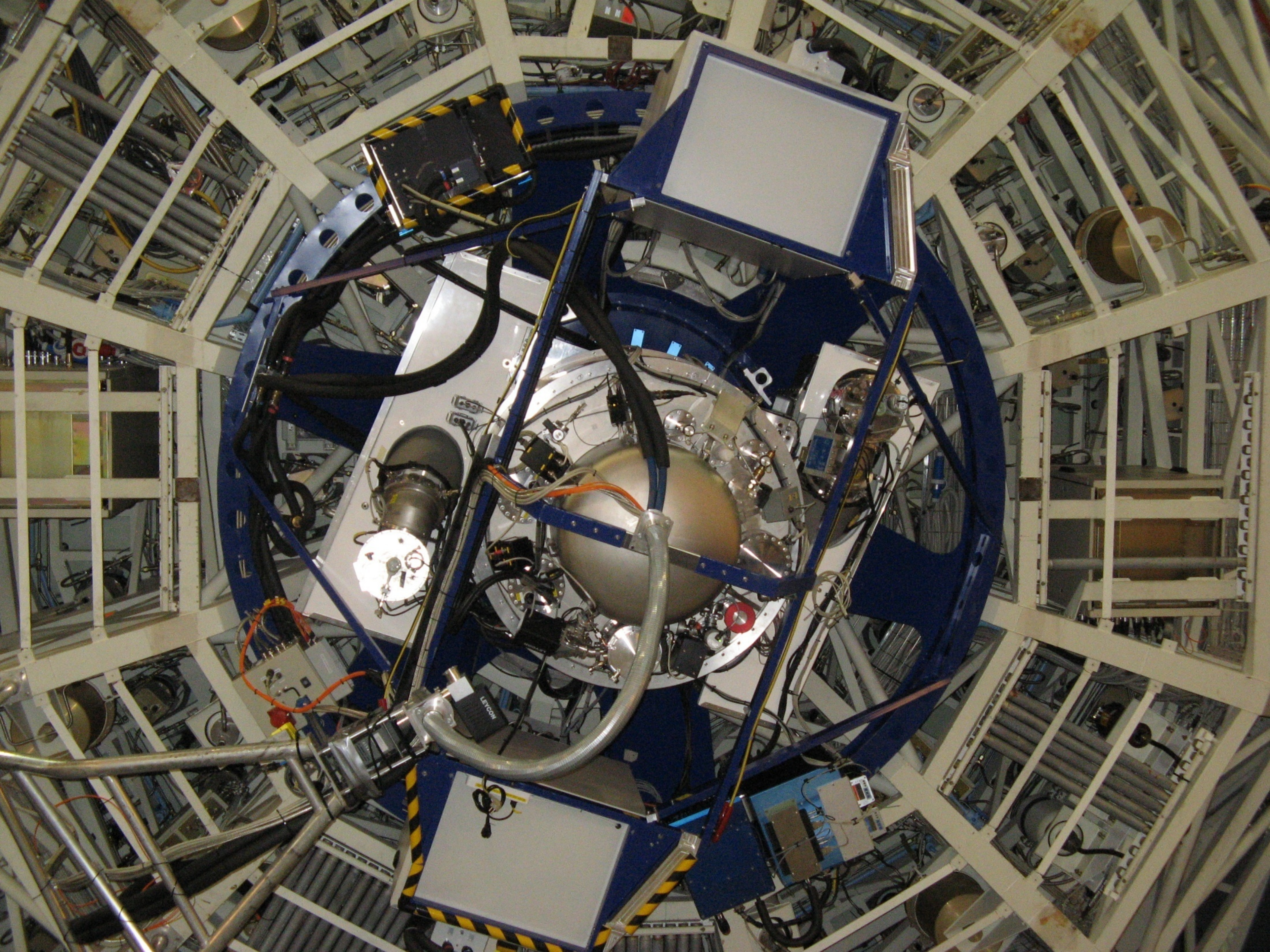
Eventually ...



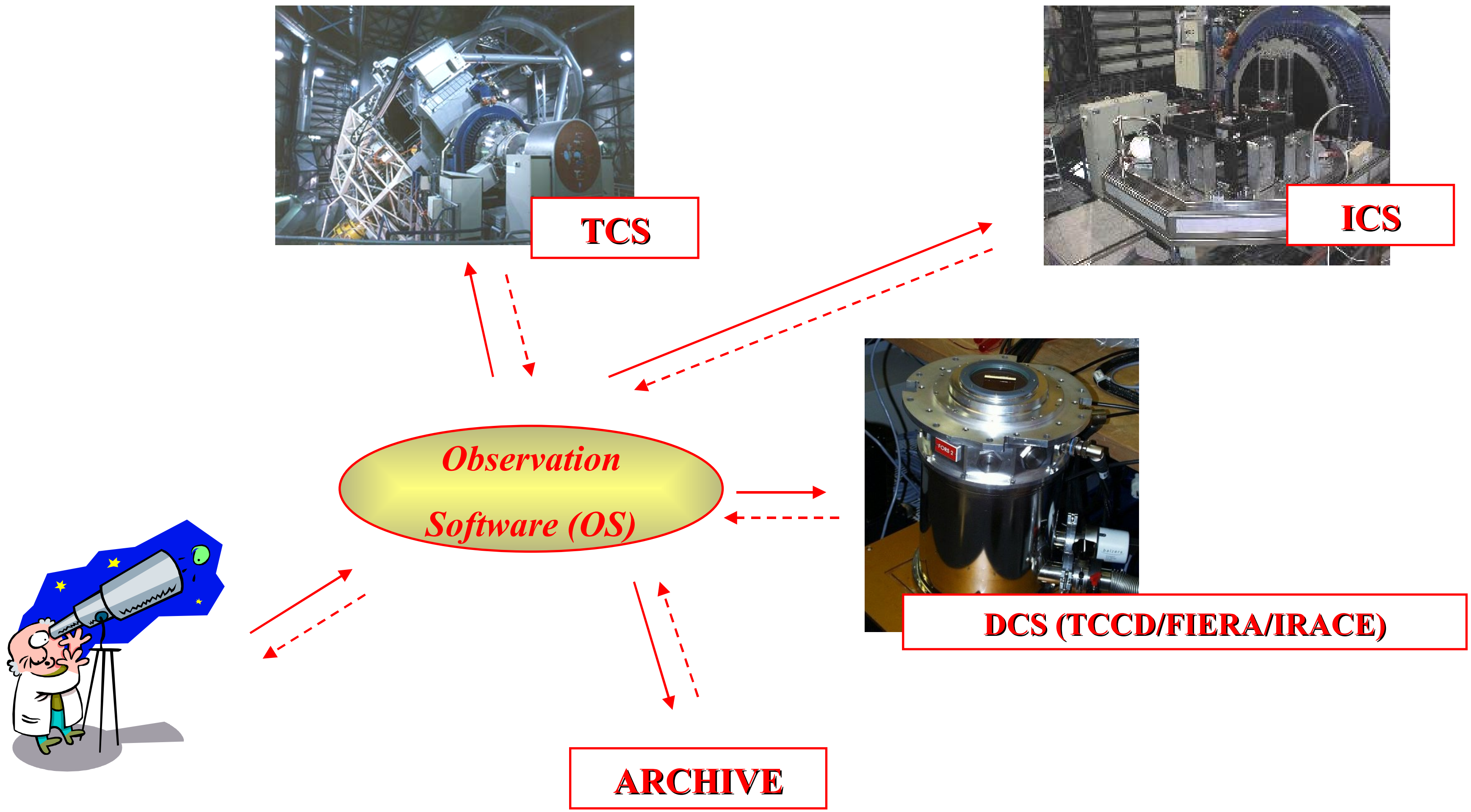
UT3 integration



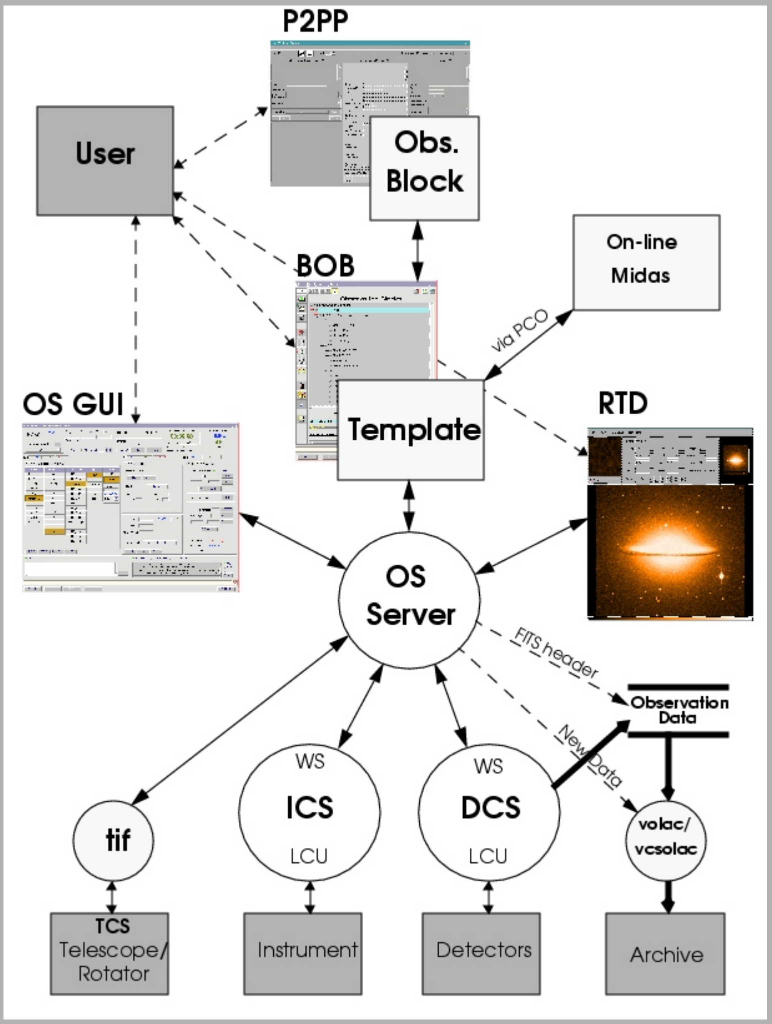



LEYCON

The ESO Control Software



ESO control software - full path

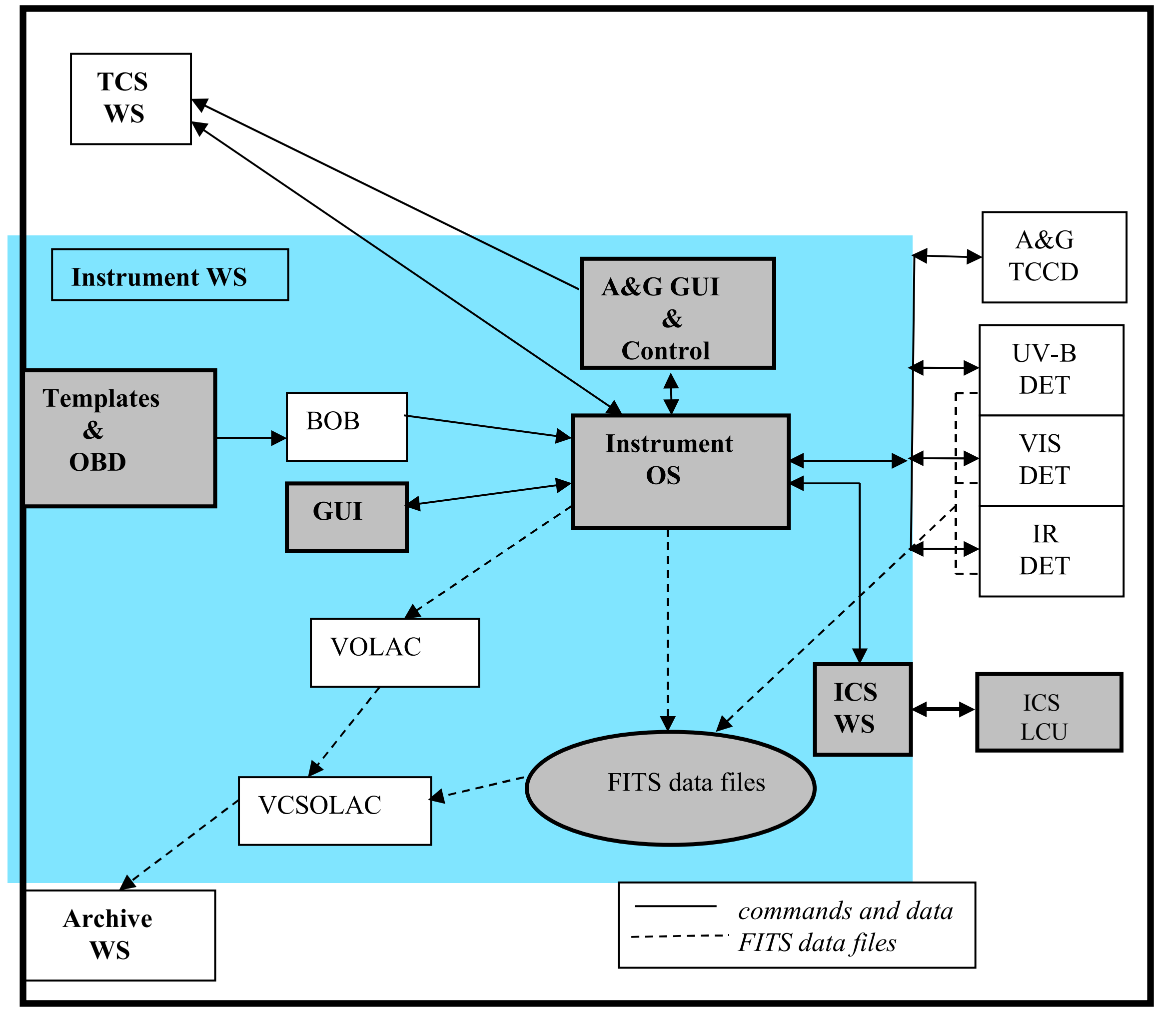


– CCS: Basic common functions.
– ERR: Error reporting.
– LOG: Logging system.
– MSG: Message system.
– CMD: Command checking.
– *DB: On Line Database.*
– *EVT: Event handling.*
– *TIMS: Time calculations & triggering.*
– NTP: Clock synchronisation.
– *SCAN: Data propagation.*
– ALRM: Alarm reporting.
– BOOK: Security checks.
– PANEL: GUI development support.
– CCSEI: Engineering UIF.
– SAMP: Sampling/Plotting tools.
– DBL: Database generation.
– ECCS: CCS C++ API & Classes.
– EVH: C++ Event Handler template.

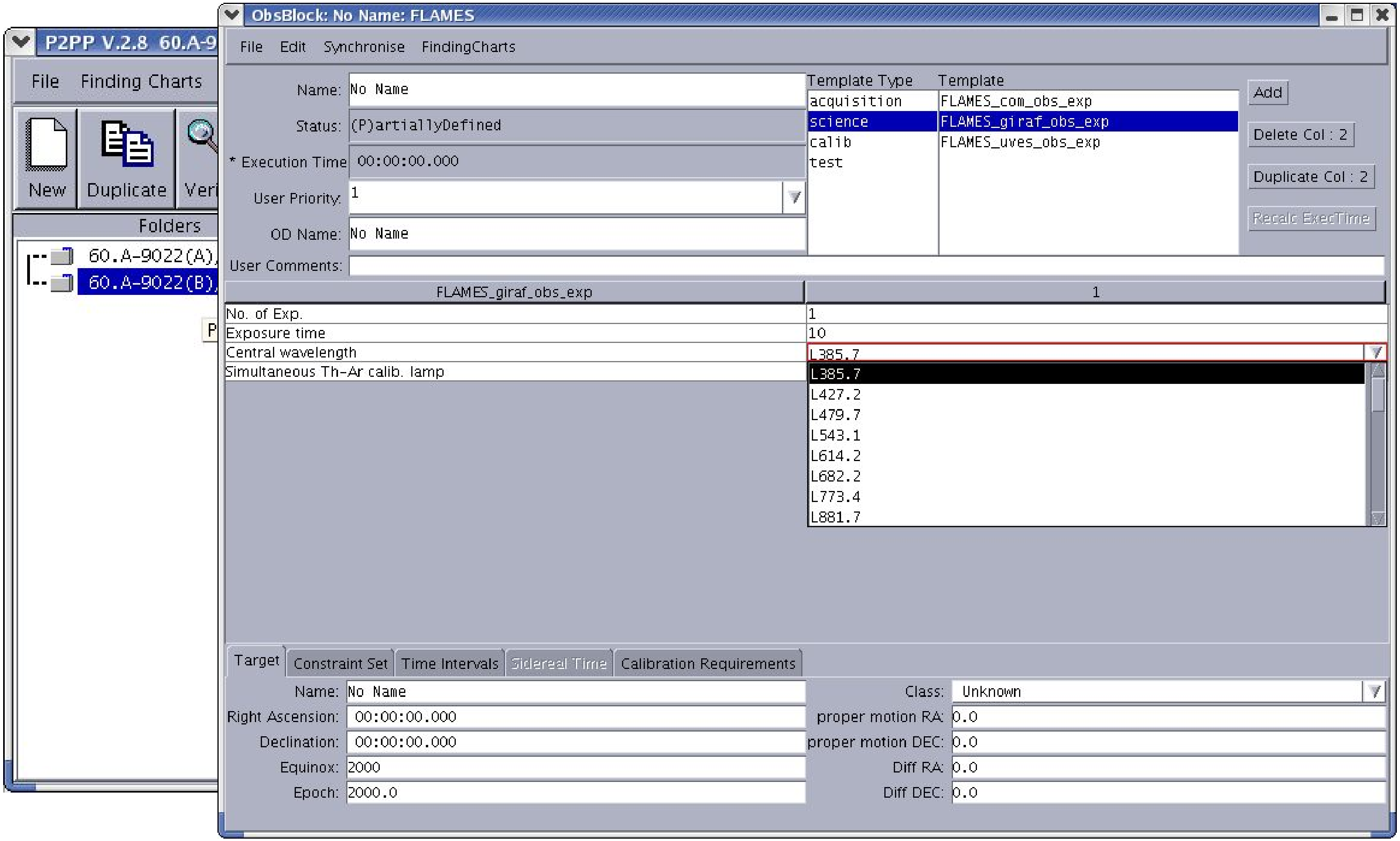
The main components of LCC are:

- Local database
- Interfaces with CCS
  - message system
  - logging system
  - error system
  - scan system
  - access control
- I/O system
- Time services
- Command Interpreter
- Start-up and shut-down procedures
- Simulation
- Drivers for ESO standards boards
- Motor Control module
- Engineering test tools

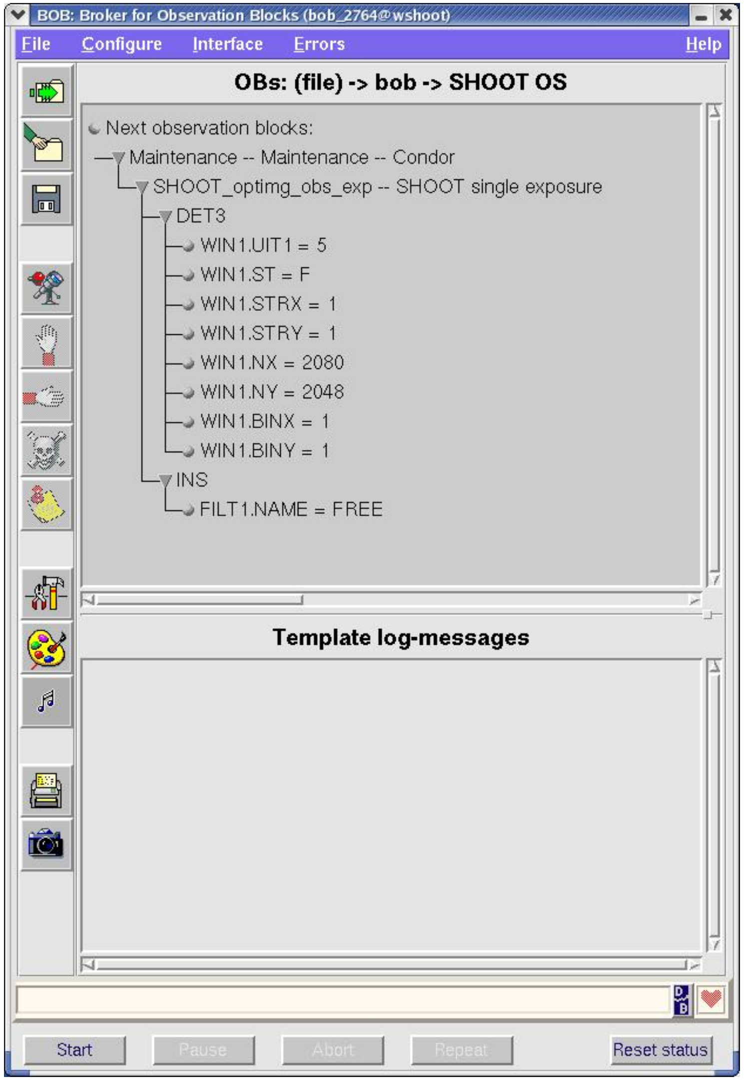
The X-shooter control sw design



P2PP


P2PP V.2.8 60.A-9
File
Finding Charts
New
Duplicate
Veri
Folders
60.A-9022(A)
60.A-9022(B)
ObsBlock: No Name: FLAMES
File
Edit
Synchronise
FindingCharts
Name: No Name
Status: (P)artiallyDefined
* Execution Time 00:00:00.000
User Priority: 1
OD Name: No Name
User Comments:
Template Type
acquisition
science
calib
test
Template
FLAMES_com_obs_exp
FLAMES_giraf_obs_exp
FLAMES_uves_obs_exp
Add
Delete Col : 2
Duplicate Col : 2
Recalc ExecTime
FLAMES_giraf_obs_exp
1
No. of Exp.
1
Exposure time
10
Central wavelength
L385.7
Simultaneous Th-Ar calib. lamp
L385.7
L427.2
L479.7
L543.1
L614.2
L682.2
L773.4
L881.7
Target
Constraint Set
Time Intervals
Sidereal Time
Calibration Requirements
Name: No Name
Right Ascension: 00:00:00.000
Declination: 00:00:00.000
Equinox: 2000
Epoch: 2000.0
Class: Unknown
proper motion RA: 0.0
proper motion DEC: 0.0
Diff RA: 0.0
Diff DEC: 0.0

Broker for the Observation Block (BOB)



Sends a buffer of keywords to OS:

"DETi.WIN1.BINX 1 DETi.WIN1.BINY 1

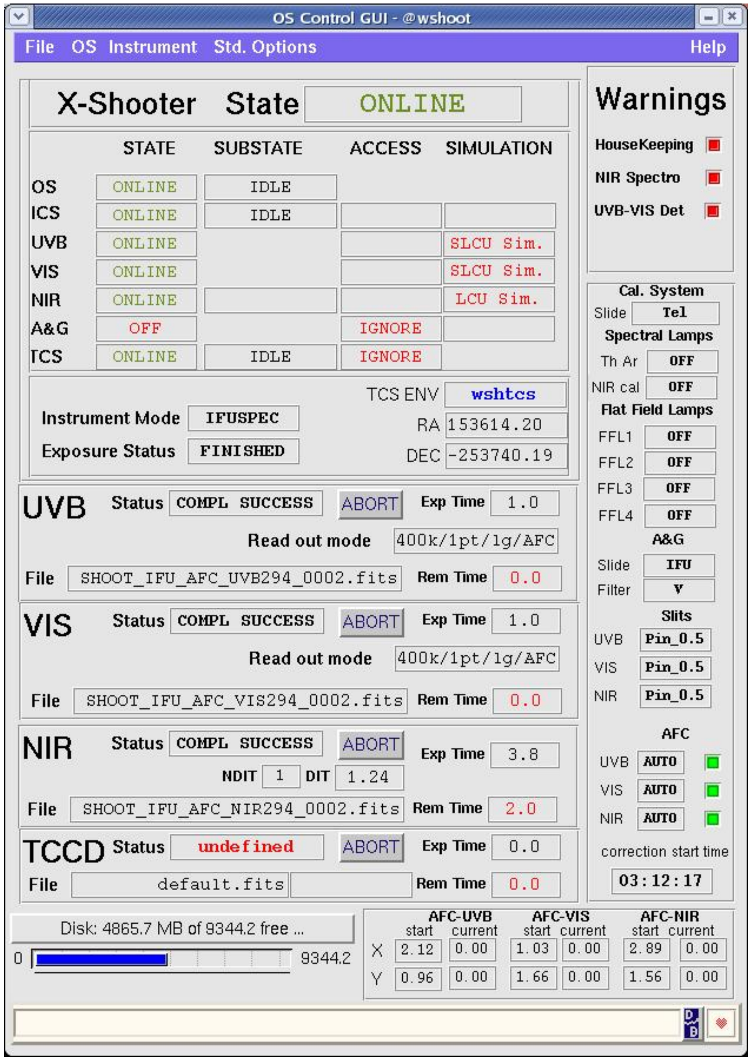
DETi.WIN1.UIT1 5 INS.FILT1.NAME FREE

INS.LAMP1.ST F INS.LAMP2.ST F

TEL.TARG.ALPHA 00 TAL.TARG.DELTA 00 …"

Start Observation: sends START to OS

Observation software (OS)



Sends:

- TEL* to TCS
- INS* to ICS
- DETi* to DCS

After the exposure, OS collects all the FITS keywords from the various subsystems, merge them into the final FITS image and send it to the archive.

The ICS SW is split into a WS and an LCU part. Fig.1 shows its general architecture.

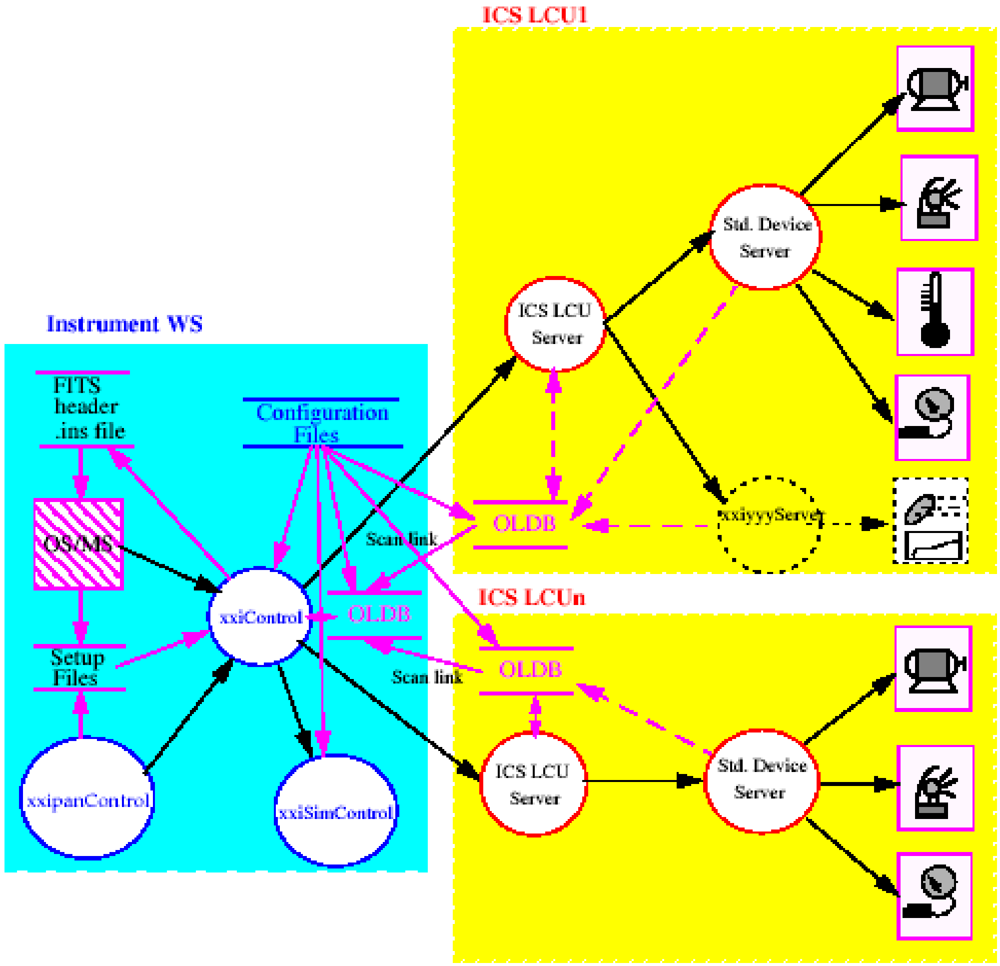
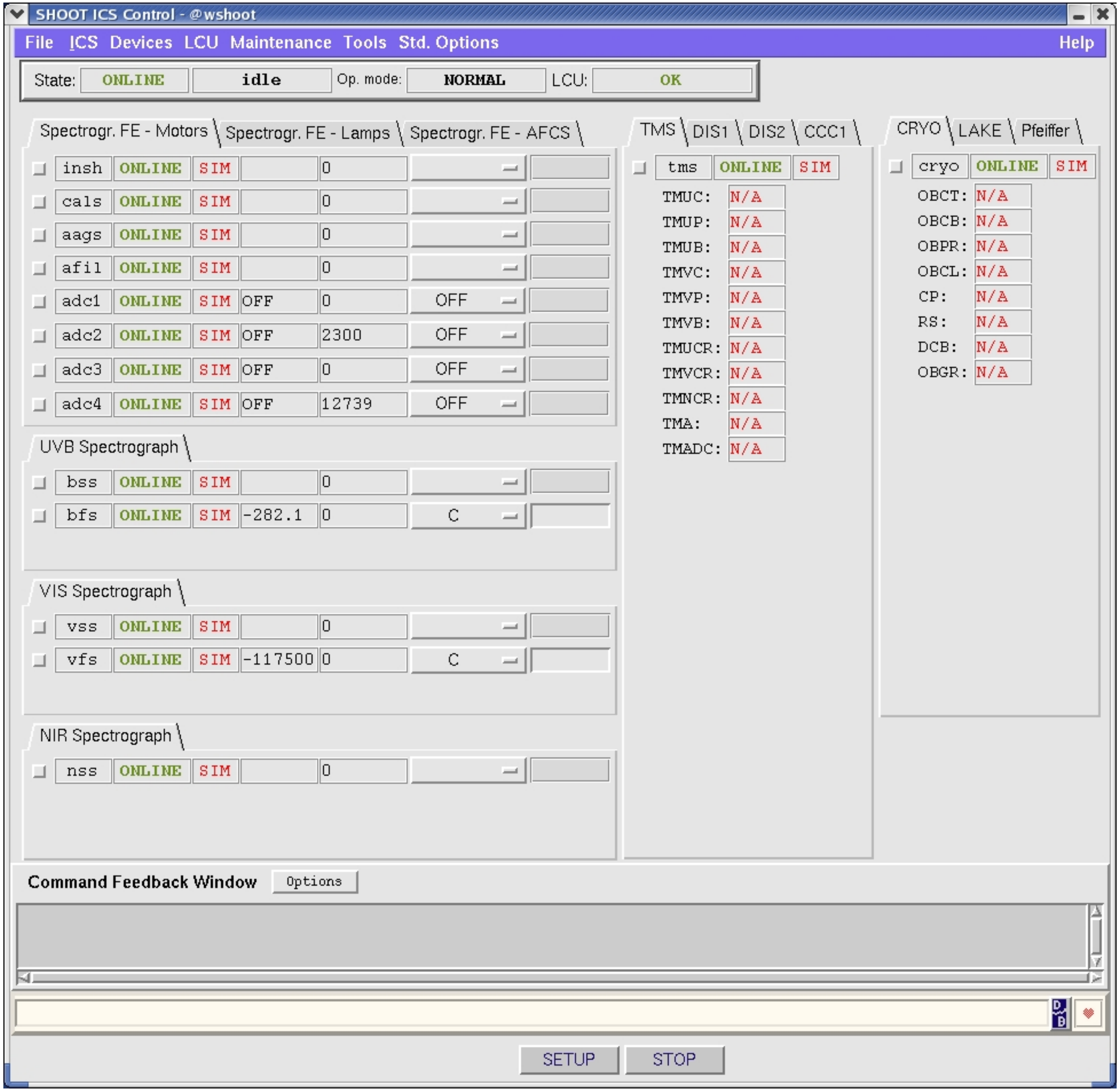


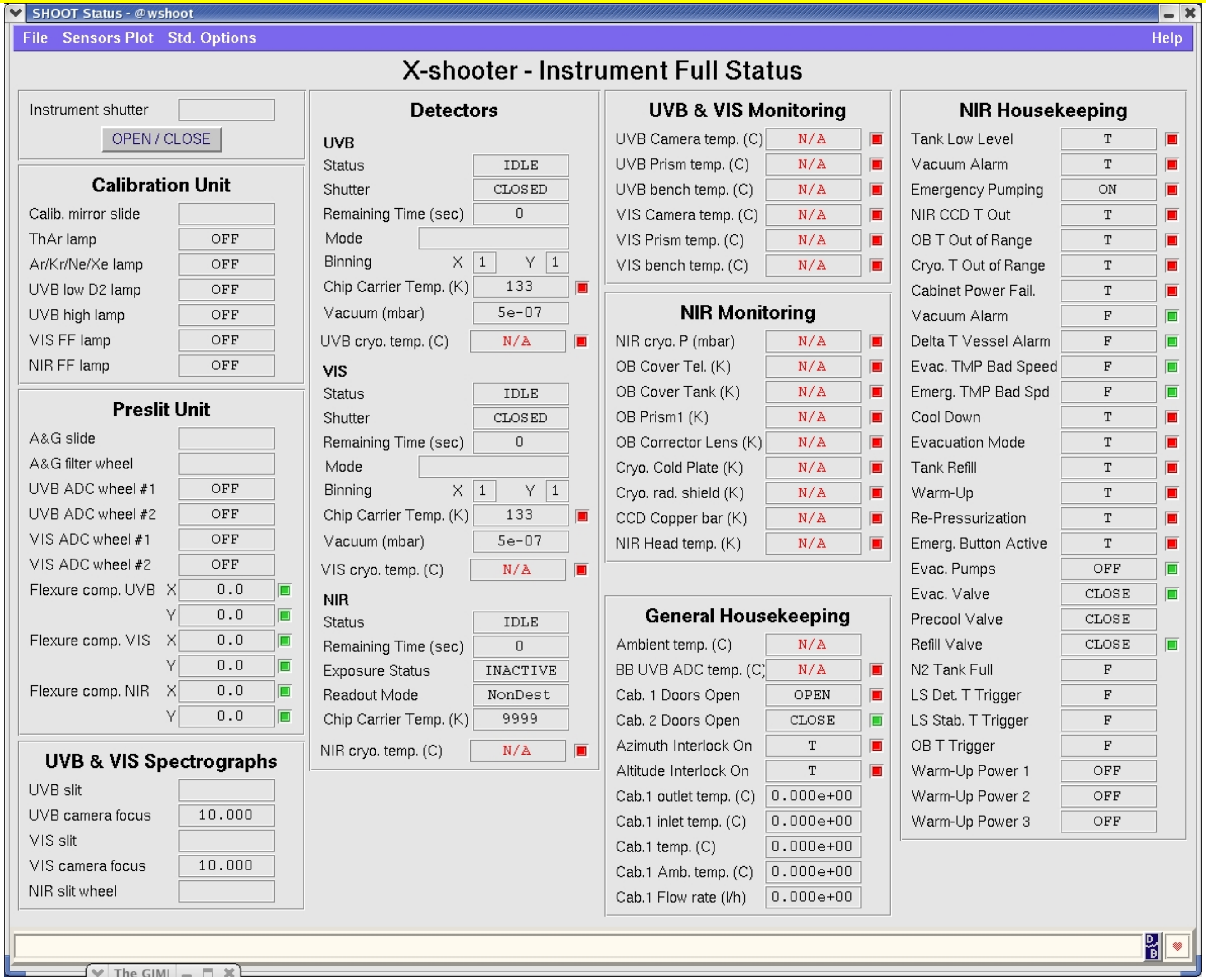
Fig.1 ICS process structure overview


SHOOT ICS Control - @wshoot
File ICS Devices LCU Maintenance Tools Std. Options Help
State: ONLINE idle Op. mode: NORMAL LCU: OK
Spectrogr. FE - Motors
Spectrogr. FE - Lamps
Spectrogr. FE - AFCS
insh ONLINE SIM 0
cals ONLINE SIM 0
aags ONLINE SIM 0
afil ONLINE SIM 0
adc1 ONLINE SIM OFF 0 OFF
adc2 ONLINE SIM OFF 2300 OFF
adc3 ONLINE SIM OFF 0 OFF
adc4 ONLINE SIM OFF 12739 OFF
UVB Spectrograph
bss ONLINE SIM 0
bfs ONLINE SIM -282.1 0 C
VIS Spectrograph
vss ONLINE SIM 0
vfs ONLINE SIM -117500 0 C
NIR Spectrograph
nss ONLINE SIM 0
TMS DIS1 DIS2 CCC1
tms ONLINE SIM
TMUC: N/A
TMUP: N/A
TMUB: N/A
TMVC: N/A
TMVP: N/A
TMVB: N/A
TMUCR: N/A
TMVCR: N/A
TMNCR: N/A
TMA: N/A
TMADC: N/A
CRYO LAKE Pfeiffer
cryo ONLINE SIM
OBCT: N/A
OBCB: N/A
OBPR: N/A
OBCL: N/A
CP: N/A
RS: N/A
DCB: N/A
OBGR: N/A
Command Feedback Window Options
SETUP STOP

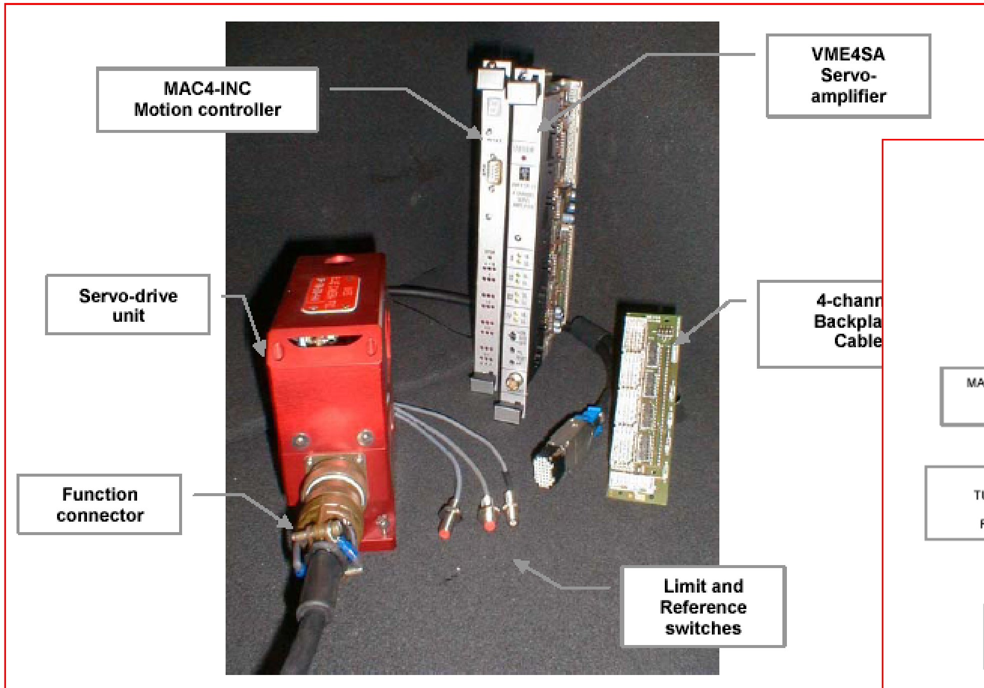
Astrophysical Technology Group

Instrument Control Software (II)

INAF-OAT



Motors/Lamps/Sensors



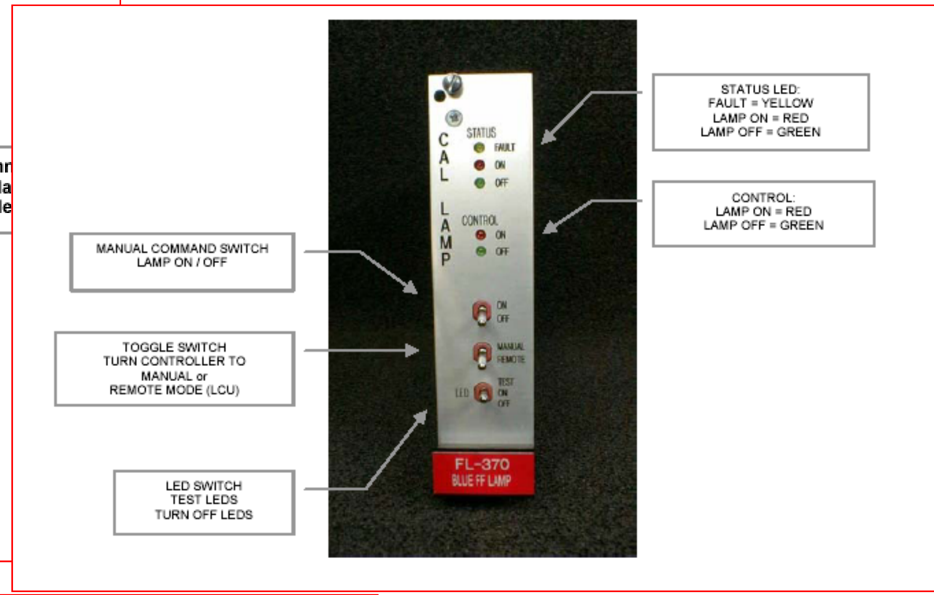


Figure 20- CFC control electronics sub-rack

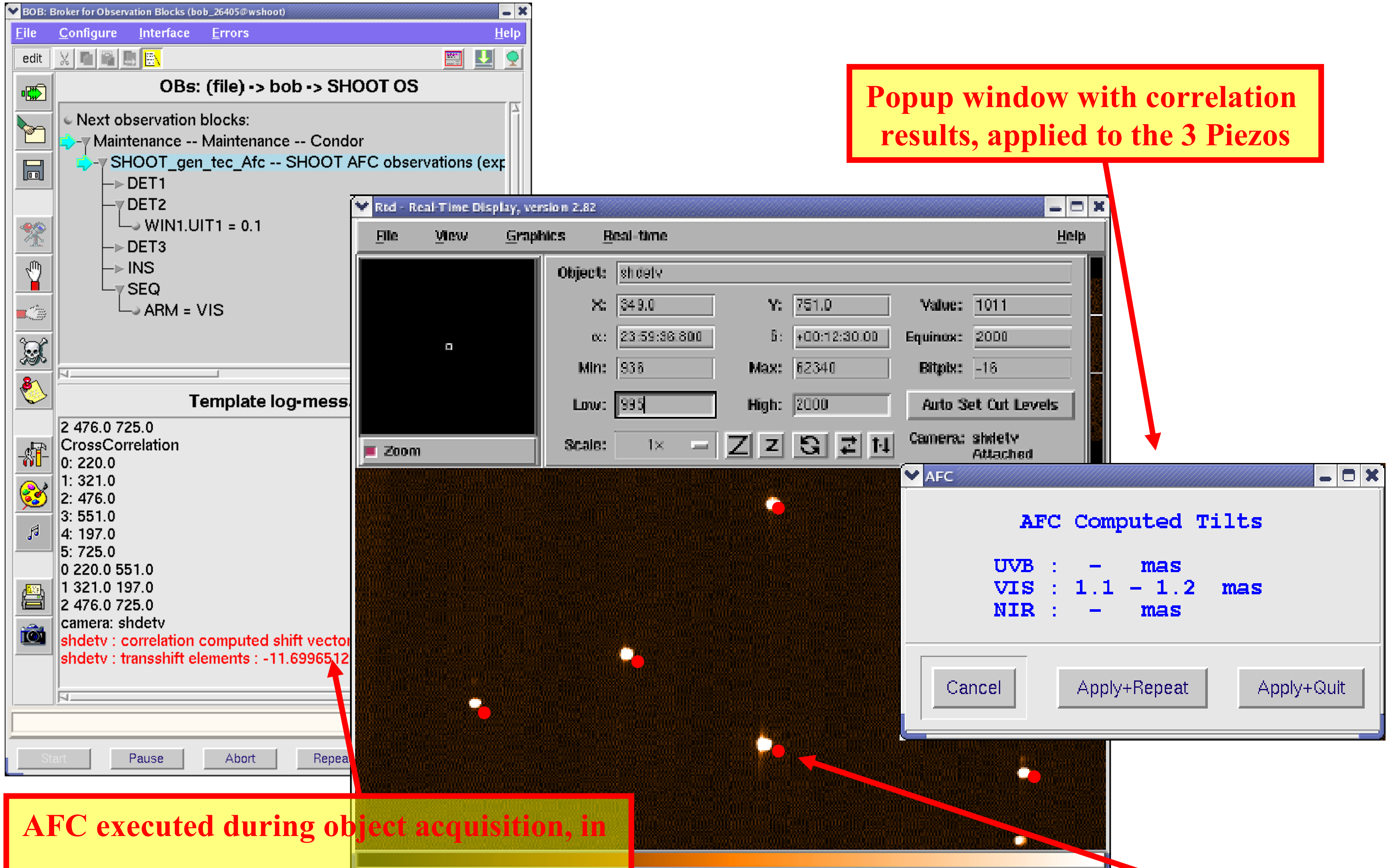
Local Control Unit (LCU)


Xenon
Argon
Krypton
Neon
ThAr
Deuterium


SIEMENS
Cryostat Overview
NIR Cryostat
Heaters
CCD Sensors
UVB
VIS
LN2 Tank
Operation Mode
Warm Mode
Cool Down
Cold Mode
Warm Up
Functions
Evacuate
Absor Pump
Emerg Pump
MAN
NIR
LN2 Refill
Pre-Cool
Warm Up
Repressure
Emergency Pumping not in AUTO Mode
Main Menu
Alarm Display
Operation Mode
Cryostat Overview
Interlocks Conditions

Active Flexure Compensation

Popup window with correlation results, applied to the 3 Piezos



AFC executed during object acquisition, in parallel with telescope Active Optics, (but generally faster)

Correlation of two arc spectra taken with a pinhole in spectrograph and one in Cass focal plane

Why AFC?

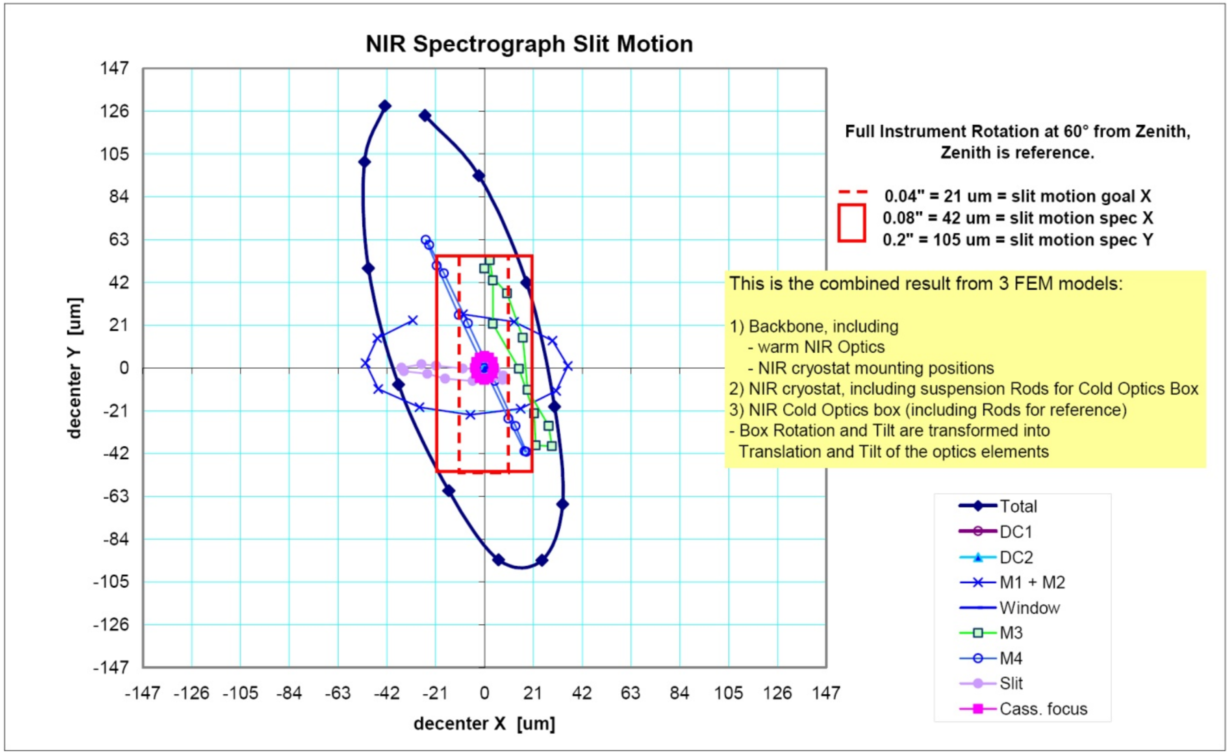
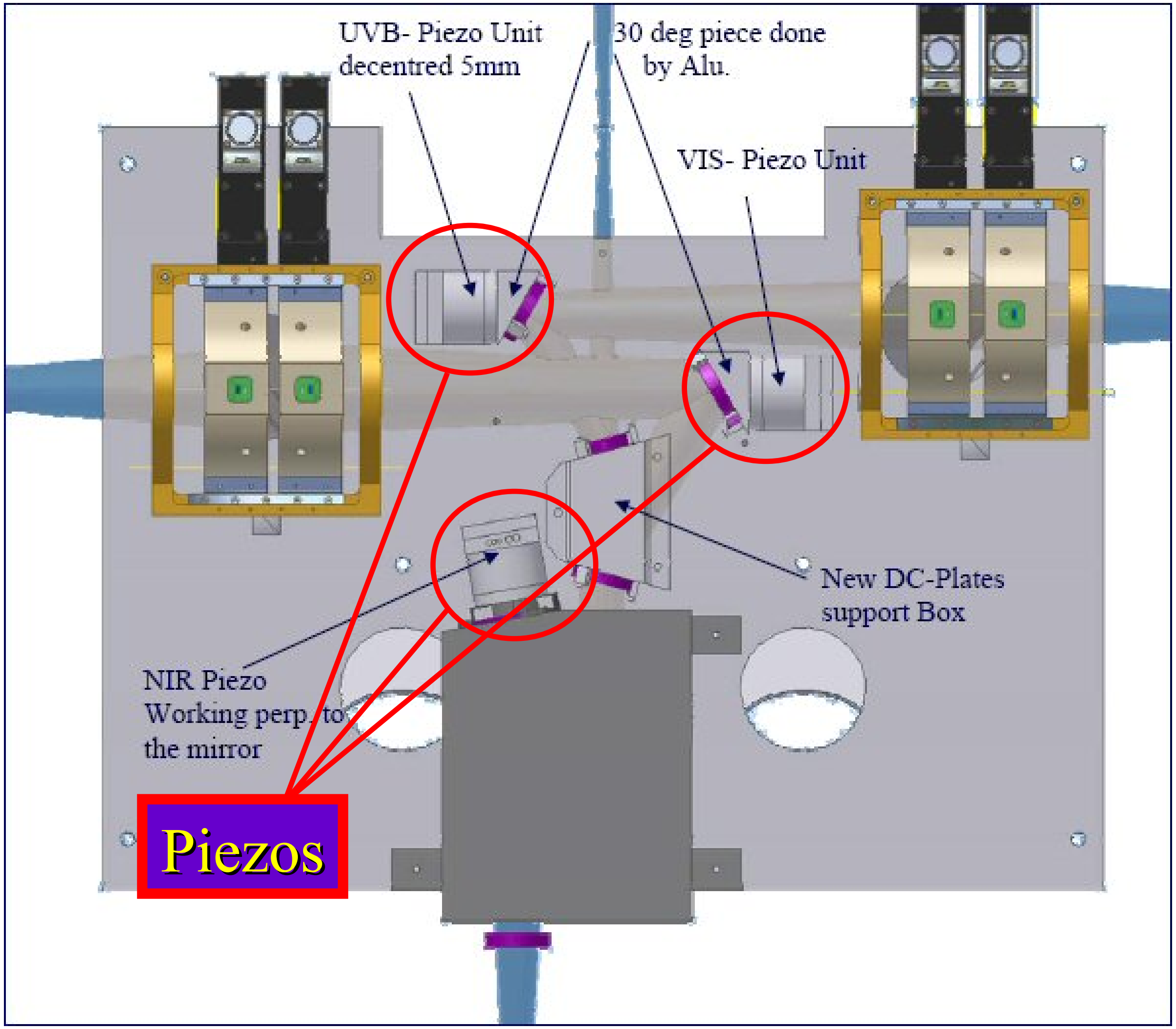
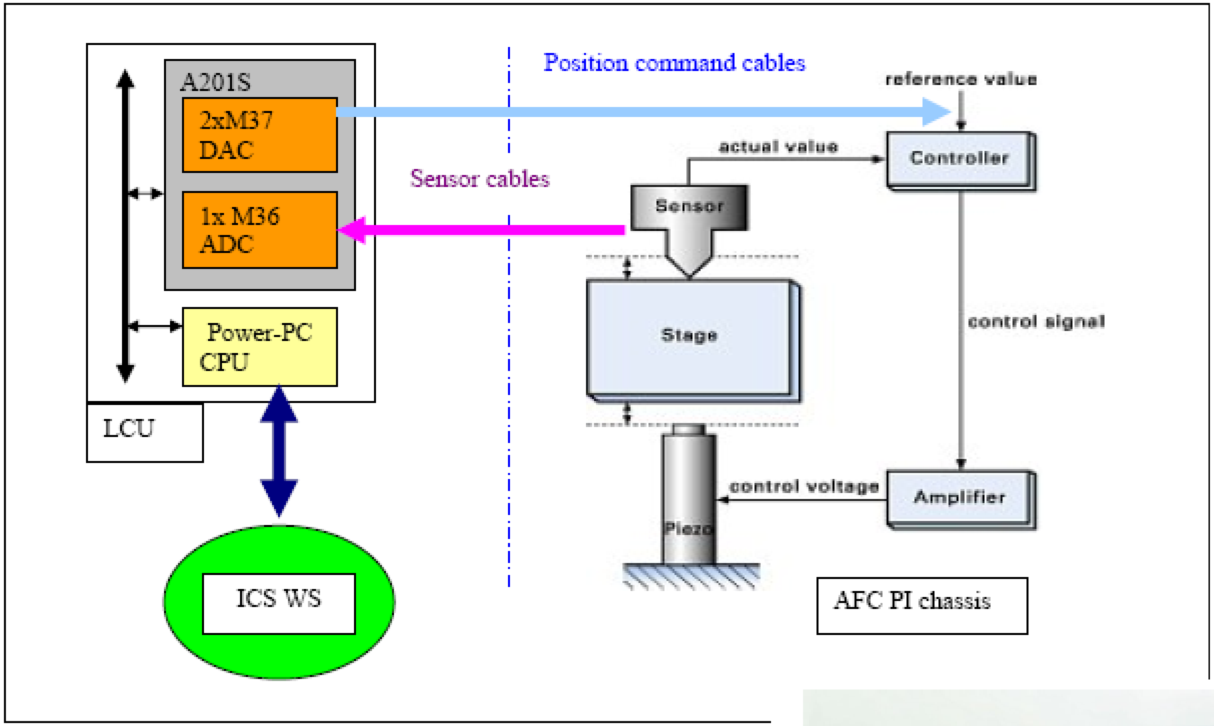


Figure 58 NIR Spectrograph Slit Motion in the NIR slit plane. Combined Result from the 3 FEM analyses. From Zenith as zero position the maximum NIR slit motion is --52 µm in X direction and +131 µm in Y direction. This is just out of specification.

AFC mechanics



AFC electronics



AFC software

- PARK – apply a fixed value corresponding to the middle position;
- STAT – maintain the current position;
- REF – moves the tables in a fixed position required for the alignment of the system witho is in zenith position);
- AUTO – activates the monitoring task whic the corrections. The corrections are calculated telescope/instrument position.
- INS.TILTi.AXISX – send a given correction
- INS.TILTi.AXISY – send a given correction

At sea level ($P = 760$ mm Hg, $T = 15°$C) the refractive index of dry air is given by (Edlén 1953; Coleman, Bozman, and Meggers 1960)

$$(n(\lambda)_{15,760} - 1)10^6 = 64.328 + \frac{29498.1}{146 - (1/\lambda)^2} + \frac{255.4}{41 - (1/\lambda)^2} \quad , \qquad (1)$$

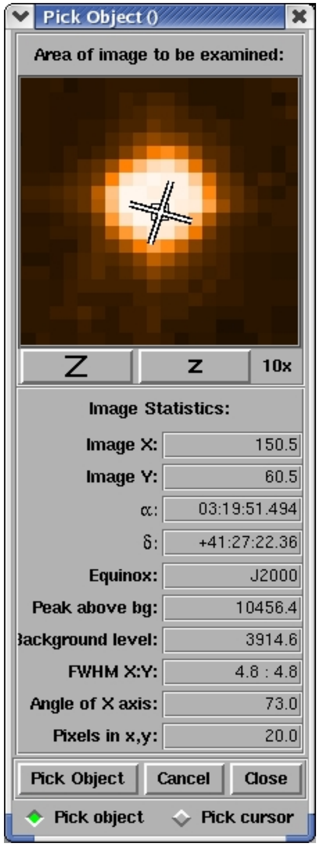
where λ is the wavelength of light in vacuo (microns). Since observatories are usually located at high altitudes, the index of refraction must be corrected for the lower ambient temperature and pressure (Barrell 1951):

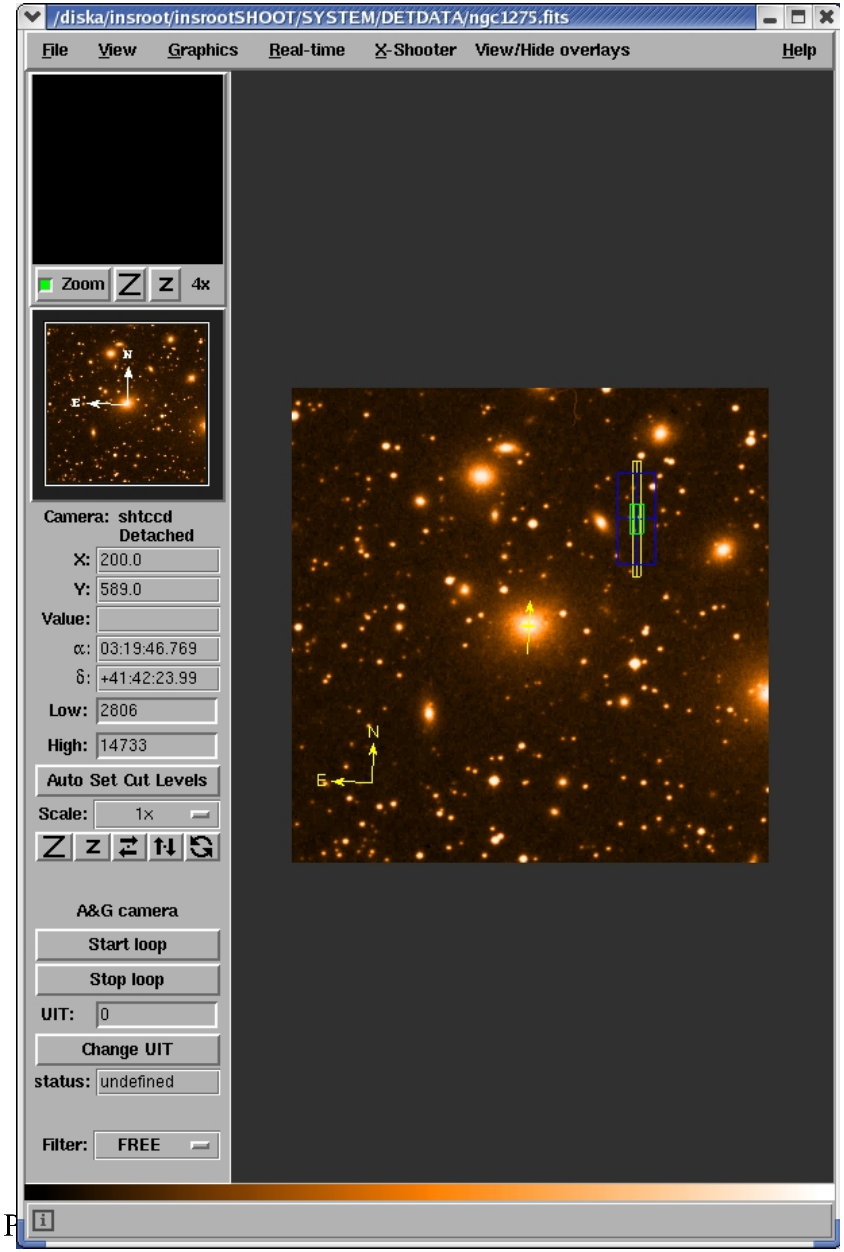
$$(n(\lambda)_{T,P} - 1) = (n(\lambda)_{15,760} - 1) \times \frac{P\,[1 + (1.049 - 0.0157\,T)10^{-6}P]}{720.883(1 + 0.003661\,T)} \quad . \qquad (2)$$

In addition, the presence of water vapor in the atmosphere reduces $(n - 1)10^6$ by

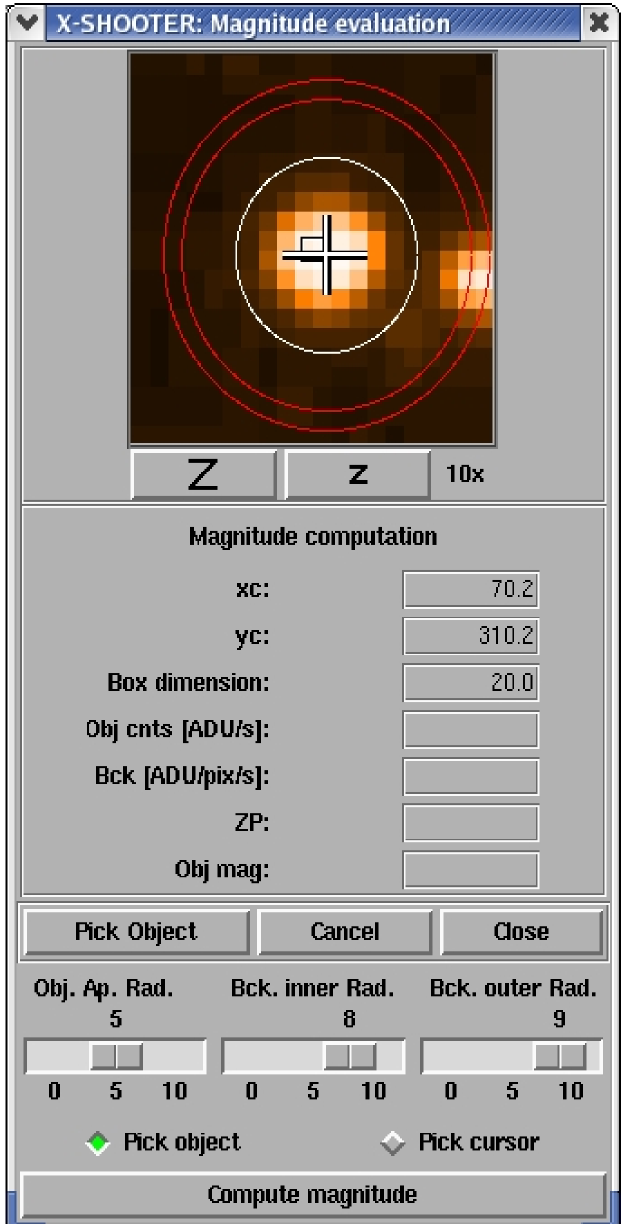
$$\frac{0.0624 - 0.000680/\lambda^2}{1 + 0.003661T}\,f \quad , \qquad (3)$$

Object Acquisition



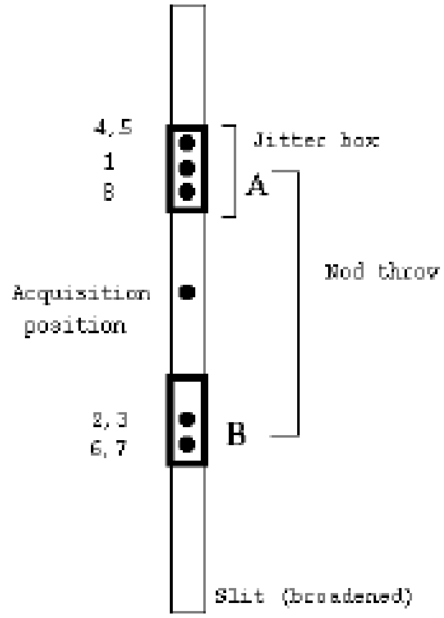


Magnitude evaluation



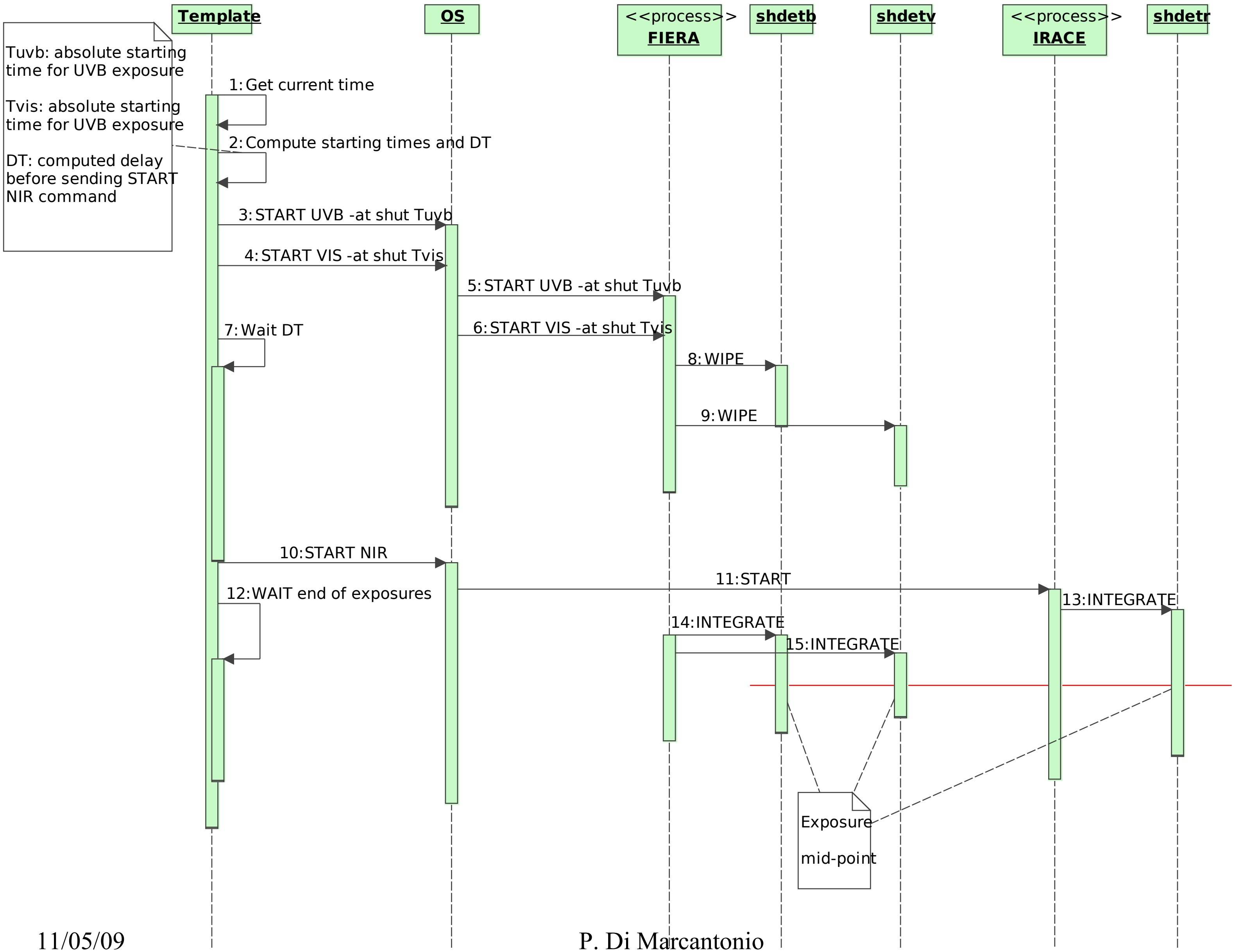
Allowed spectroscopic observations

- staring – each arm at a fixed position on sky;
- staring synchronized – exposures synchronized at their mid-time;
- nodding;

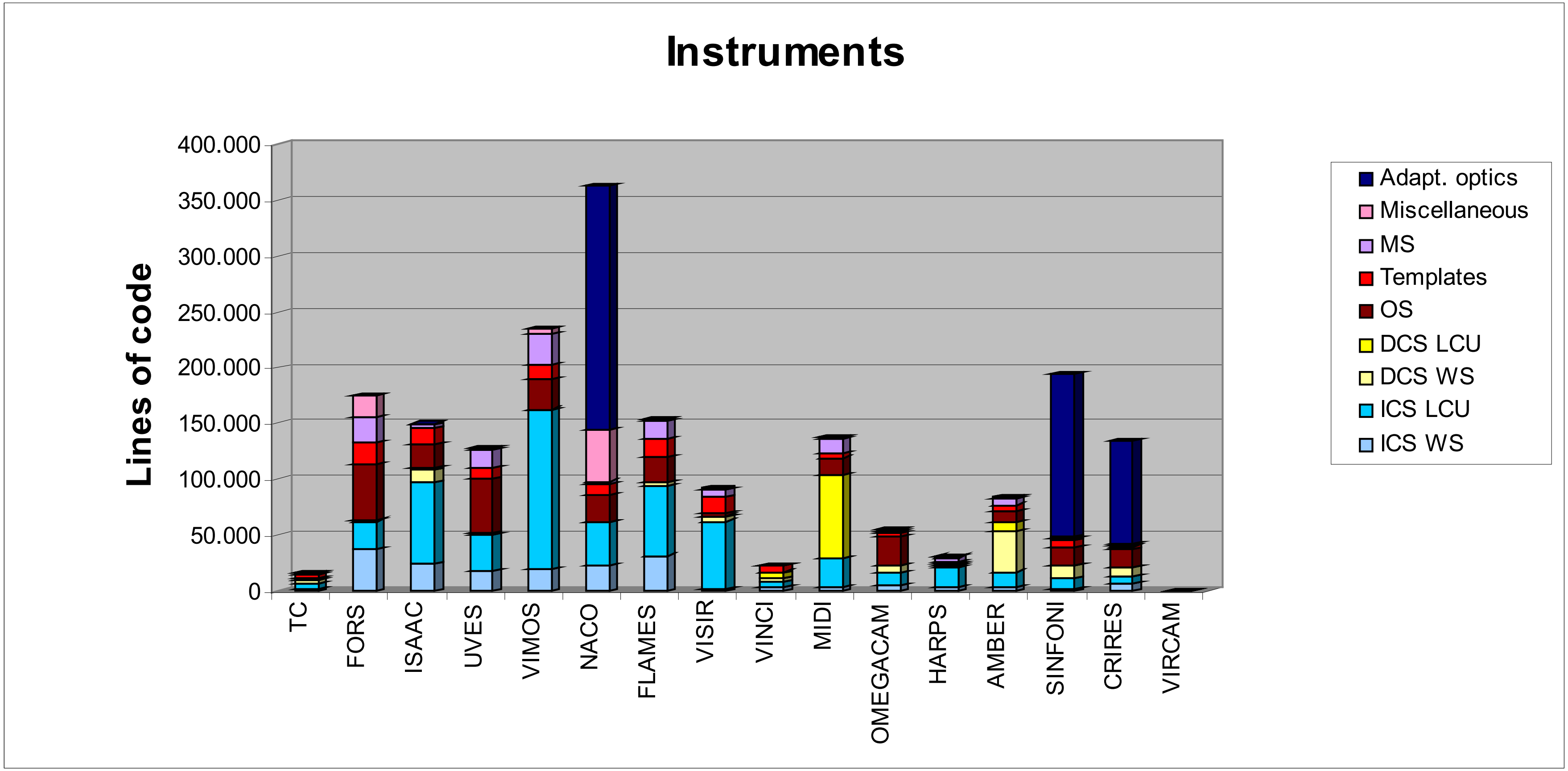


- fixed offset;
- generic offset;

Synchronized exposures



Sw complexity



Commissioning runs

Some results from the three commissioning periods:

- nov 2008 and jan 2008- integration/installation of the UVB and VIS spectrograph with a dummy NIR;

Cited from a report sent to STC:

*"… a total of **17 nights**, **no losses due to technical problems or weather**. The overall efficiency and mechanical flexure are in spec. The hardware, software and operational interfaces with the telescope environment (A&G procedures, OBs, flexure compensation system, ADCs, IFU…) all work as expected in line with the desired **"point and shoot"** objectives for this instrument."*

- march 2009 – first light with the full instrument:

Excerpt from a report sent to STC:***March 14***

*"… first light was achieved quite smoothly on. Commissioning continued until the morning of March 20 (**6 nights**, of which 0.75 lost due to VLT SW problems not directly related to the instrument and 1.75 due to weather). There were no significant losses due to problems with specific instrument hard- or software. NIR spectral resolution as a function of slit width was verified and found in agreement with predictions. Nodding and sky offset modes mostly used for the on sky observations. On faint targets, integration times of up to 25 minutes were used, also in the NIR. Classical A – B nodding was tested and works very well in the UVB and VIS arms."*

Expected Efficiency

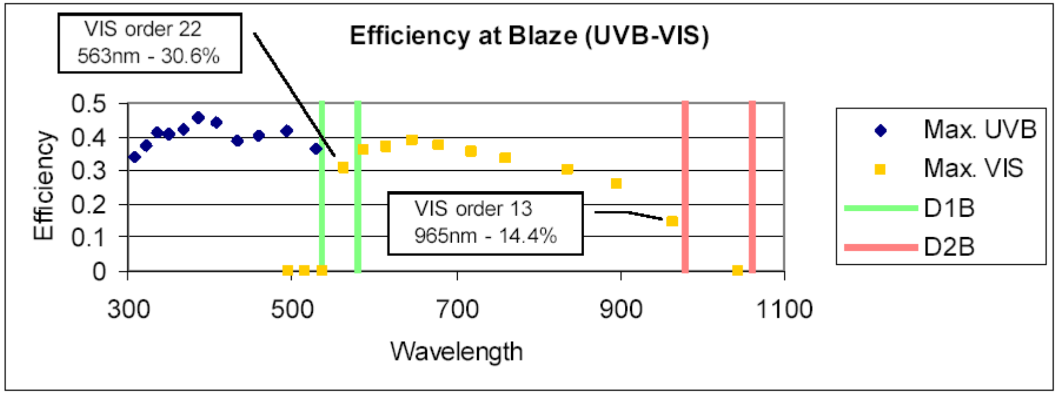


Figure 35: Expected efficiency at blaze wavelengths in UVB and VIS arms.

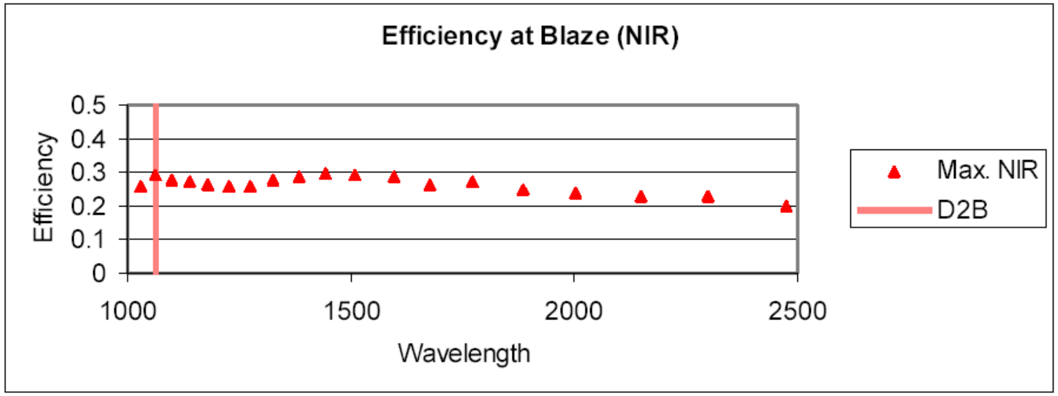


Figure 36: Expected efficiency at blaze wavelengths in NIR arm.

Spec:

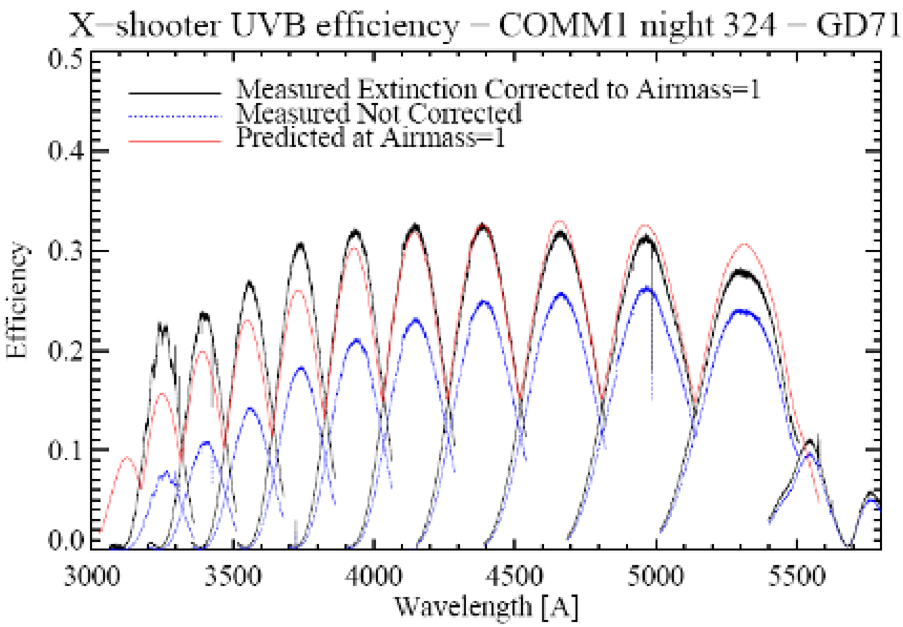
> 25% avg @ blaze 320 – 1800 nm. Goal 30%

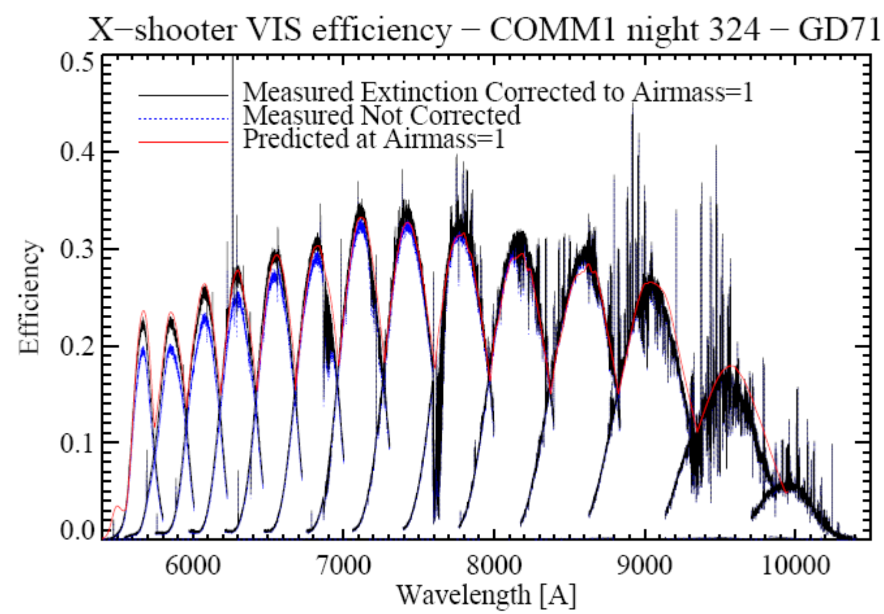
> 10% min in FSR 300 – 1900 nm. Goal: 10%

Wavelength coverage:

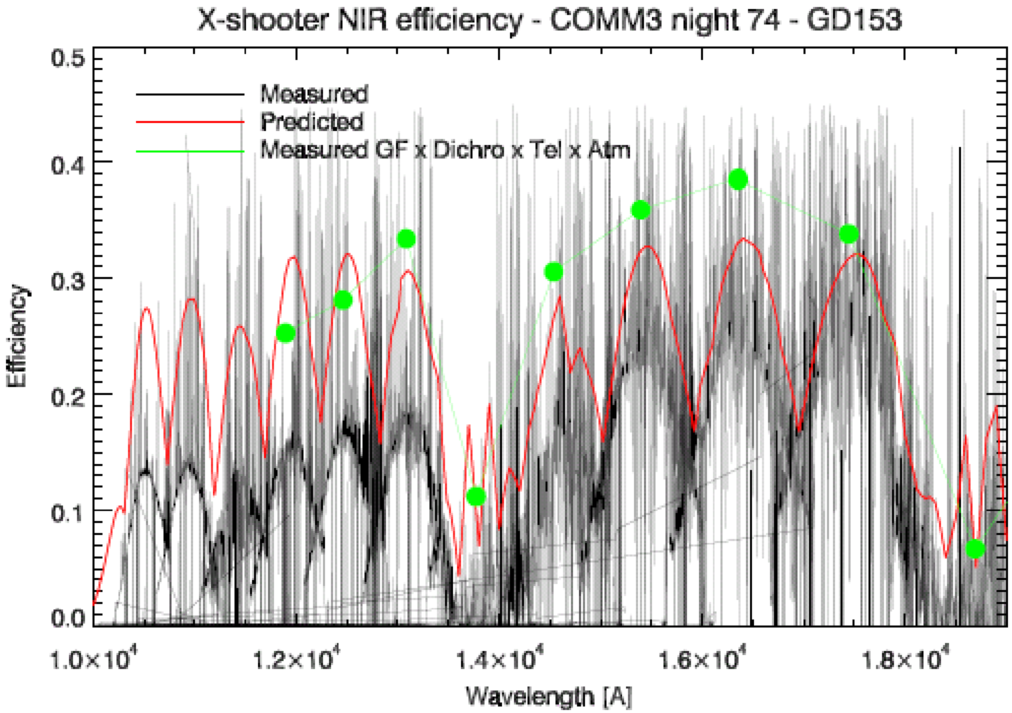
> 95% 300-1800 nm; less than 60 nm lost in dichroic crossover ranges

Measured Efficiency UVB/VIS



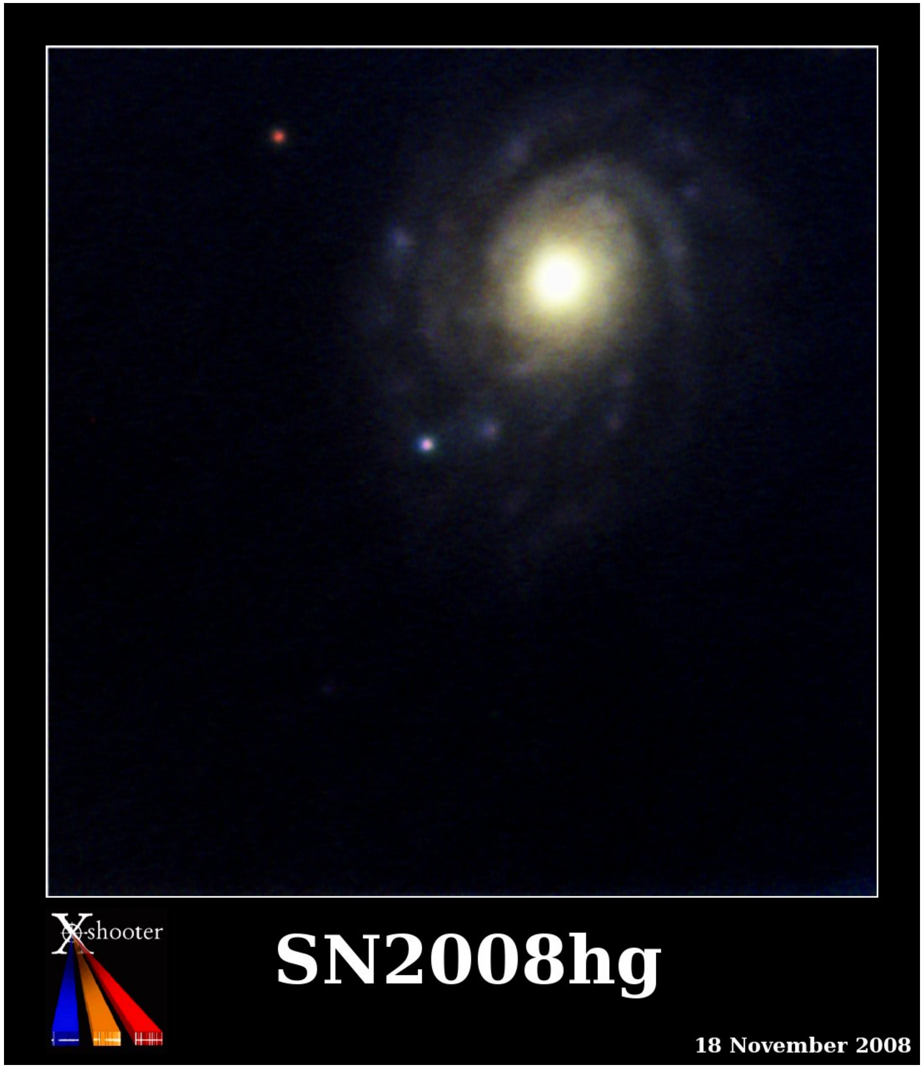


Measured Efficiency NIR

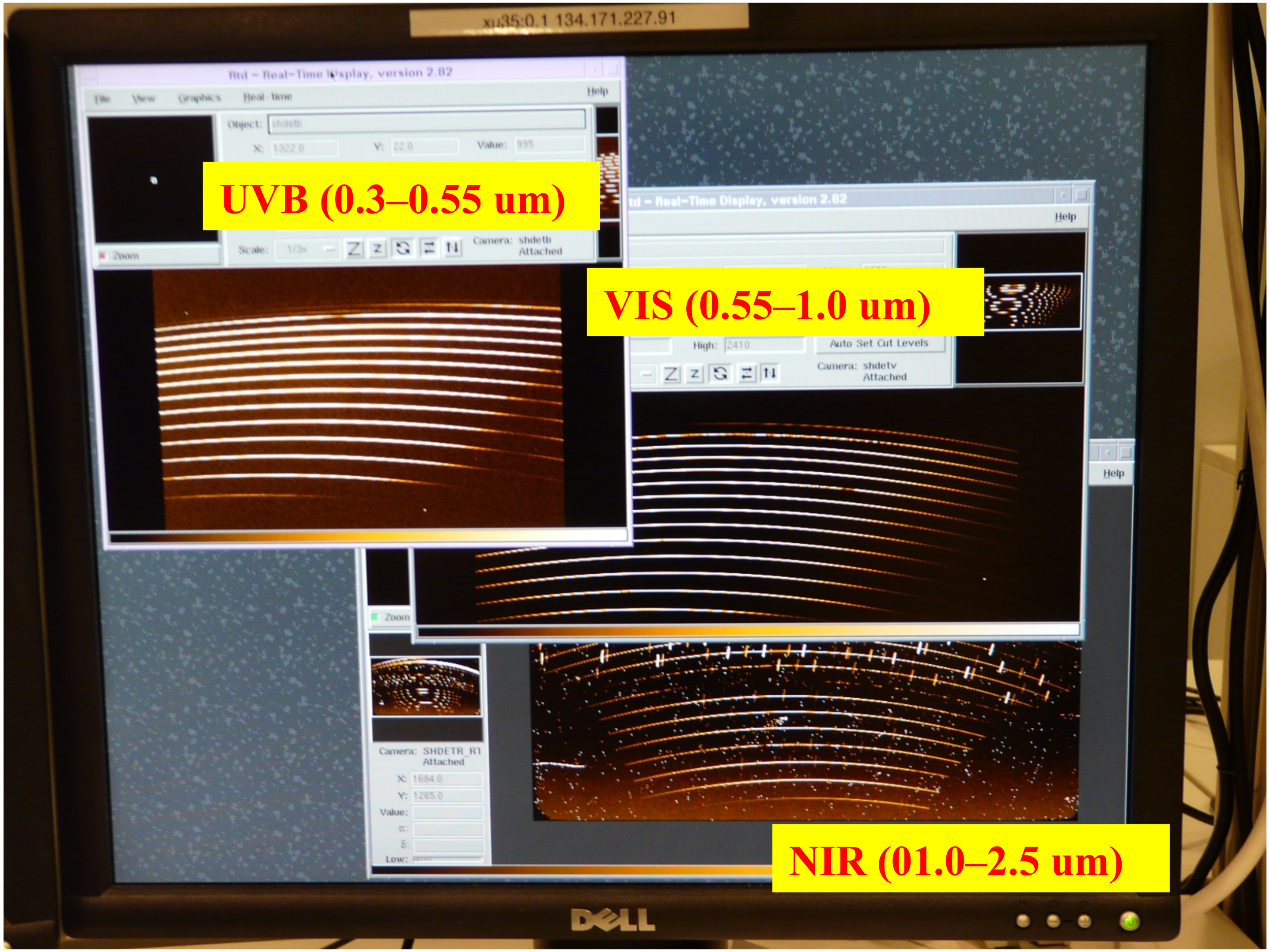


Reduction of the observations of standard stars shows a peak blaze efficiency in U – H band which exceeds or is equal to predictions, except in J band. K band is still being analyzed.

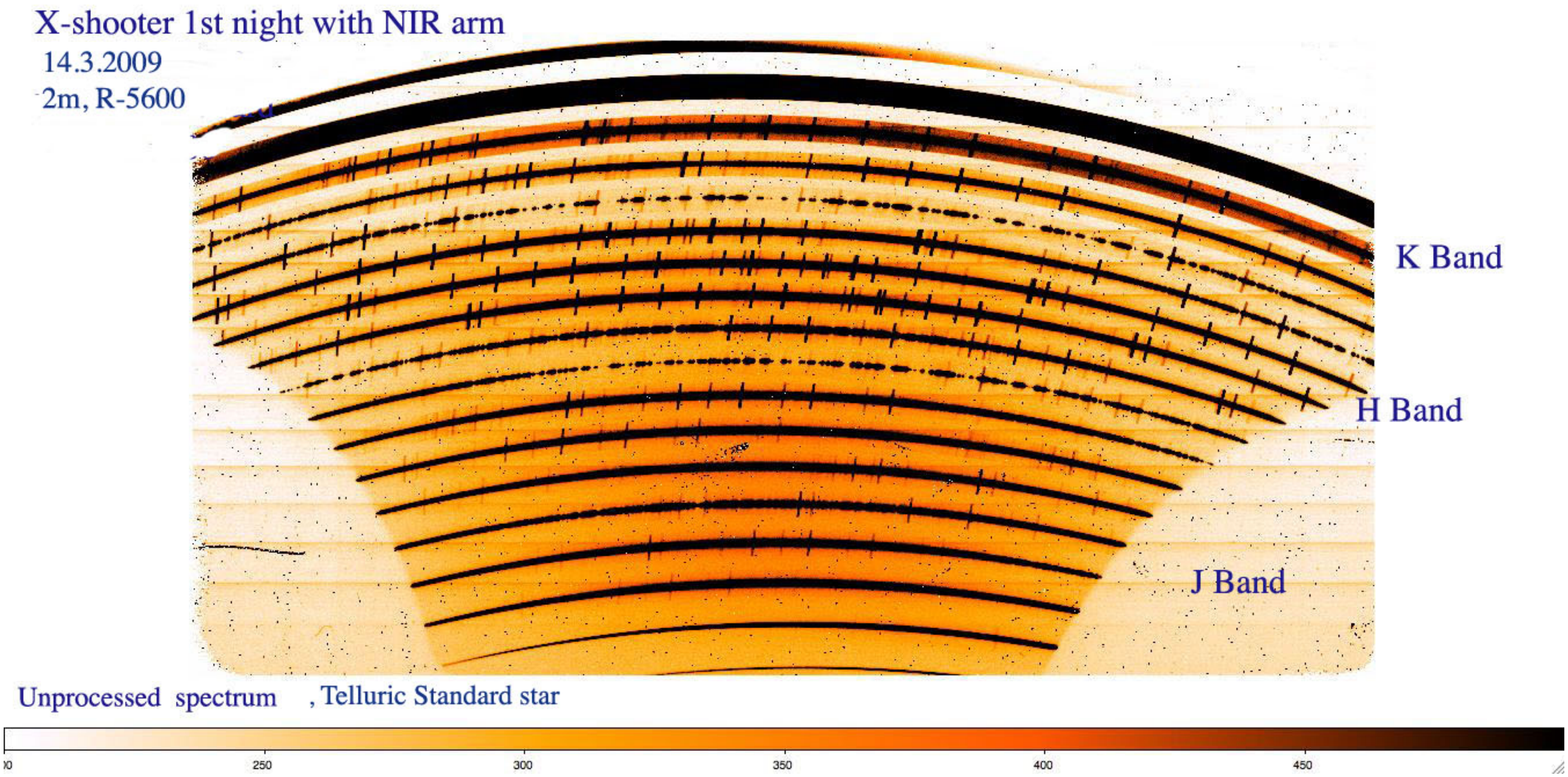
SN2008hg



First light 14/03/09 23:22 standard star, 10s

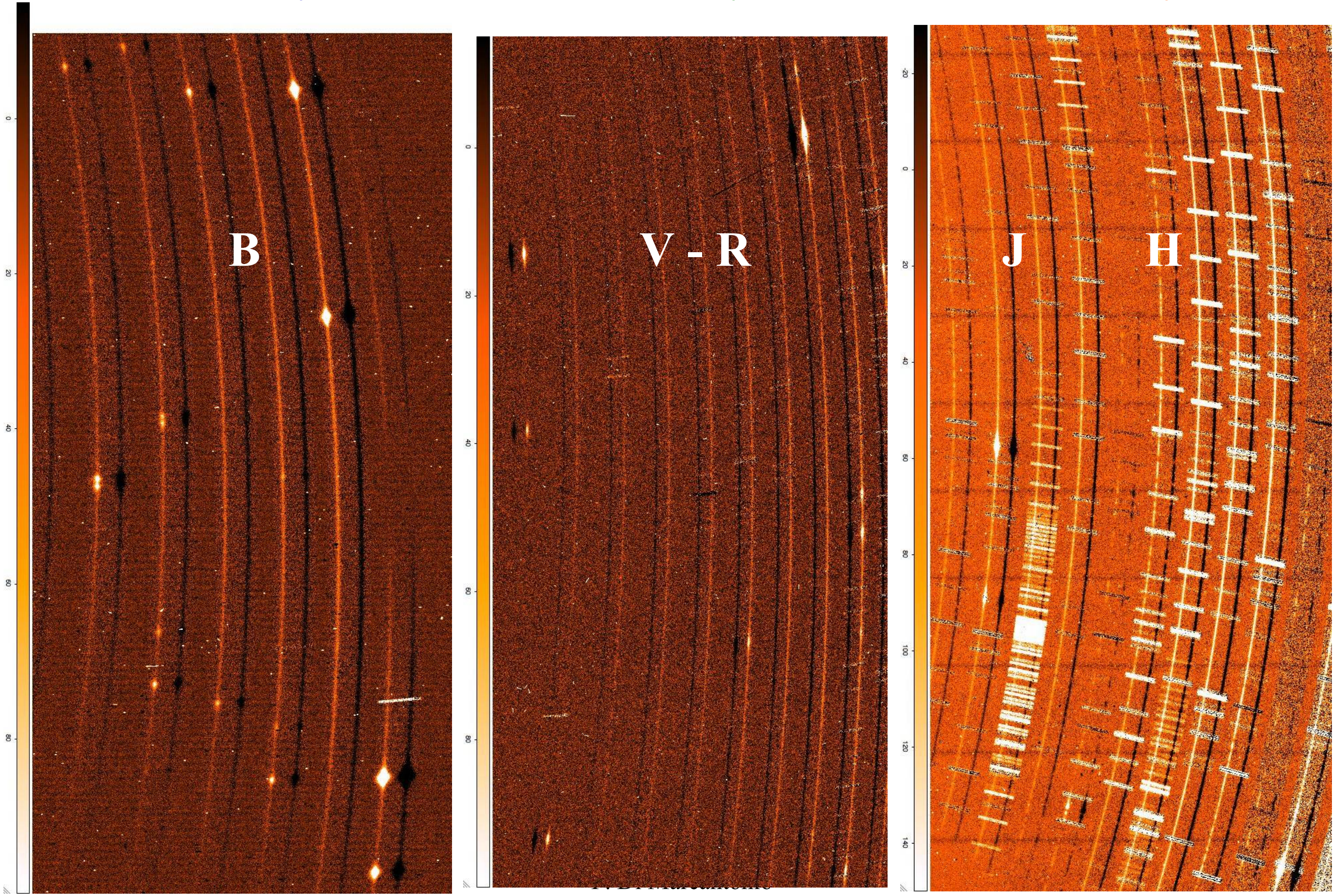


NIR arm J, H, K

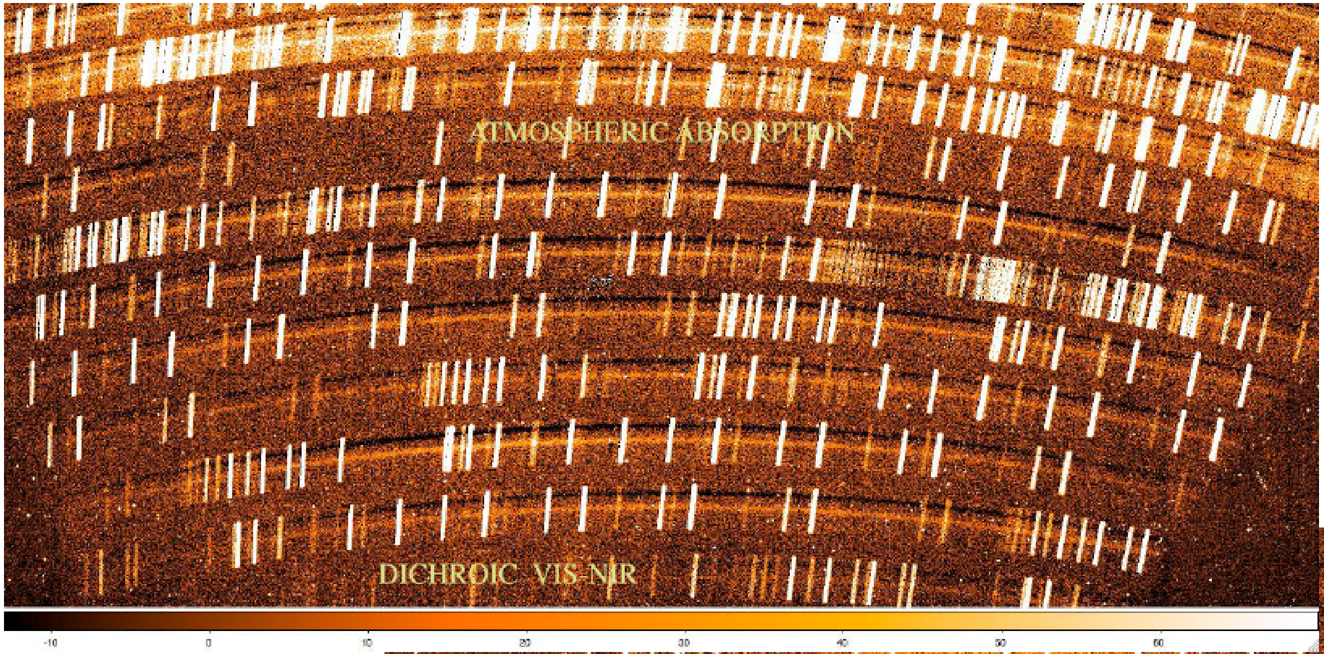

X-shooter 1st night with NIR arm
14.3.2009
2m, R-5600
K Band
H Band
J Band
Unprocessed spectrum , Telluric Standard star
250
300
350
400
450

4x1200s exp. GRB host, starburst , emission line galaxy at z=0.105, r=20.5, K=16.6

UVB: 320-559nm, R= 5100 VIS:560-1040nm, R=8800 NIR: 1040-2300, R=5600



Observations of faint targets: a QSO at z=6 (2x30m, subtracted one from the other)

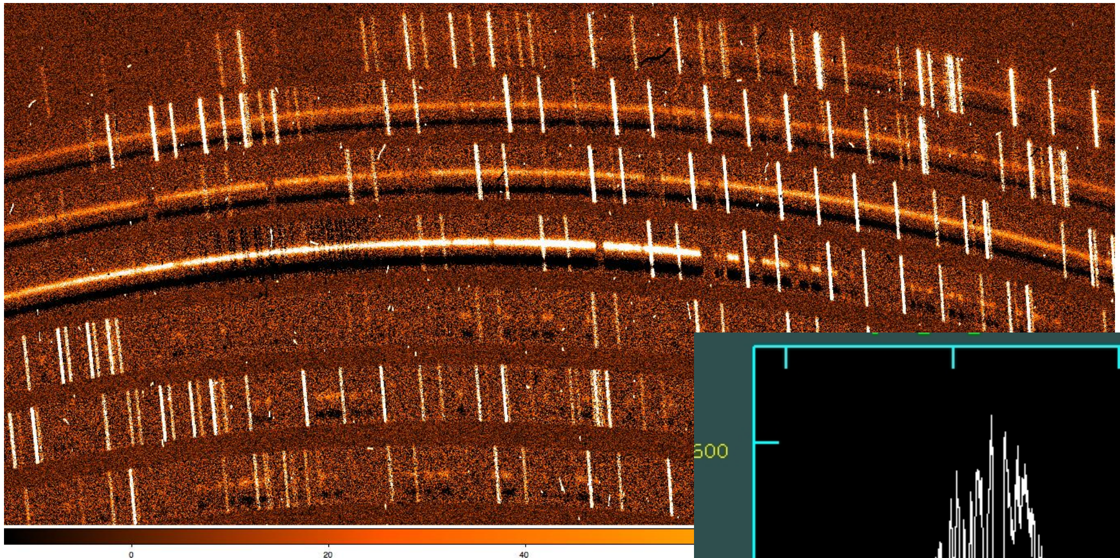


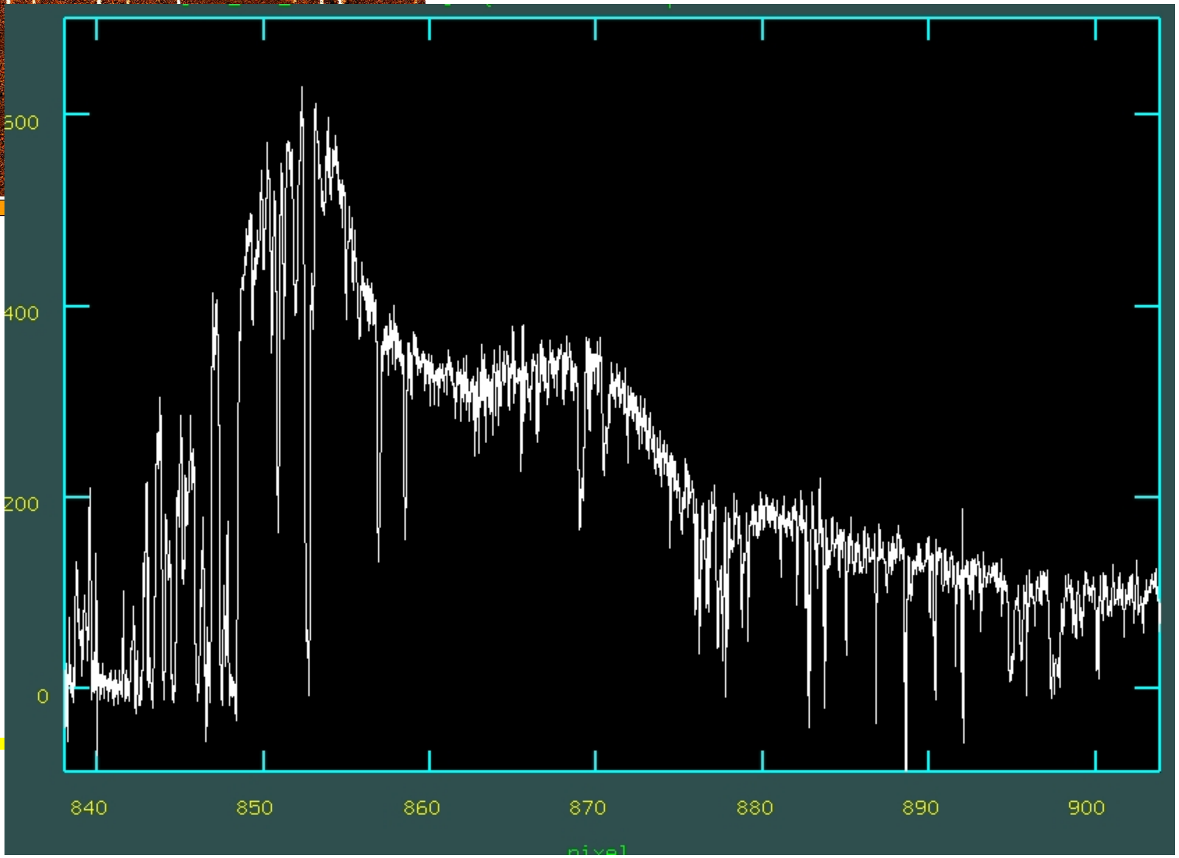
H and J Bands,
R= 5900

N.B. Residual sky due to intensity variations in the night

VIS-RED above 700nm,
R= 8800

QSO at z=6.016





VIS-R above 700nm,

R= 8800