Overview of the VLTs optical instruments

By C.CAVADORE

Instrumentation division - Optical Detector Team

European Southern Observatory

ccavador@eso.org

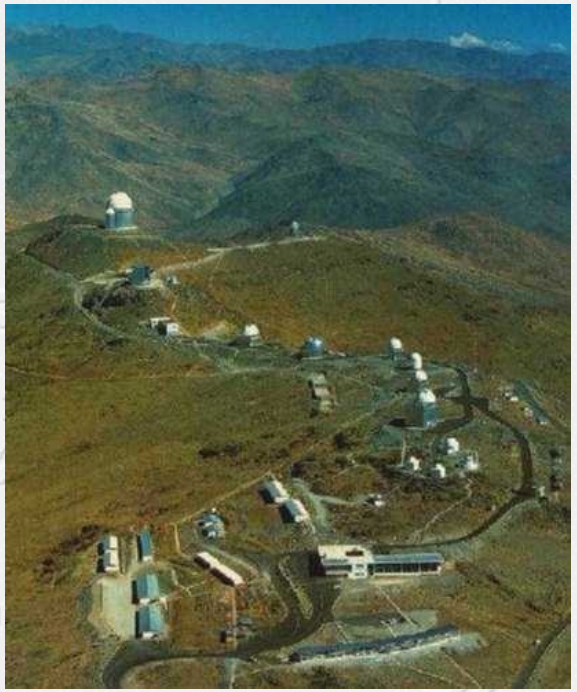
www.eso.org

• ESO founded in 1962, 481 people, 10(+2) countries
• Goal : to provide observation facilities in Southern hemisphere.

ESO in Chile

2 observatories :

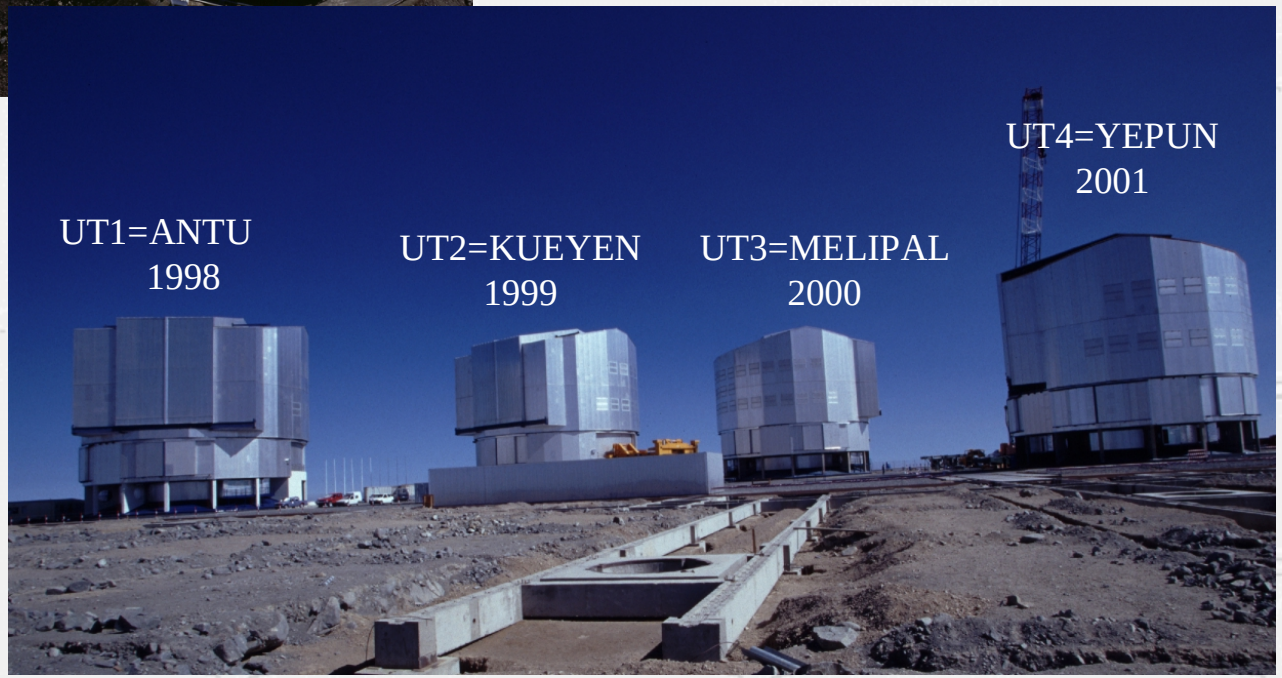
- La Silla (14 telescopes)



- Paranal (4 telescopes)

PARANAL Observatory

- 8 years of site testing (83-91)
- Altitude : 2640 m
- 5-10% humidity, rain /year 70mm
- Photometric nights : 77%
- seeing <0.66 ’’ ⇨ 50% probability



Atacama Desert,
north Chile

VLTs Telescopes

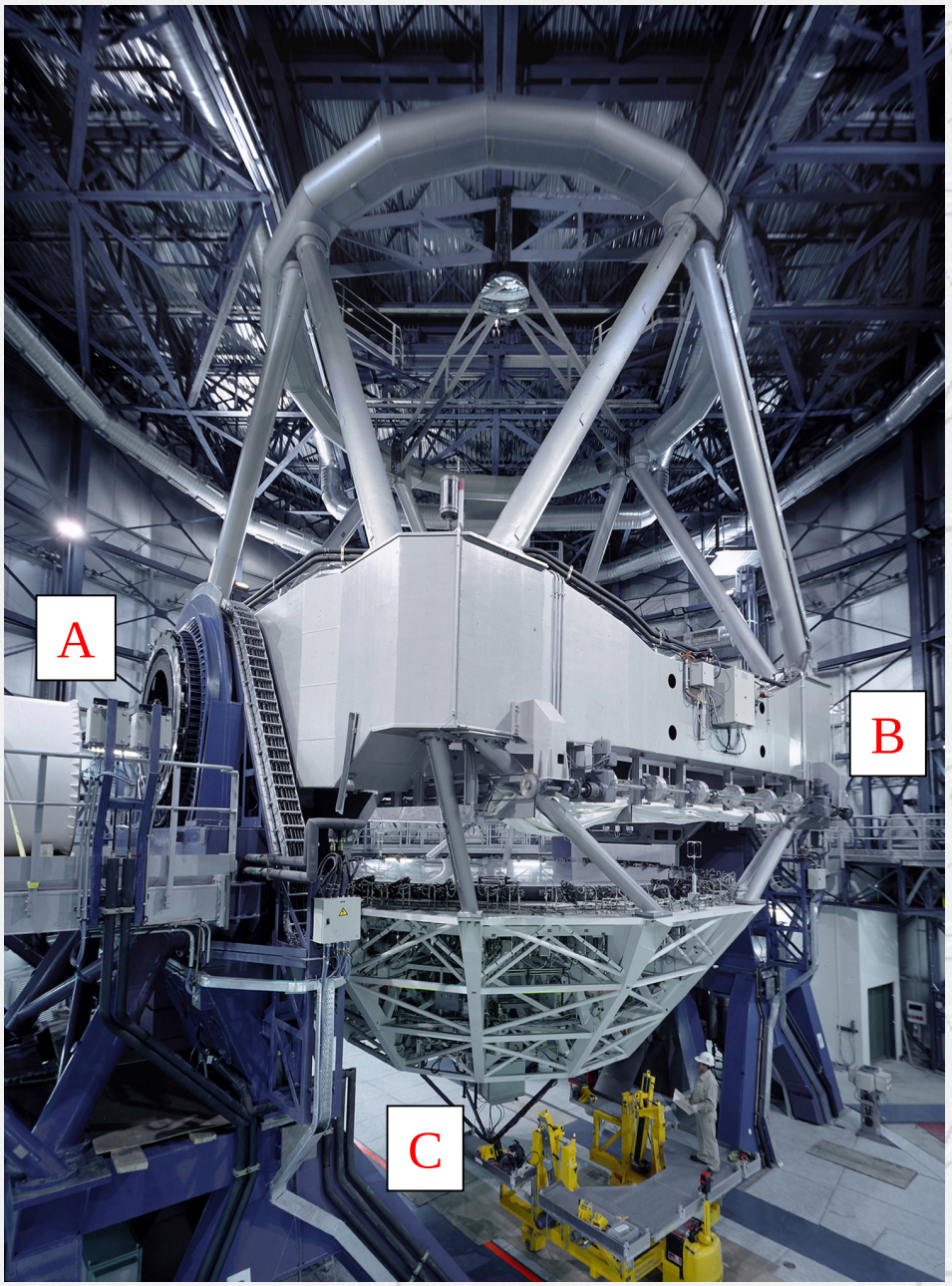
- Diameter : 8.2 m f1.8

- Type : Alt-Az.430 tons of mobile parts.

- Optic : M1-M2 active
  - 3 Focal planes
    - 1 cassegrain, 108m f/13
    - 2 Nasmyth, 120m f/15
  - 1 coudé (VLTI) 378m f/47

- 3 instruments per UT

- λ : 0.3 µm to 25µm



M1 Active optics

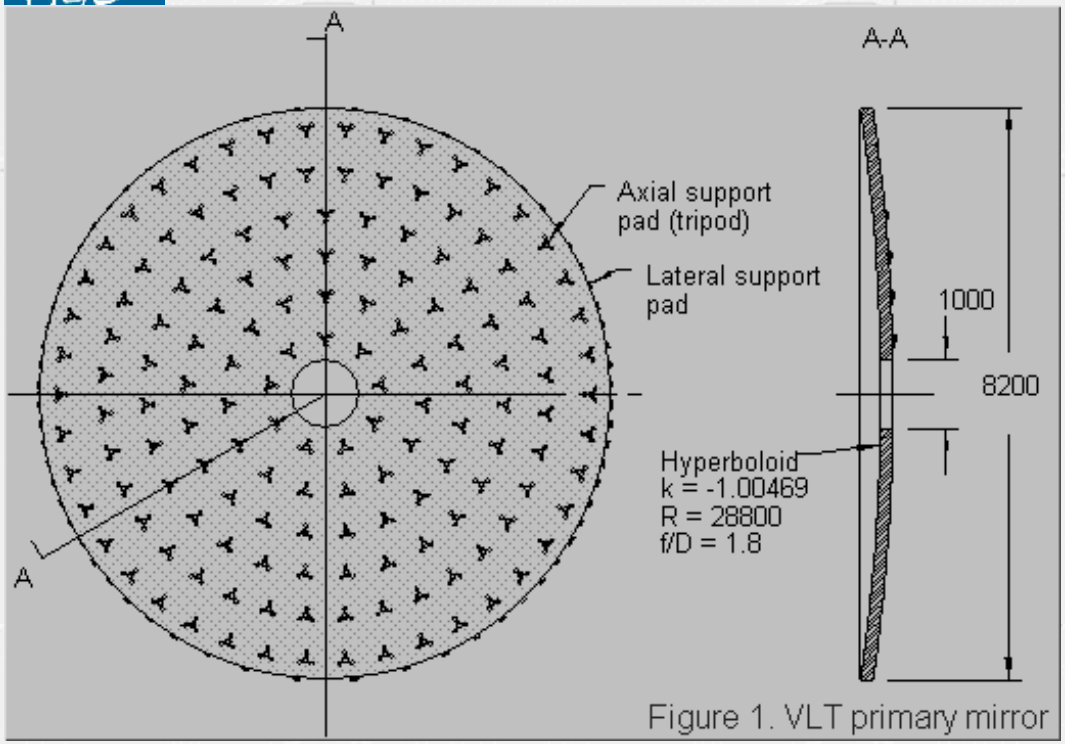


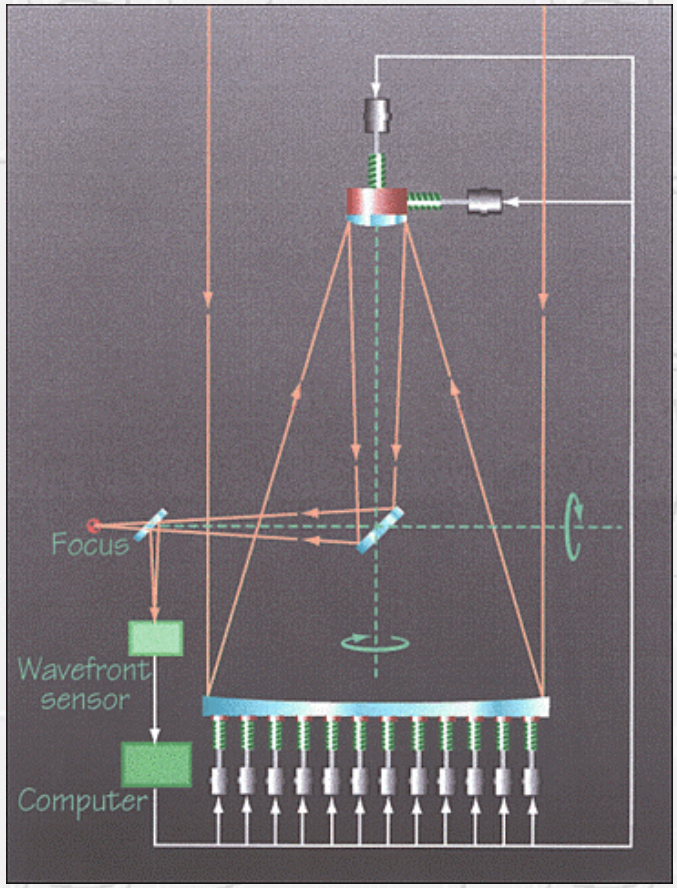
Figure 1. VLT primary mirror

M1 :

- Thickness 175 mm
- 150 actuators 800N/act.
- 23 tons, 53m²
- ACTIVE M1 Cell

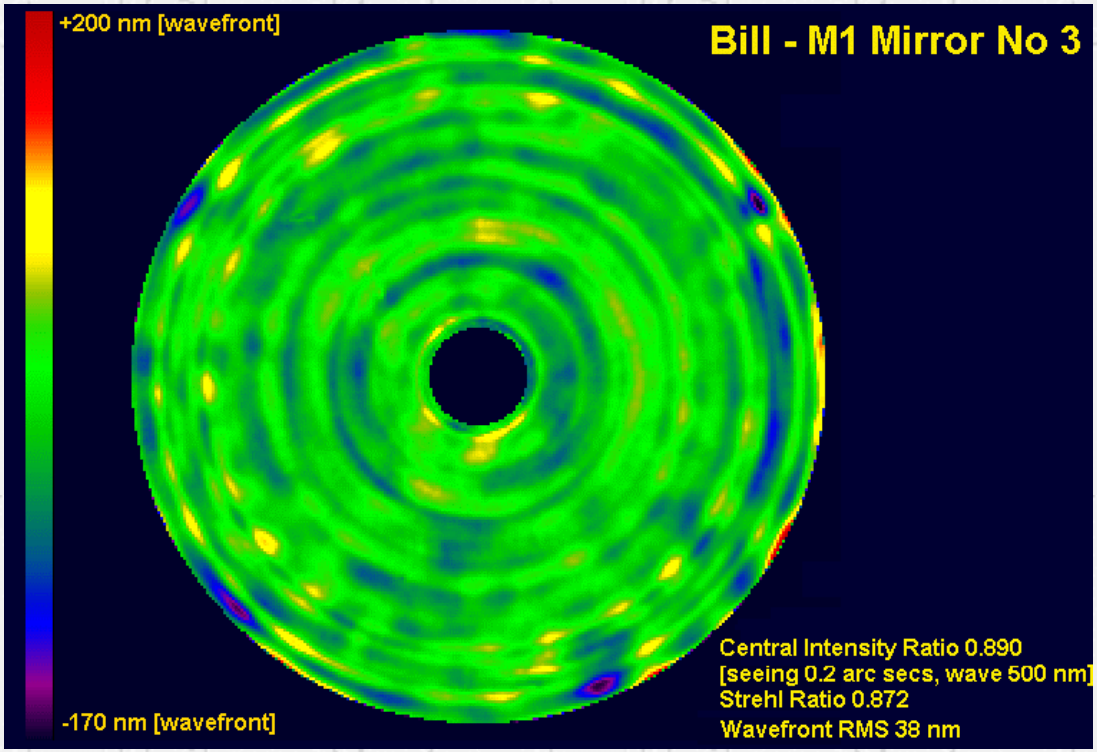
M2 :

- Beryllium (metal), 1.12m, 43kg
- Active Support (wind & vibrations)



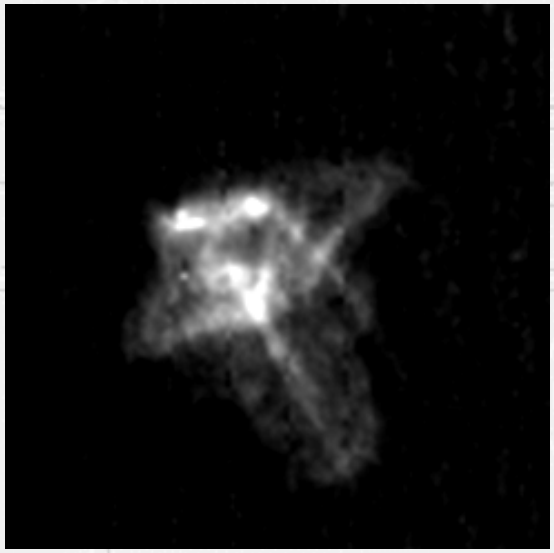
No images can be achieved without active optics !

Optical performances

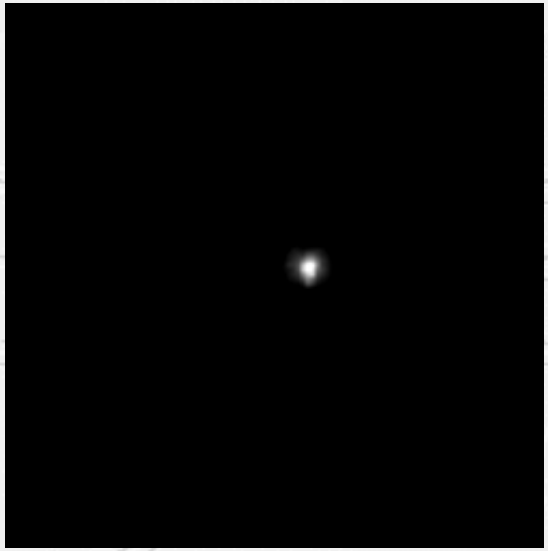


- Made by REOSC (France)
- Accuracy : Lambda/10 rms

Goal : Star < 0.20 arcsec, seeing limited



No active optics



With active optics

Some figures about UTs performances ….

- Slewing time : less than 3min.

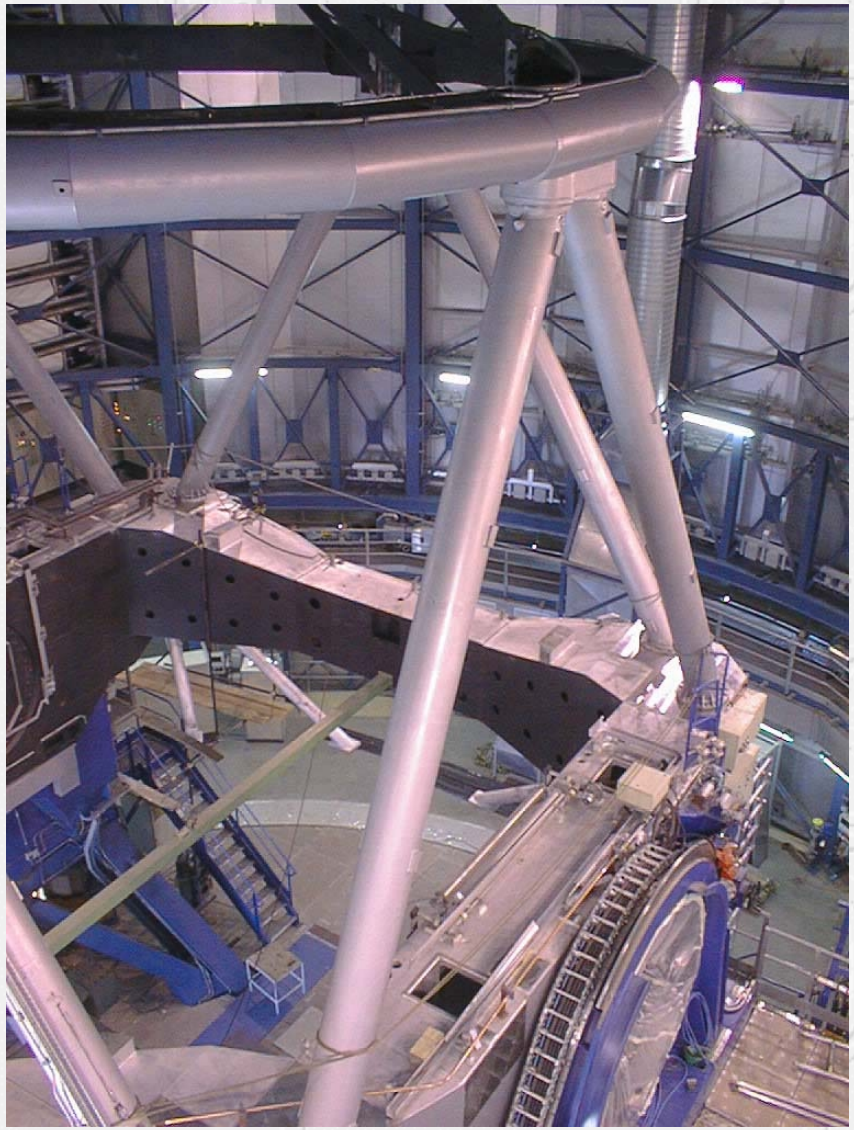
- Down to 30° without obstruction by others UTs

- Pointing accuracy 1 arcsec rms
- Tracking < 0.05arcsec 1h exposure

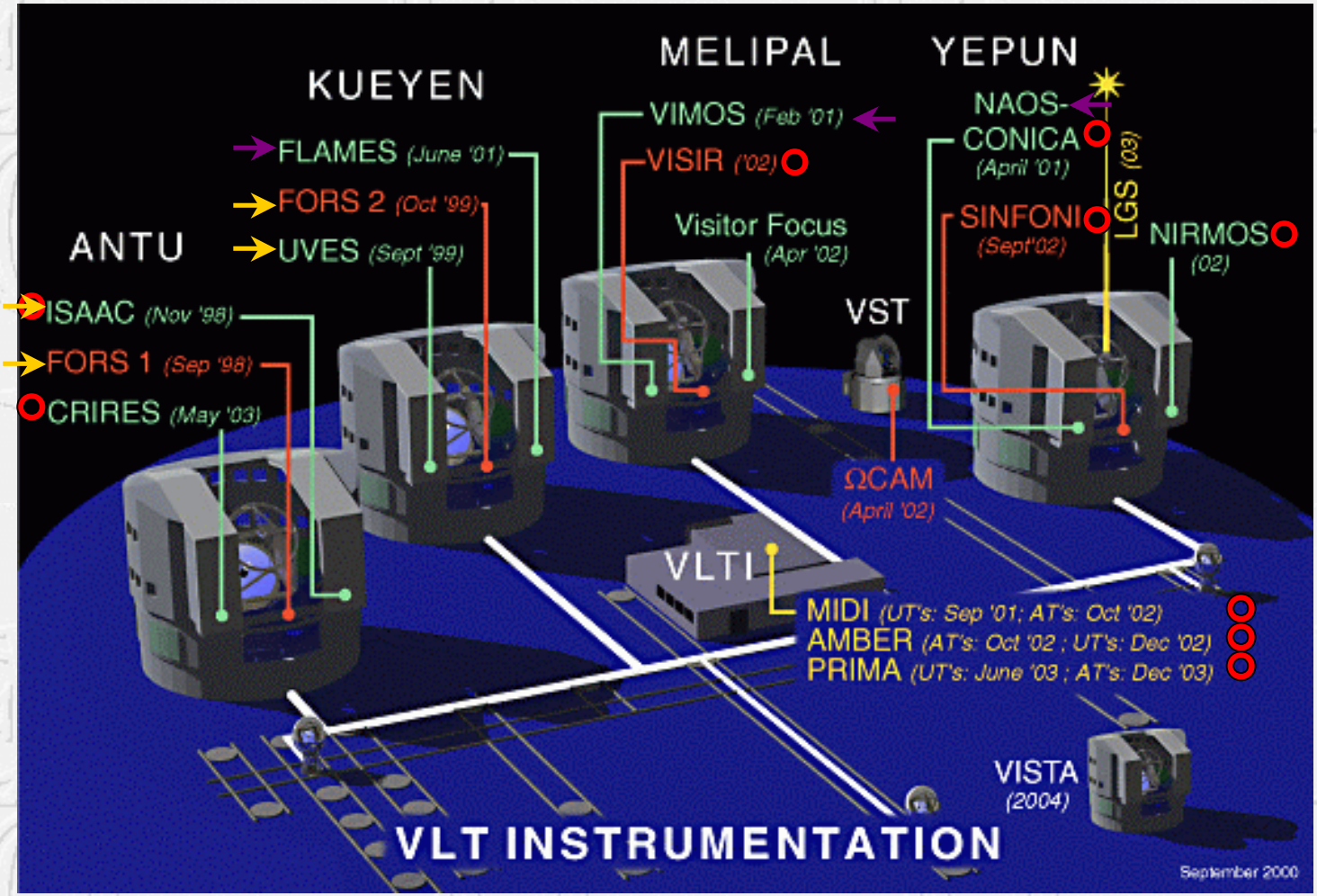
- FWHM 0.25arcsec images, 5 min exposure

- 1° zenith blind area

- **FULLY COMPUTERIZED**



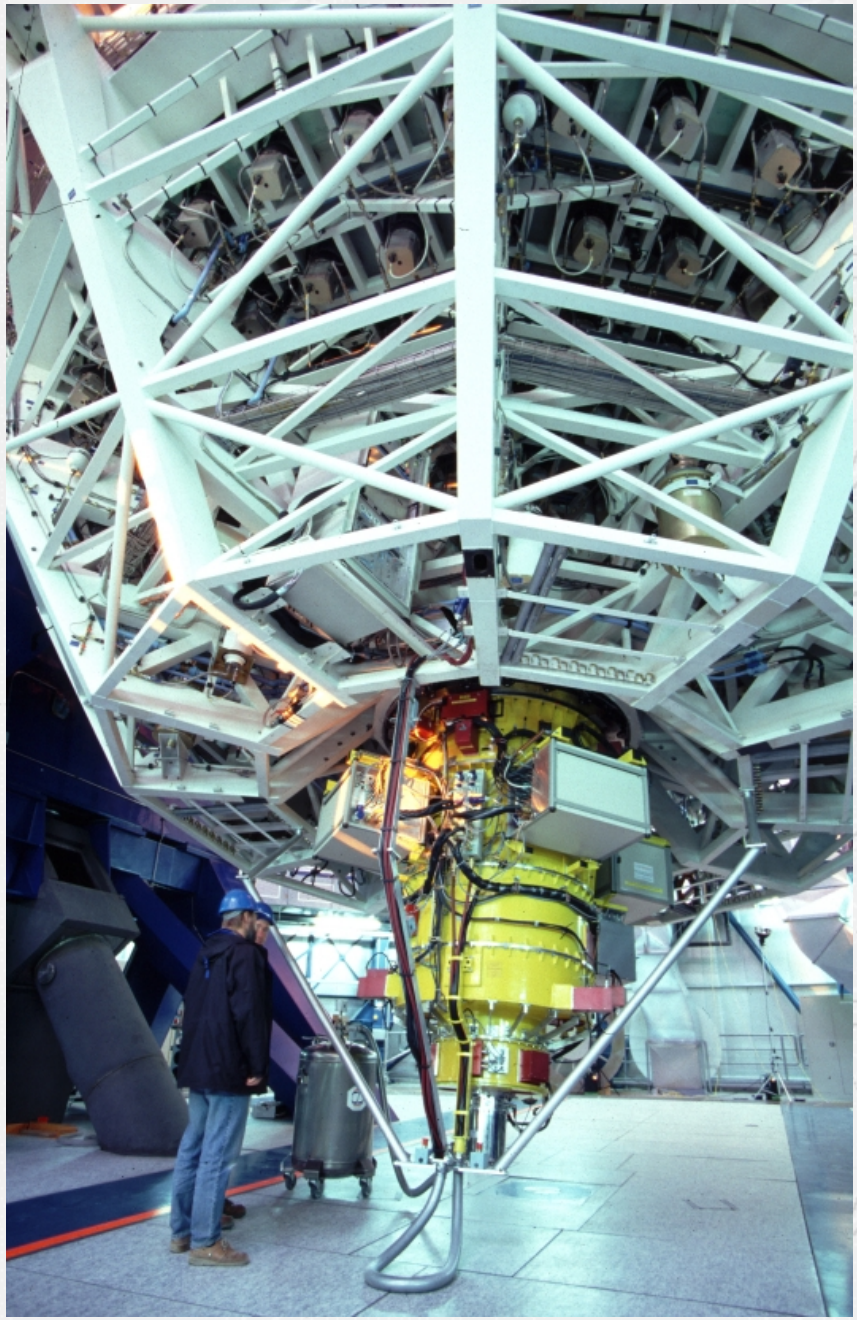
VLT instrumentation



- 11 focal plane to be supplied, 1 visitor focal plane
- Focal planes dedicated to IR/Visible range : Imaging, spectrographs, IR imagery with adaptive optics...

FORS1 & 2

FOcal **R**educer and low dispersion **S**pectrograph



Imaging mode :

- Field 6.8x6.8’ , F/D =3
- 0.2’’/pixel, CCD2x2K
- Mode HR 0.1 ’’/pixel

Spectrograph :

- 45 - 170 Å/mm or 15 - 41 Å/mm
- Long slit / 19 slits FOV 22’’ : multi- objects spectroscopy

Detector :

- SITe/TK 2x2K, 24µm pixels

Polarimetry :

- Circular, linear
- Combine with spectrographic and imaging mode.

FORS, astrophysical goals

- Redshifts of distant galaxy clusters (z > 0.5, V ~ 25m)
- Galaxy counting, colors and morphology down to V ~ 27m - 28m
- Quasar - galaxy associations, fuzz around quasars
- Gravitational lenses: arcs, multiply lensed quasars, lensing galaxy
- Spectropolarimetry: white dwarfs, active galactic nuclei (AGNs), jets, broad absorption line quasars, BL Lacertae objects, optically violent variables (OVVs)
- Chemical abundances in extragalactic stars and emission line nebulae

The Crab Nebula in Taurus (VLT KUEYEN + FORS2)

ESO PR Photo 40f/99 (17 November 1999)

Ngc6822 + Hα filter

M1

1800s exposure time : 28th Magnitude reached, 0.5’’ seeing B band

Nice images recorded by FORS

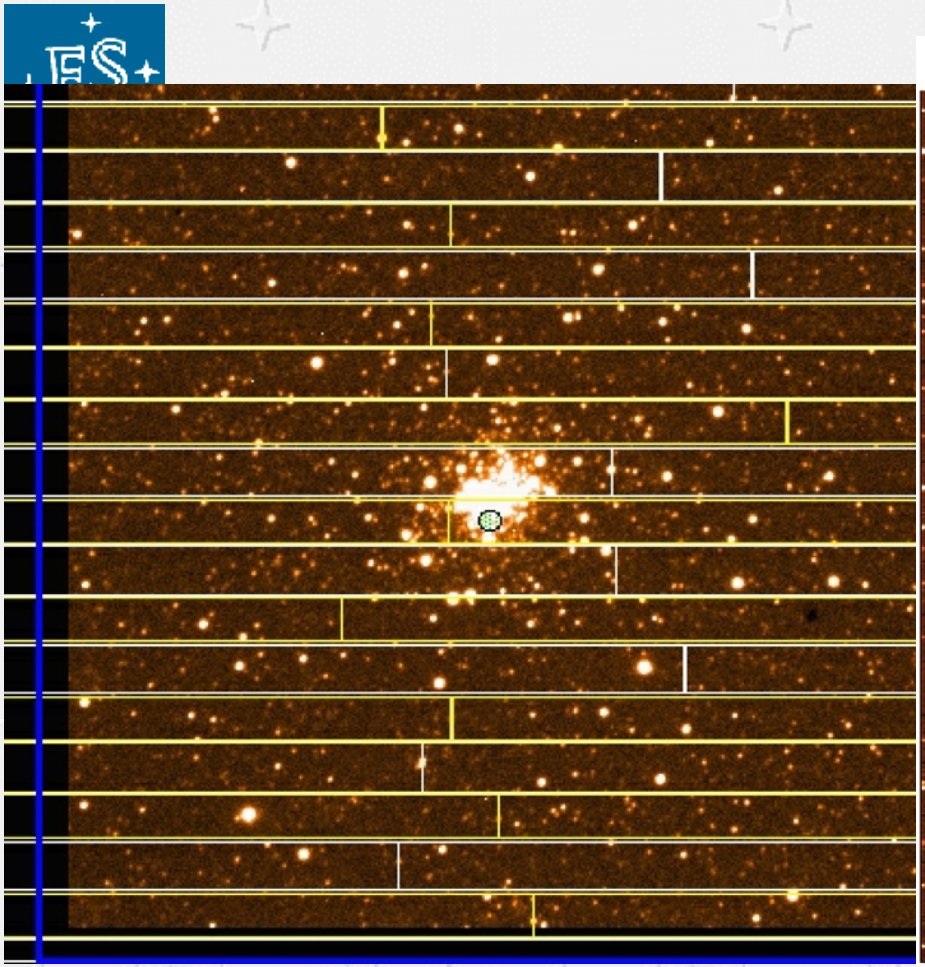
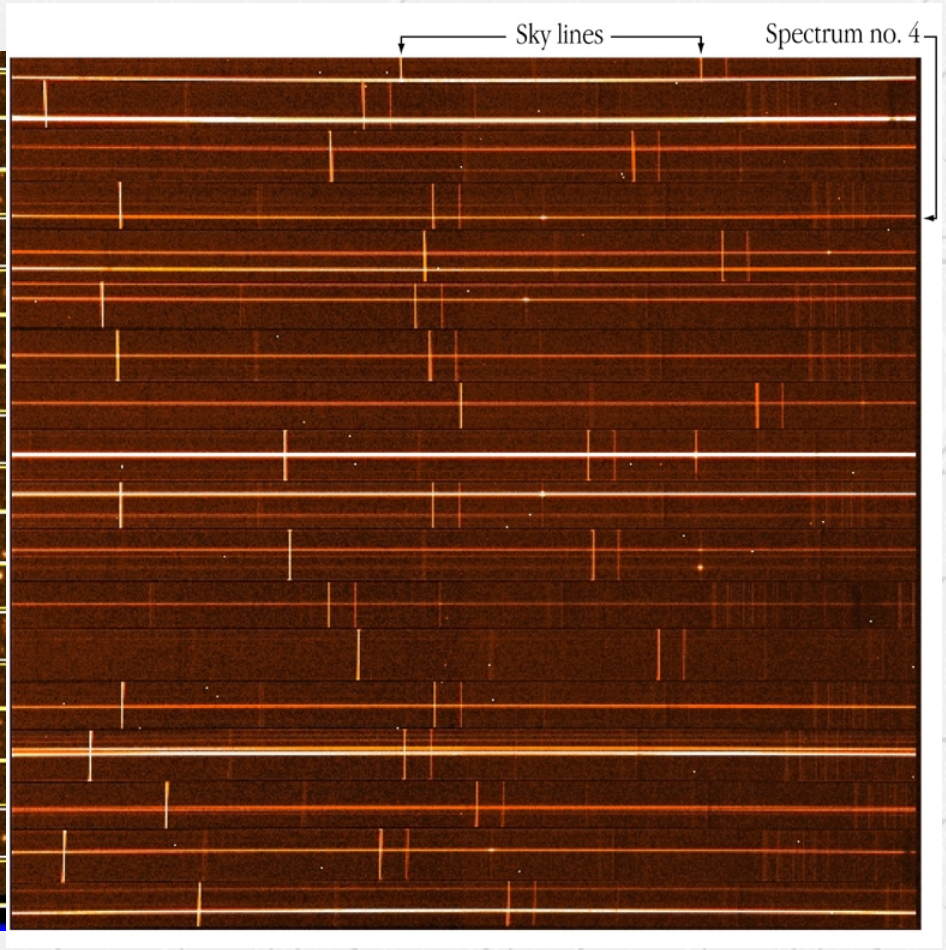


Image used to compute MOS positions
of the 19 slits



19 spectrums
R=70 Å/mm

Spectrographic Mode with FORS

UVES

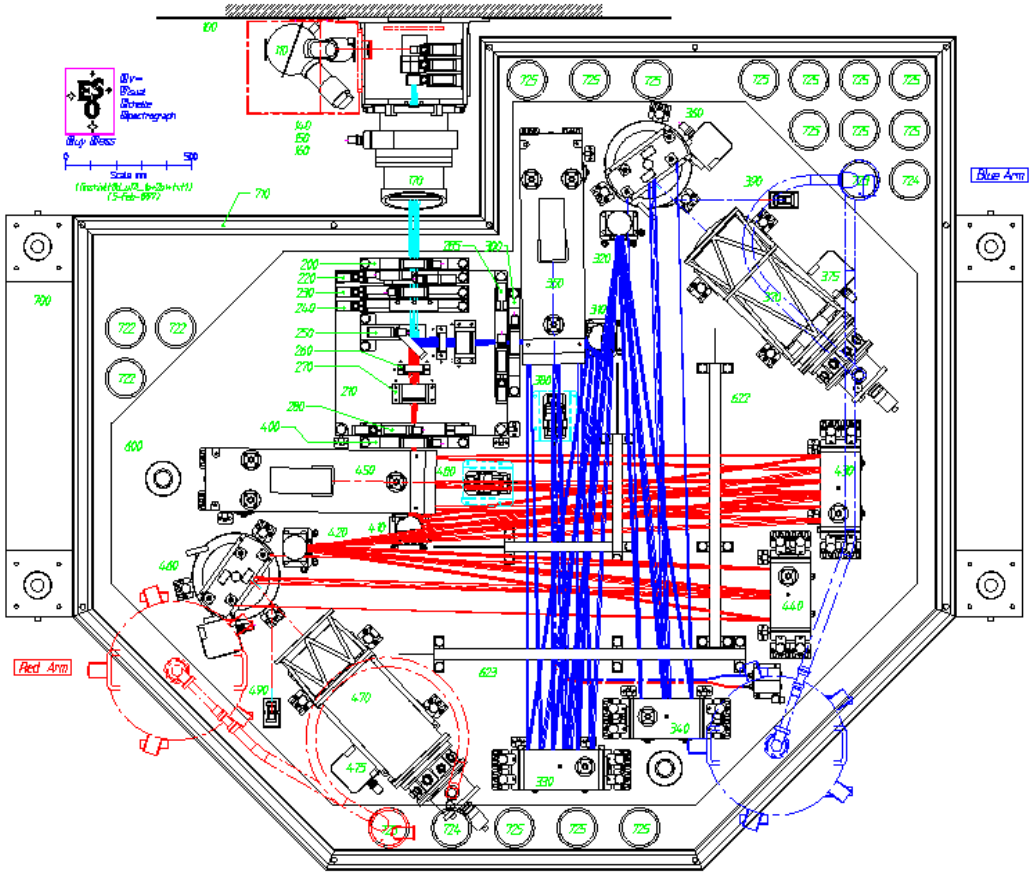
UV-Visual (0.3-1.1 μm) Echelle Spectrograph

- Two arms spectrograph (300-500 nm (blue) et 420-1100 nm (red)

- High dispersion : R $\lambda/\Delta\lambda$=80000 - 110000 (slit=0.3")

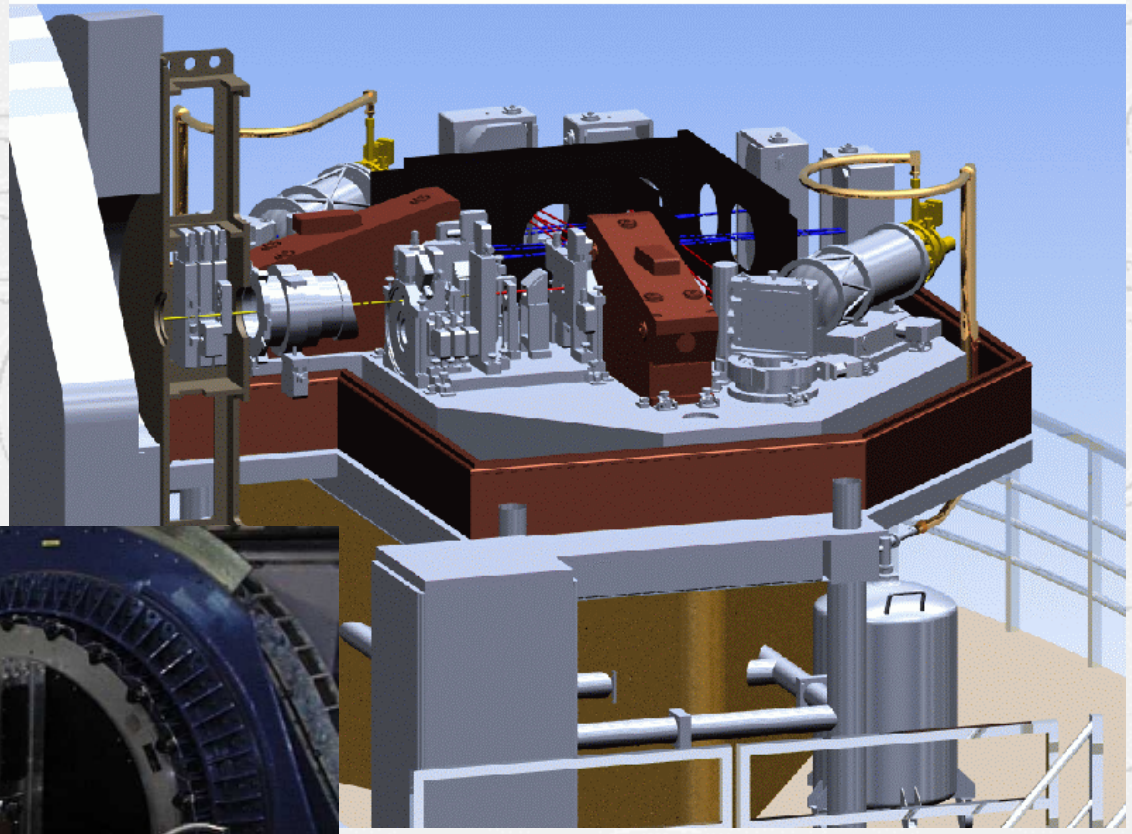
- Echelle Spectrograph, cross dispersed

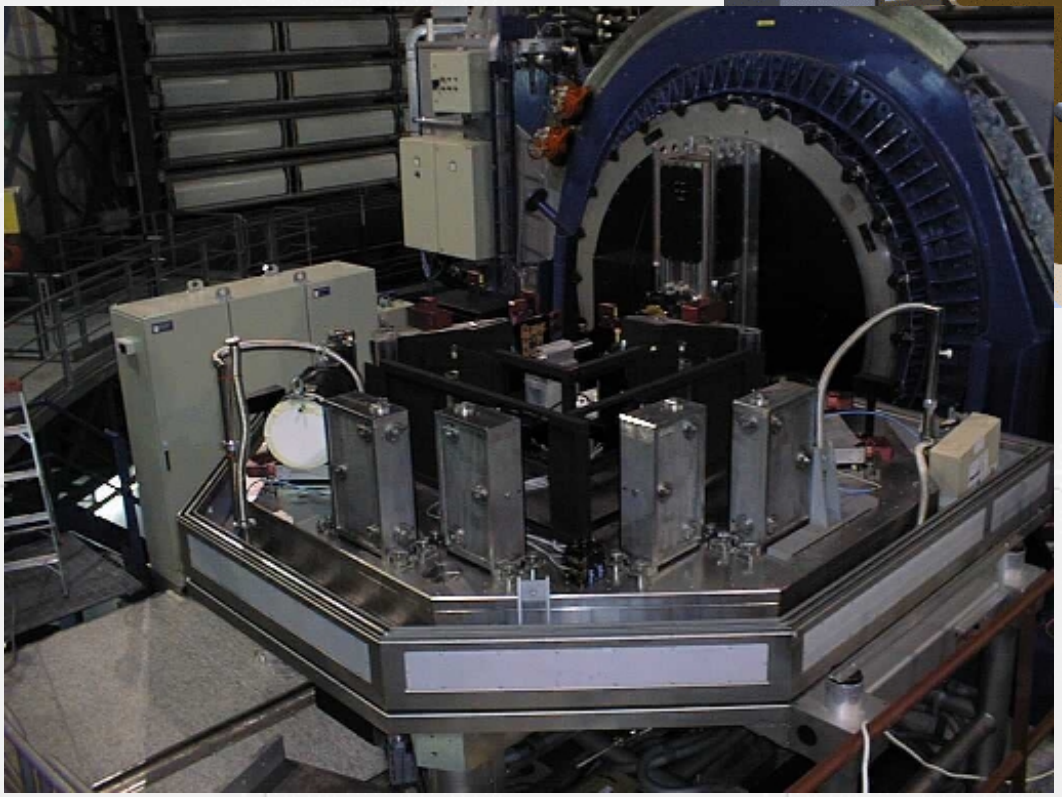
- 2 CCD systems
  - 4x4k EEV +MIT/LL (mosaic) red arm
  - 2x4k EEV blue arm



UVES

Achieved successfully
first light in Sept. 99



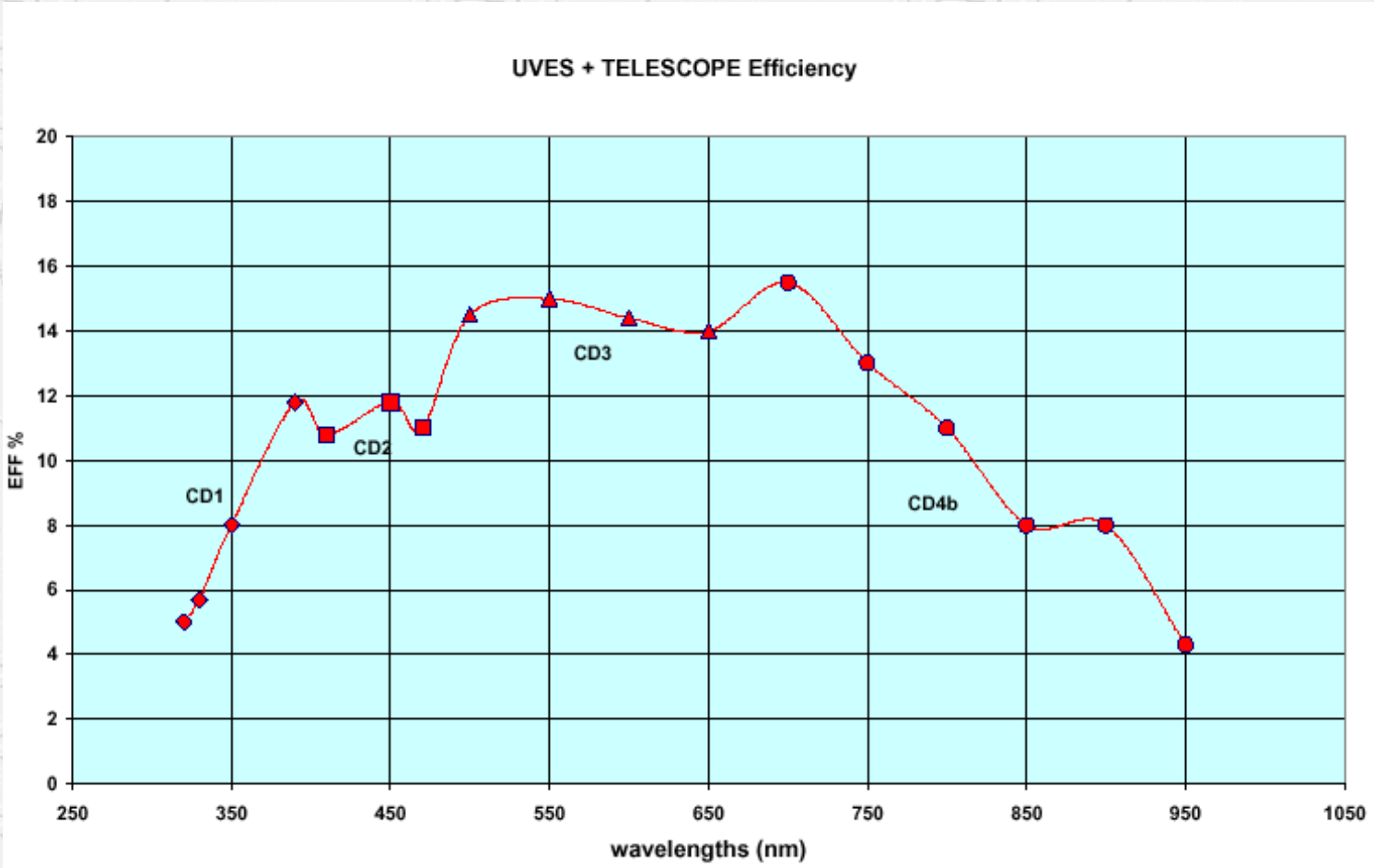


Performances

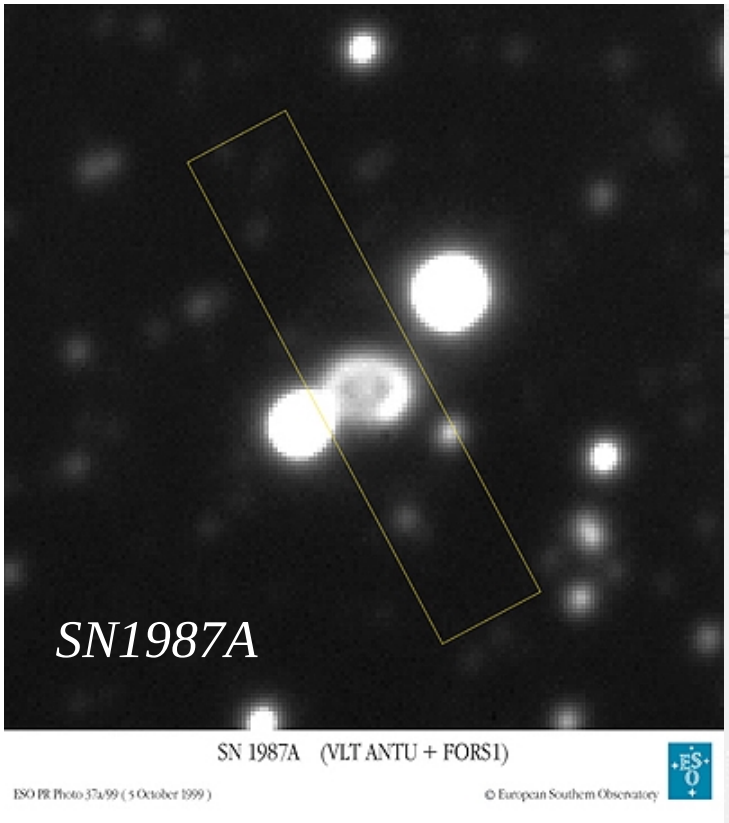
Magnitude :
3 hours exposure, SN:10, median seeing

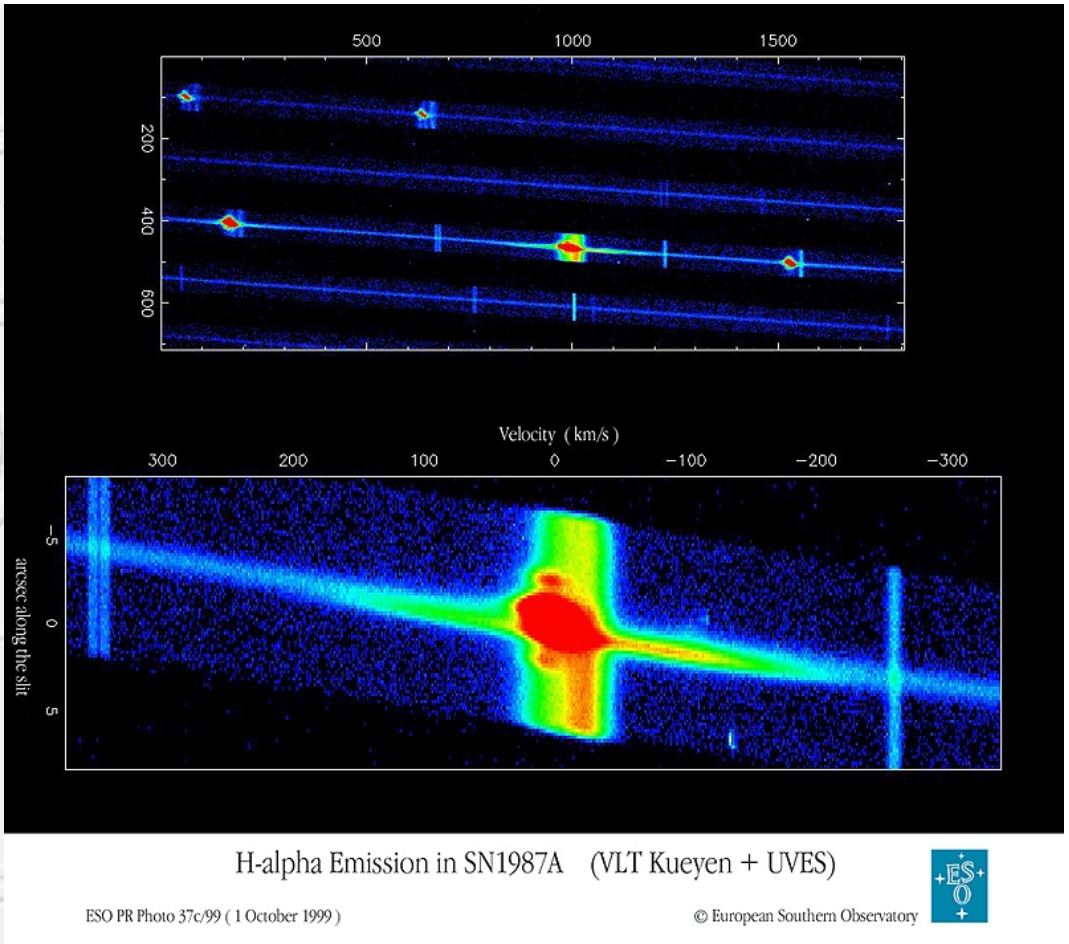
- 18.7 (R=55000 - U)
- 20.3 (R=55000 - V)
- 18.9 (R=90000 - V)

UVES efficiency



No atmosphere, No slit losses. Includes telescope (three reflections, instrument,detectors). Measurements from standard stars with the four different cross dispersers (CD1, etc). All range covered in two dichroic exposures.

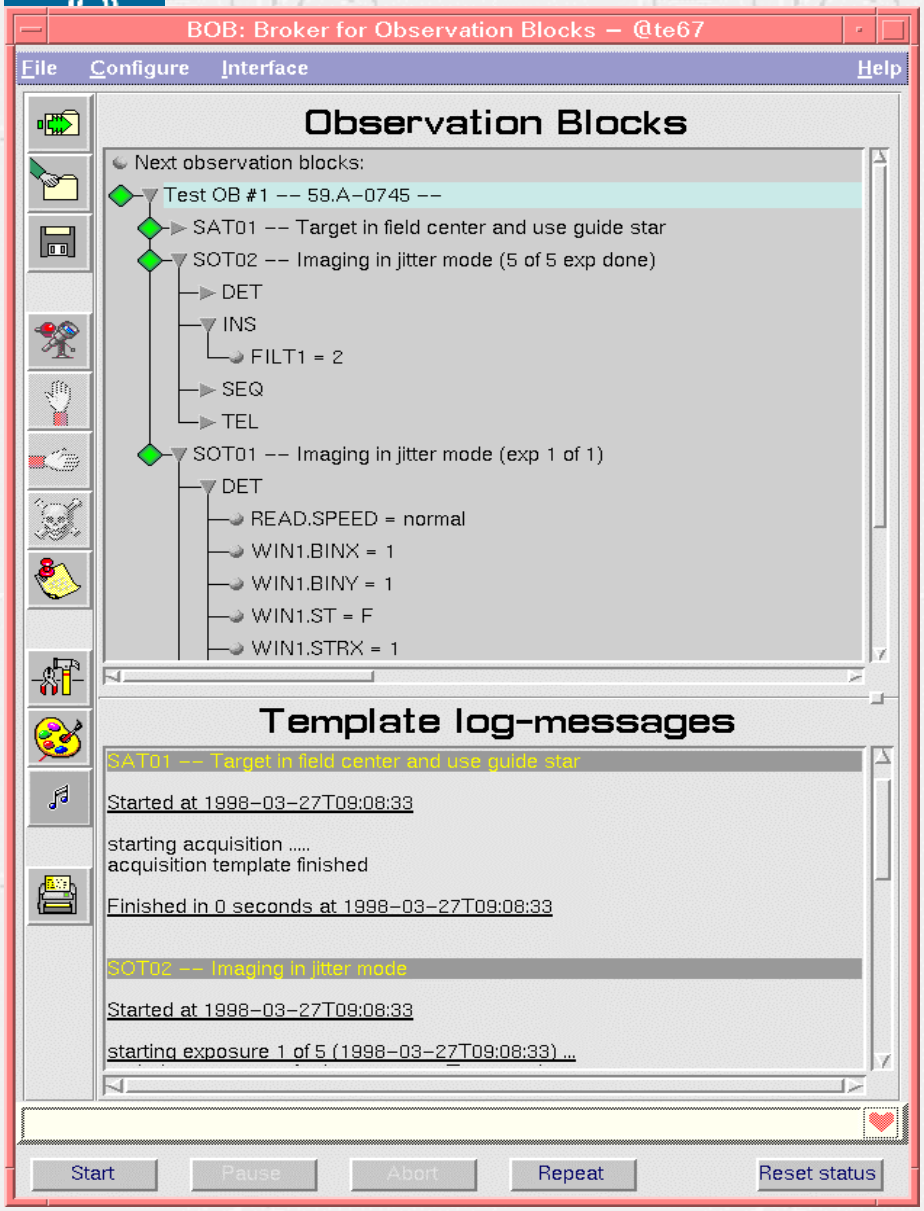




UVES scientific targets

- Structure, physical conditions and abundances of interstellar and intergalactic gas at early epochs from the absorption spectra of high redshift QSO's
- Kinematics of gas and stars in galactic nuclei
- Kinematics and mass distributions of star clusters
- Composition, kinematics and physical conditions of the interstellar medium in the galaxy and in nearby systems
- Chemical composition and atmospheric models of galactic and extragalactic stars
- Substellar companions of nearby stars (high-precision radial velocity studies over long timescales)
- Stellar oscillations

The way to observe at the VLTs



«Observation Blocks - OBs»

⇨ ***Telescope***

- pointing, active optics, guiding

⇨ ***Instrument***

- Detector (CCD, SWR)
- Filters, setup, spectral resolution

Visiting Mode (40%)

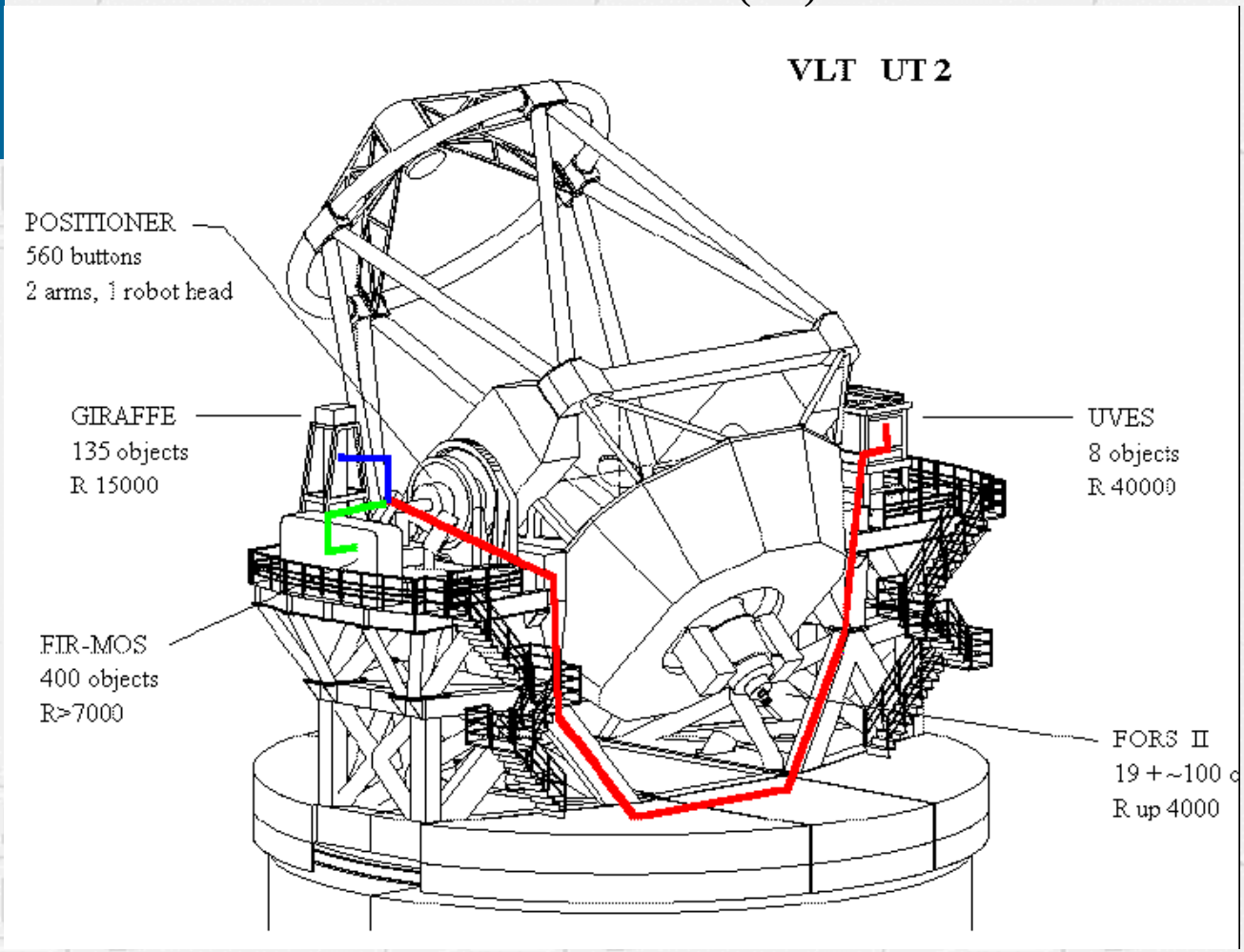
- Astronomer at the VLT, mean observing time =8/10h

Service Mode (60%)

- «OBs» send, observation done remotely by ESO astronomer.

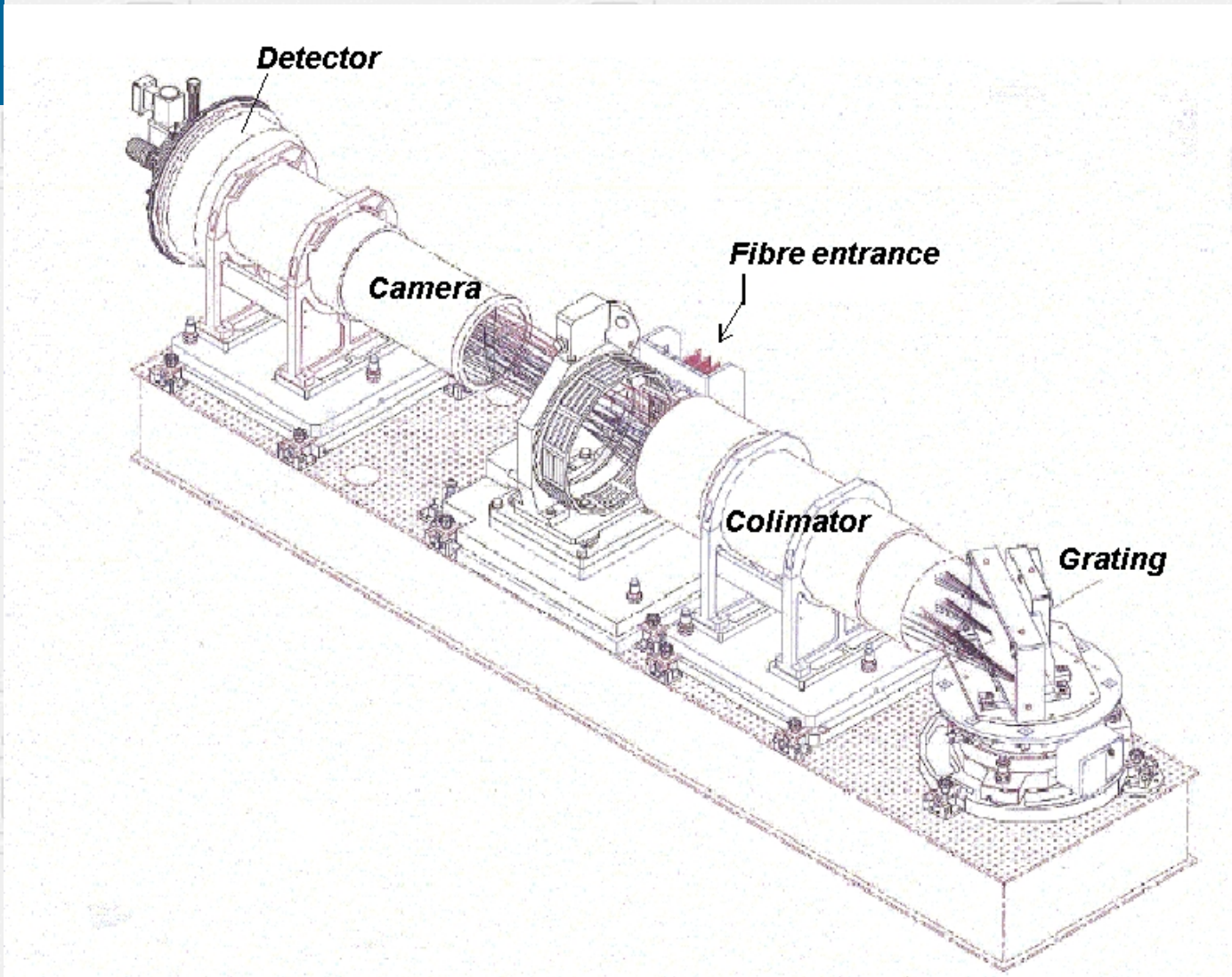
UVES : 2974 science spectra in 6 months, 70% of the UT2 time, 80% open shutter time

GIRAFFE – FLAMES (1/2)



- Medium-high Resolution R=7500-25000 spectrograph
- Fibre fed :
  - 4 plates of 132 fibres positioned over a corrected field of 25 arcmin (1.2” FOV)
  - 15 object +15 sky Integral field units (2x3” FOV) : 20 fibres each
  - Central Integral field units of 300 fibres

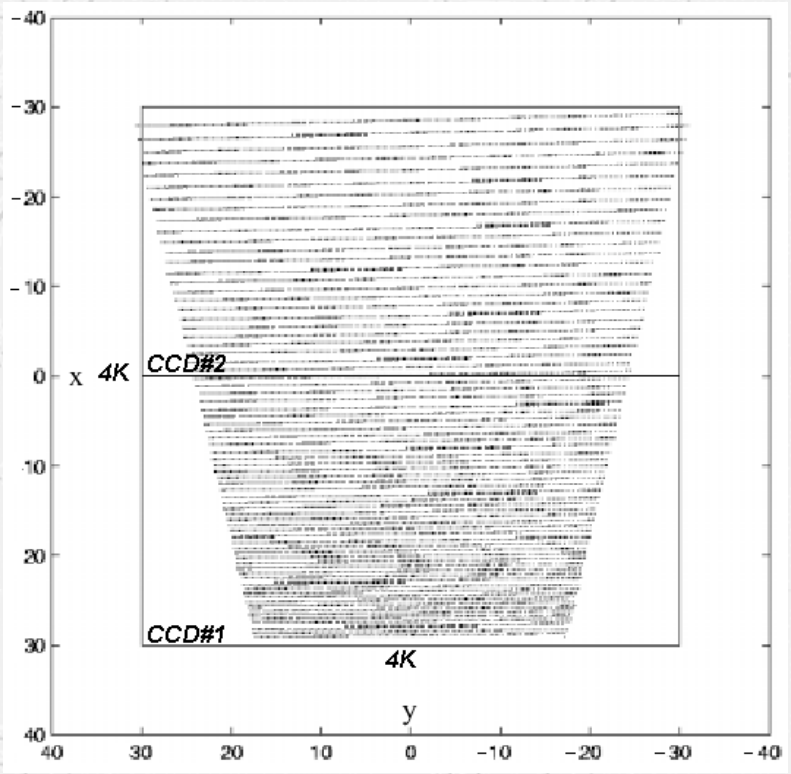
GIRAFFE – FLAMES (2/2)

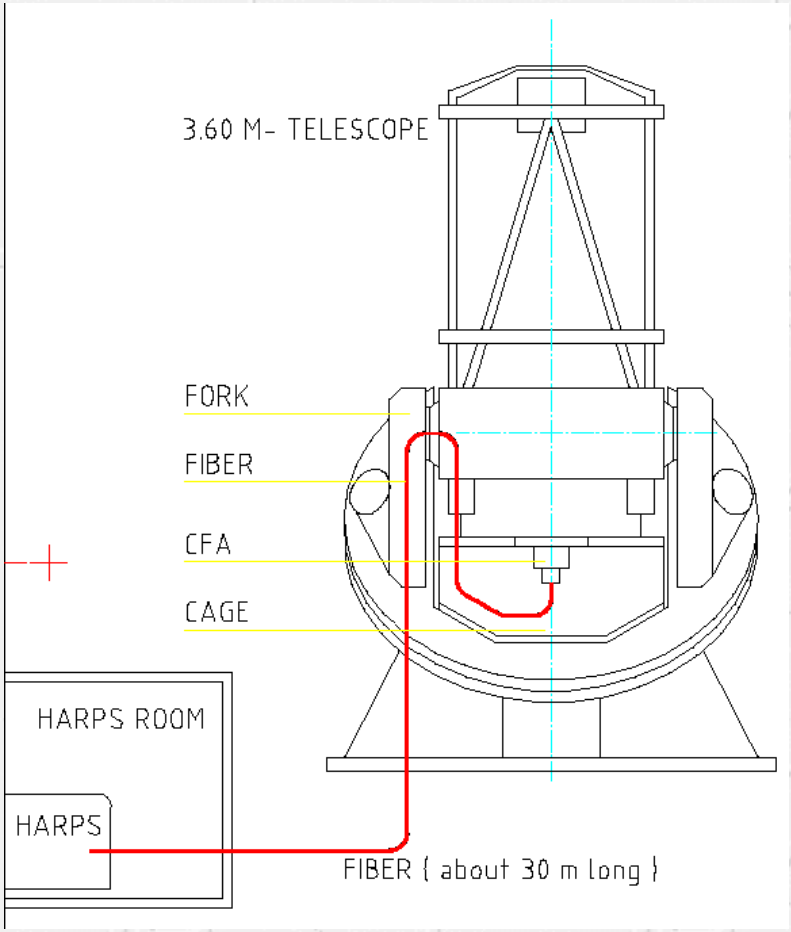


Spectrograph table

!! 315 spectra on a 2x4K EEV CCD !!

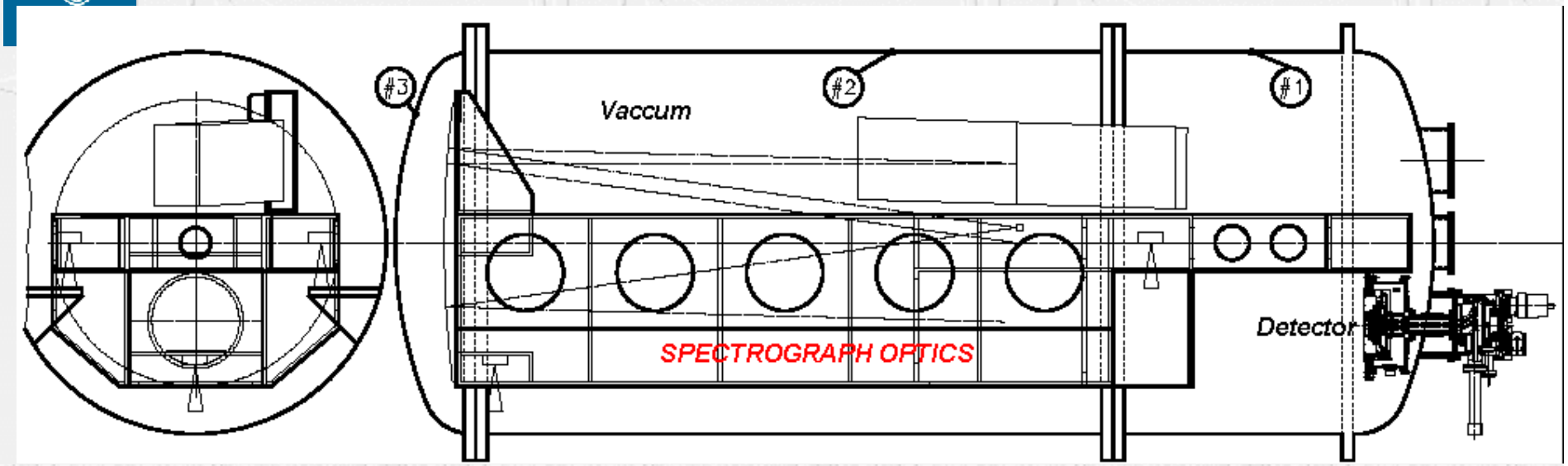
Harps (1/2) [La Silla, 3.6]



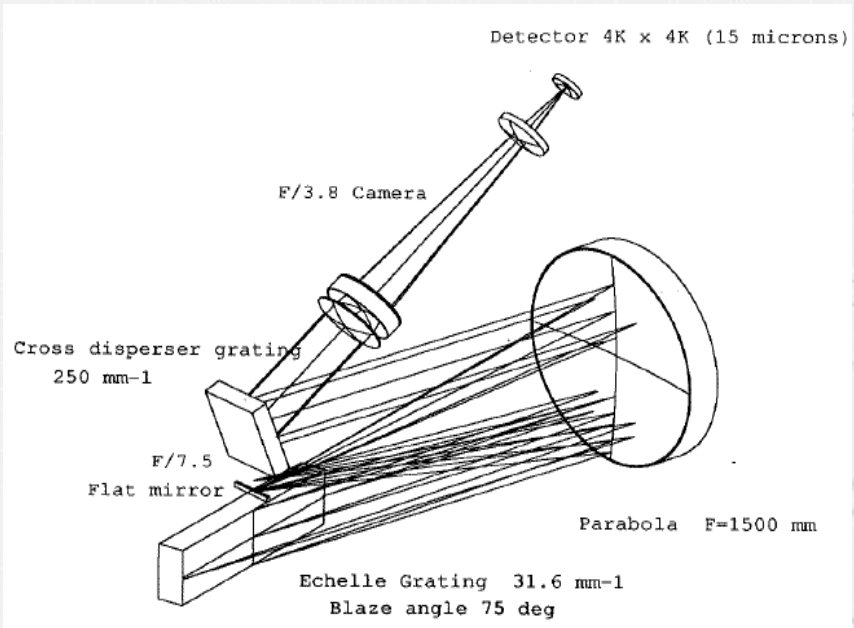


- Echelle spectrograph dedicated to discover planets close to stars (2/10 Saturn).
- Radial speeds measurements : accuracy of 1m/s
- 380-650 nm, R=84000, FOV = 1”
- Installed at the 3.6m at La Silla
- CCDs : mosaic of two 2x4K -> EEV44-82: 4x4K

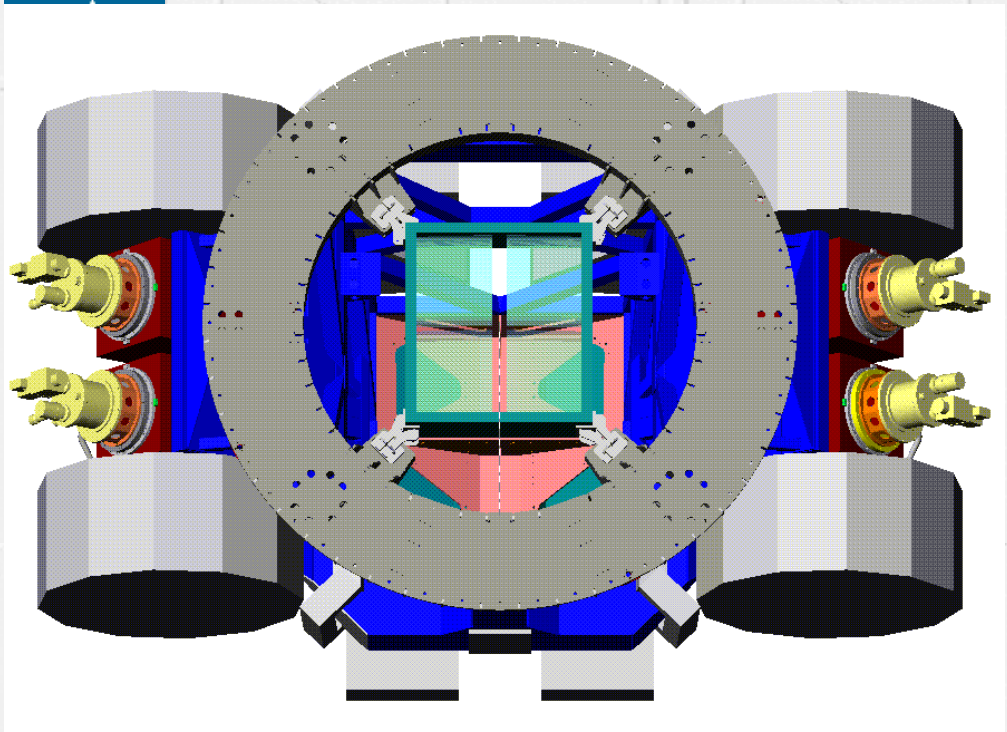
Harps (2/2)

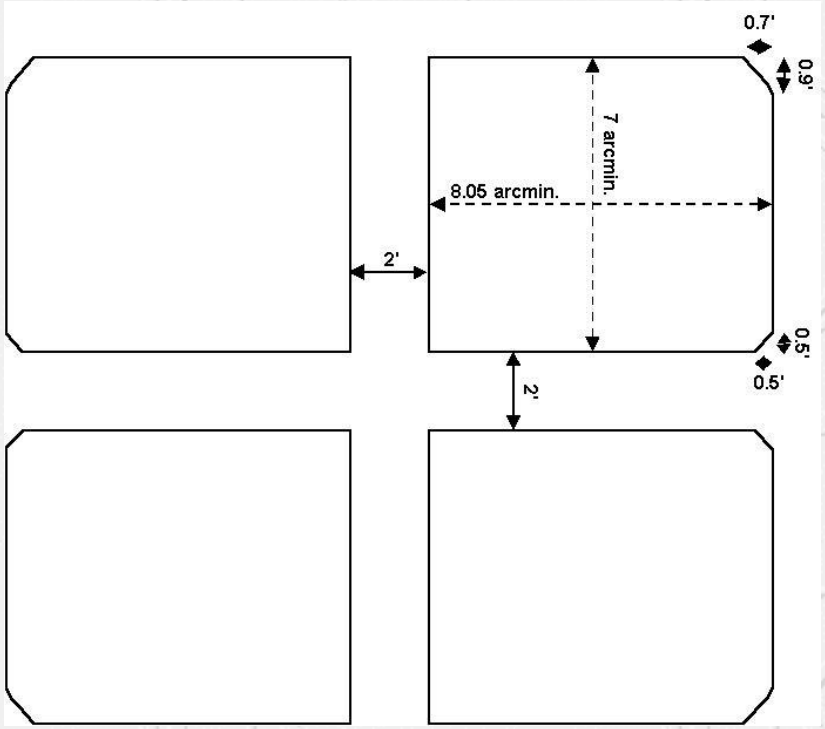


- Requires ultra high stability : all optics in vacuum
- Temperature stability : 0.01K
- 1m/s -> 1/1000 of a CCD pixel : fine centroiding and statistics
- Long term reliability >5 years
- Overall spectrograph efficiency : 10%



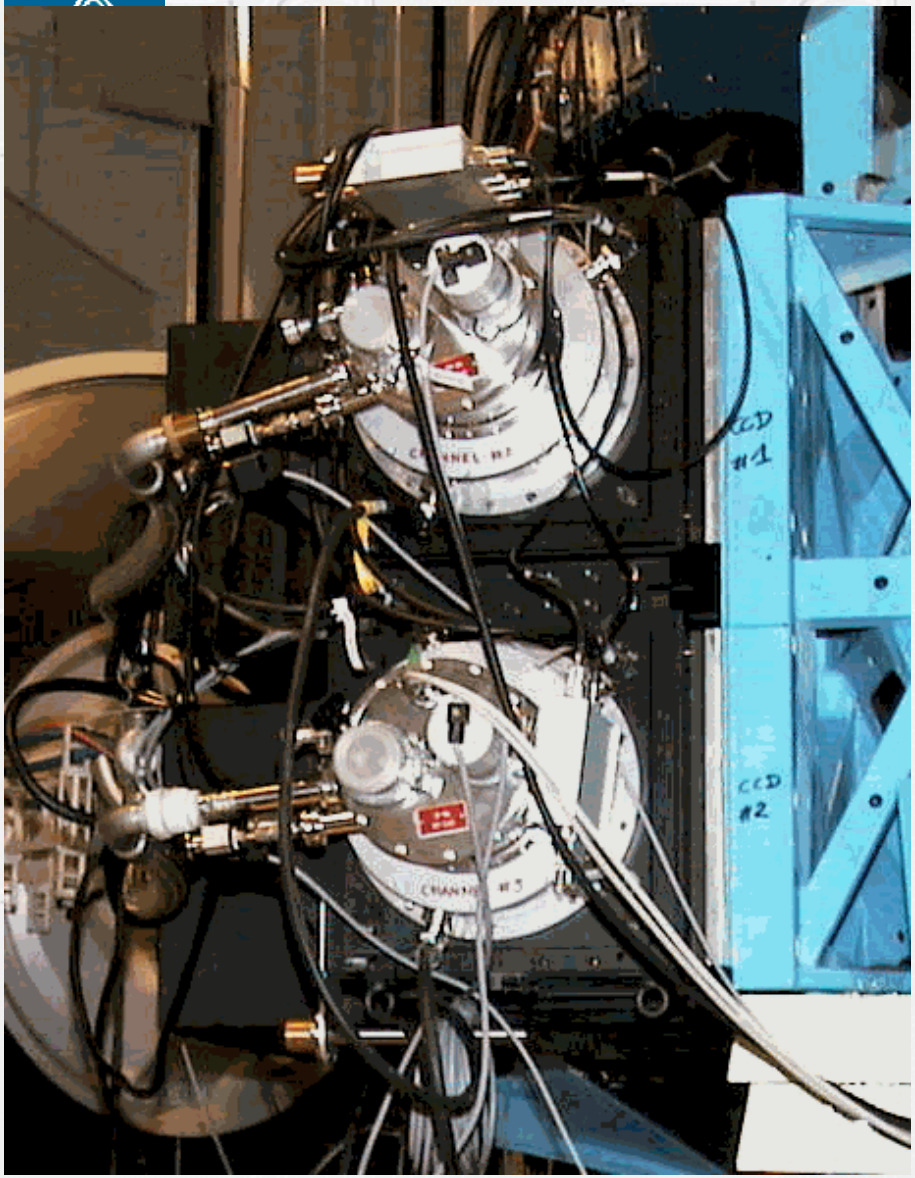
VIMOS : VIsible MultiObject Spectrograph (1/2)



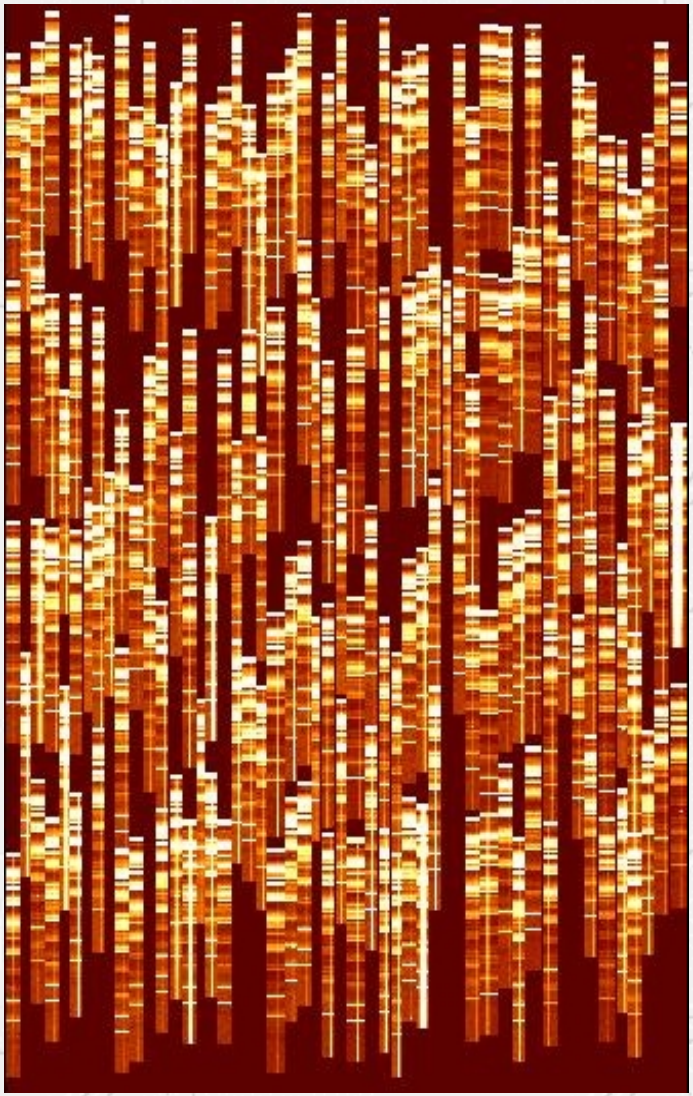


- Imaging and multi-object spectroscopy in four 7' x 8‘, 0.2"/pixel sampling
- Spectral resolution for 1” slit: ~ 200, ~ 600 ~ 2000
- ~ 150 slits @ R = 2000, ~ 750 slits @ R = 200, 10" slit height.
- Integral field Unit, providing up to 54" x 54“, 6400 spectrum at once
- Four 2kx4k EEV CCD detectors, 15 µm pixels..

VIMOS (2/2)



2 of the 4 detector head installed to VIMOS



MOS simulation in LR,
160 slits, one quadrant.

Next coming instruments

Infrared (1-8µm)

- CONICA : High resolution IR imaging
- CRIRES : High resolution IR echelle Spectrograph
- NIRMOS : NIR multi-objects Spectrograph (750 objects)

Infrared + Adaptive Optics

- NAOS : S/H AO + 1x1K InSb array 27 µm pixels

Thermal Infrared (8-25 µm)

- VISIR : Imaging/Spectrograph

All VLTI instruments

http://www.eso.org/instruments/

Optical detectors at ESO

By C.CAVADORE

Optical Detector Team (ODT)

Instrumentation division

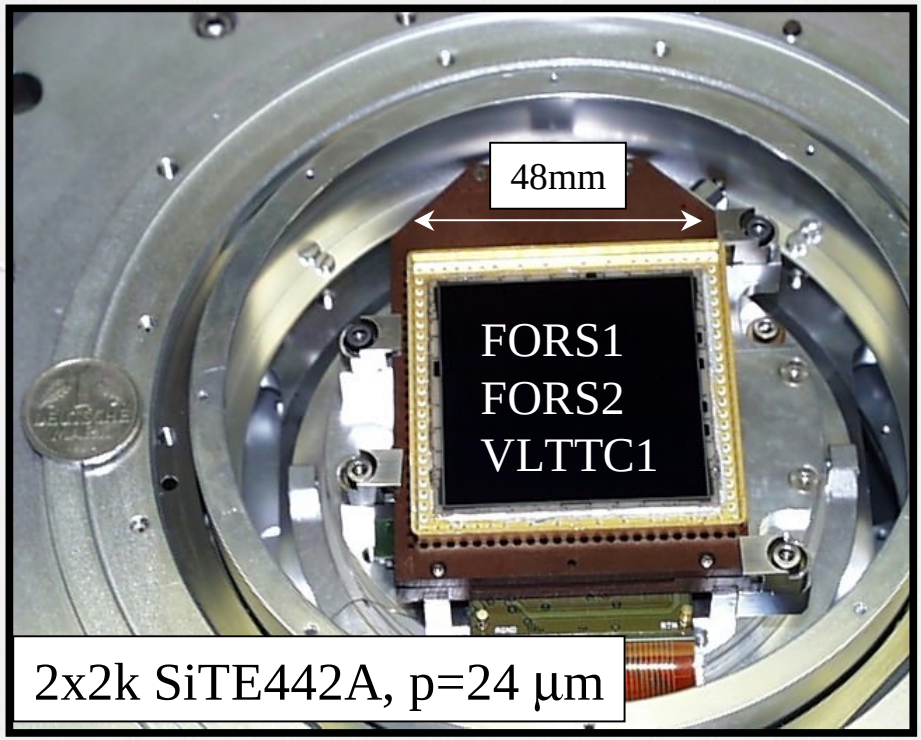
European Southern Observatory

ccavador@eso.org

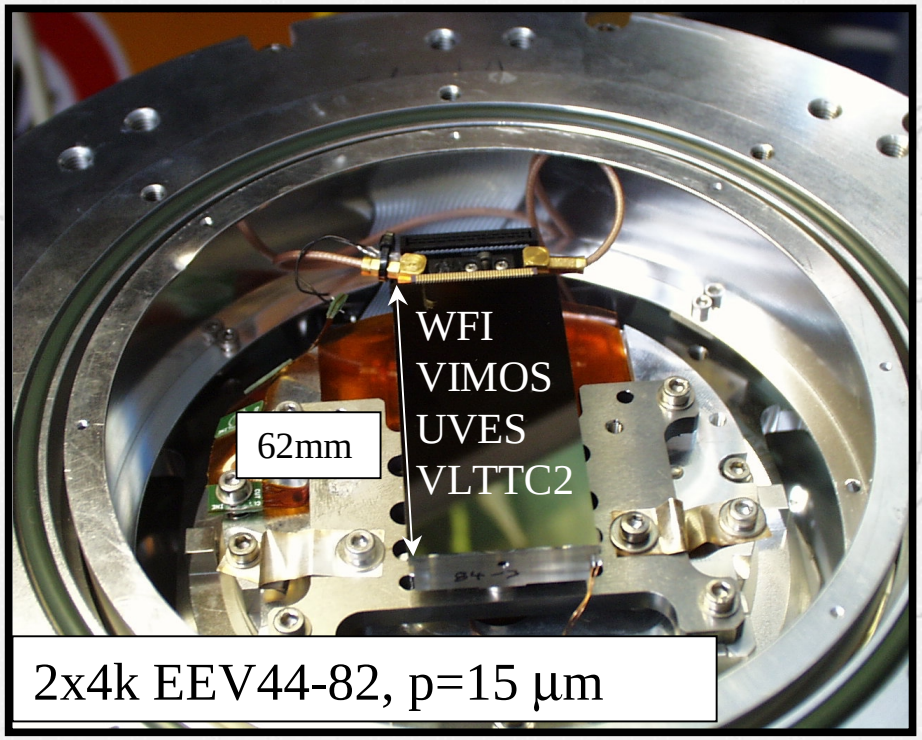
www.eso.org

Optical Detector Team deliveries between 1997-2000

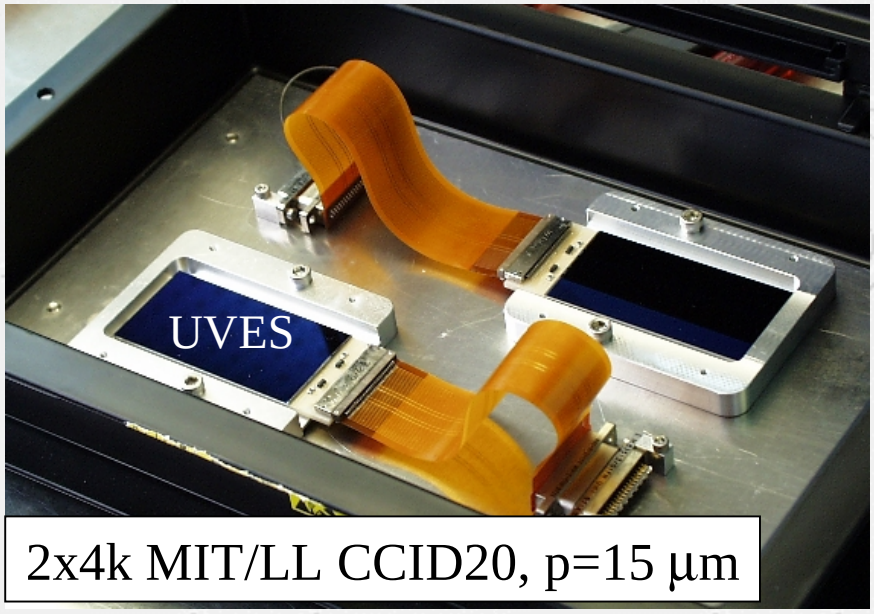
Instrument	CCD	Telescope	Application
FORS 1	Tektronix/SITe 2k x 2k	UT 1	Spectroscopy/Imaging
UVES (red arm)	MIT/LL 2k x 4k +EEV 2k x 4k	UT 2	Spectroscopy
UVES (blue arm)	EEV 2k x 4k	UT 2	Spectroscopy
FORS 2	Tektronix/SITe 2k x 2k	UT 2	Spectroscopy /Imaging
VIMOS	4 EEV 2k x 4k	UT 3	Spectroscopy / Imaging
NAOS	EEV 128 x 128 CCD50	UT 4	Adaptative optics
VLTTC 1	Tektronix/SITe 2k x 2k	UT 1/2/3/4	Imaging, test camera
VLTTC 2	EEV 2k x 4k	UT 1/2/3/4	Imaging, test camera
FEROS	EEV 2k x 4k	***1.52m***	Spectroscopy
EFOSC2	Loral/Arizona 2k x 2k	***3.6m***	Spectroscopy/Imaging
WFI	9 EEV 2k x 4k	***2.2m***	Imaging
CES	EEV 2k x 4k	***3.6m***	Spectroscopy
SUSI-II	2 EEV 2k x 4k	***NTT***	Imaging



2x2k SiTE442A, p=24 µm



2x4k EEV44-82, p=15 µm



2x4k MIT/LL CCID20, p=15 µm

Devices at ESO

- EEV/ Marconi 44-82
- EEV CCD50 (AO)
- MIT/LL CCID20 (th. 20µm-40µm)
- SITe st424A

Means to read out CCDs : FIERA

Before 1997

ACE CCD controller « VME based »

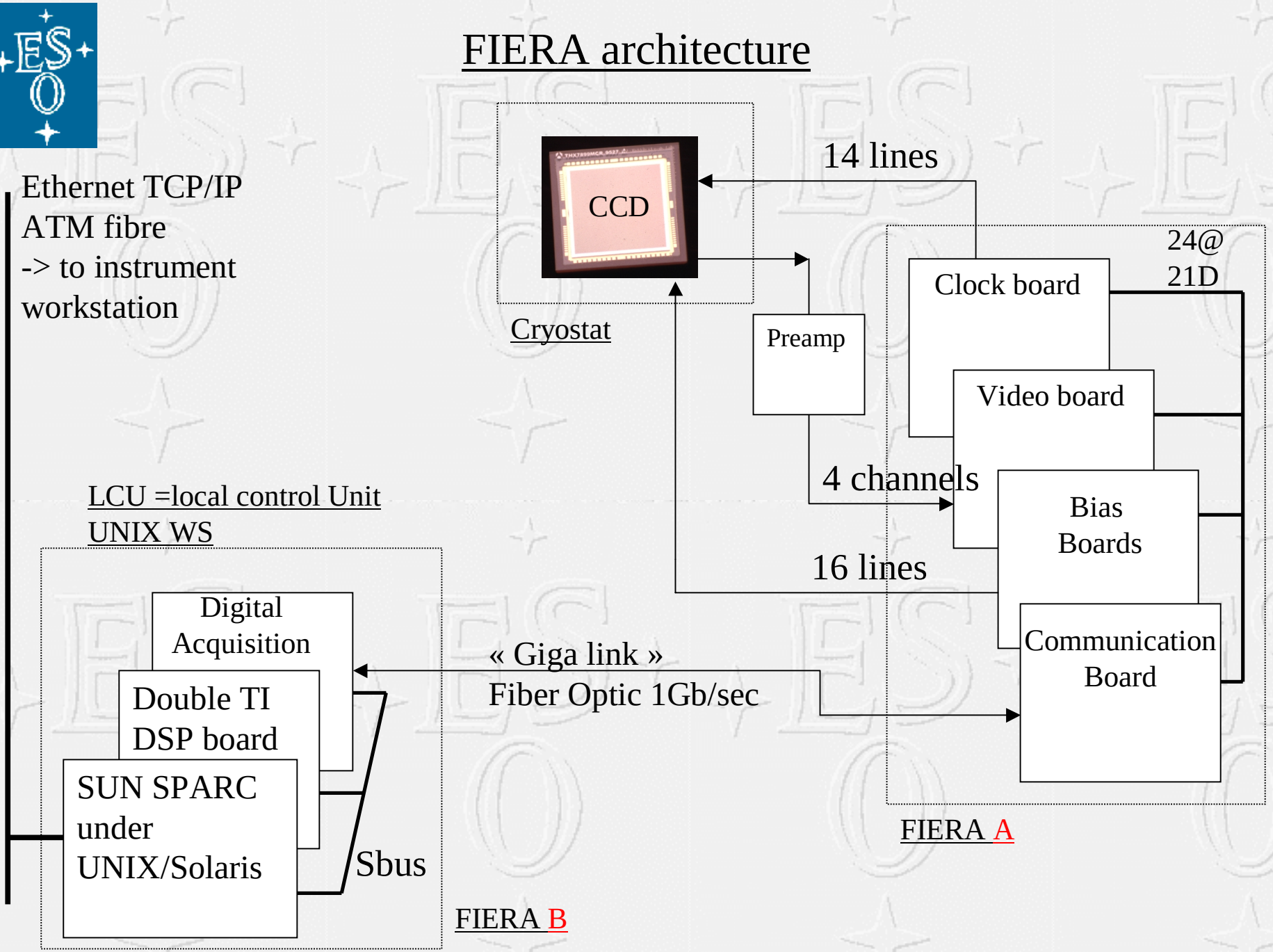
- Slow (< 100 kpx/s), noisy
- VME technology, not really versatile...

FIERA (**F**ast **I**mager **E**lectronic **R**eadout **A**ssembly)

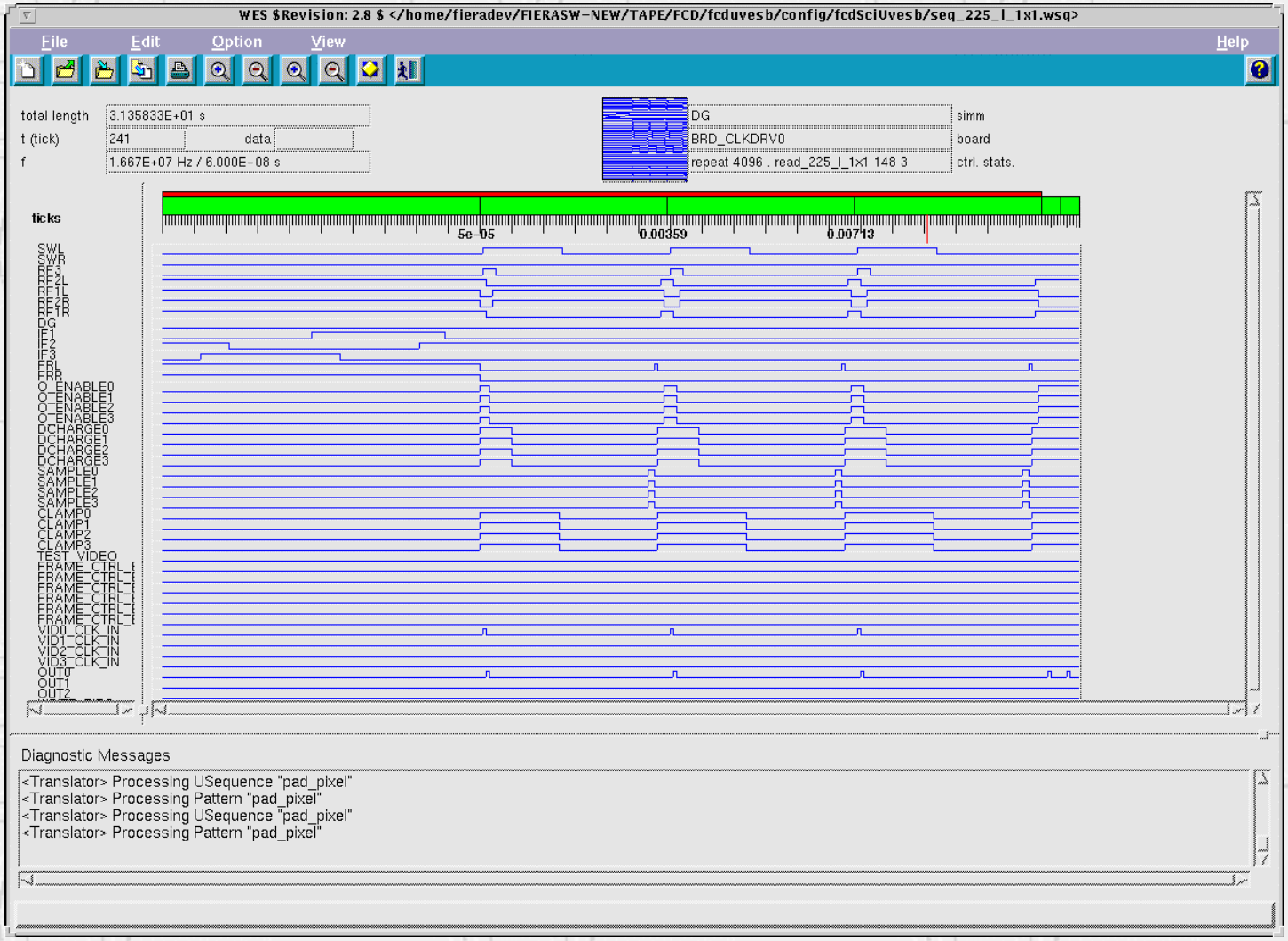
- 5 Mpx/s (4x4k can be read in 3.2sec), resolution 21bits/pixel
- Limited only by intrinsic CCD noise
- Programmable Clock level by software
- Can simultaneously read up to 32 CCD outputs = 160Mpx/s
- Clock patterns made by software (DSP)
- 200m to 20km remote control system
- made with industrial parts
- life expectancy 5-10, must be modular !

$\Rightarrow$ FIERA is only limited by user's imagination

FIERA architecture



CCD readout clocking patterns generation

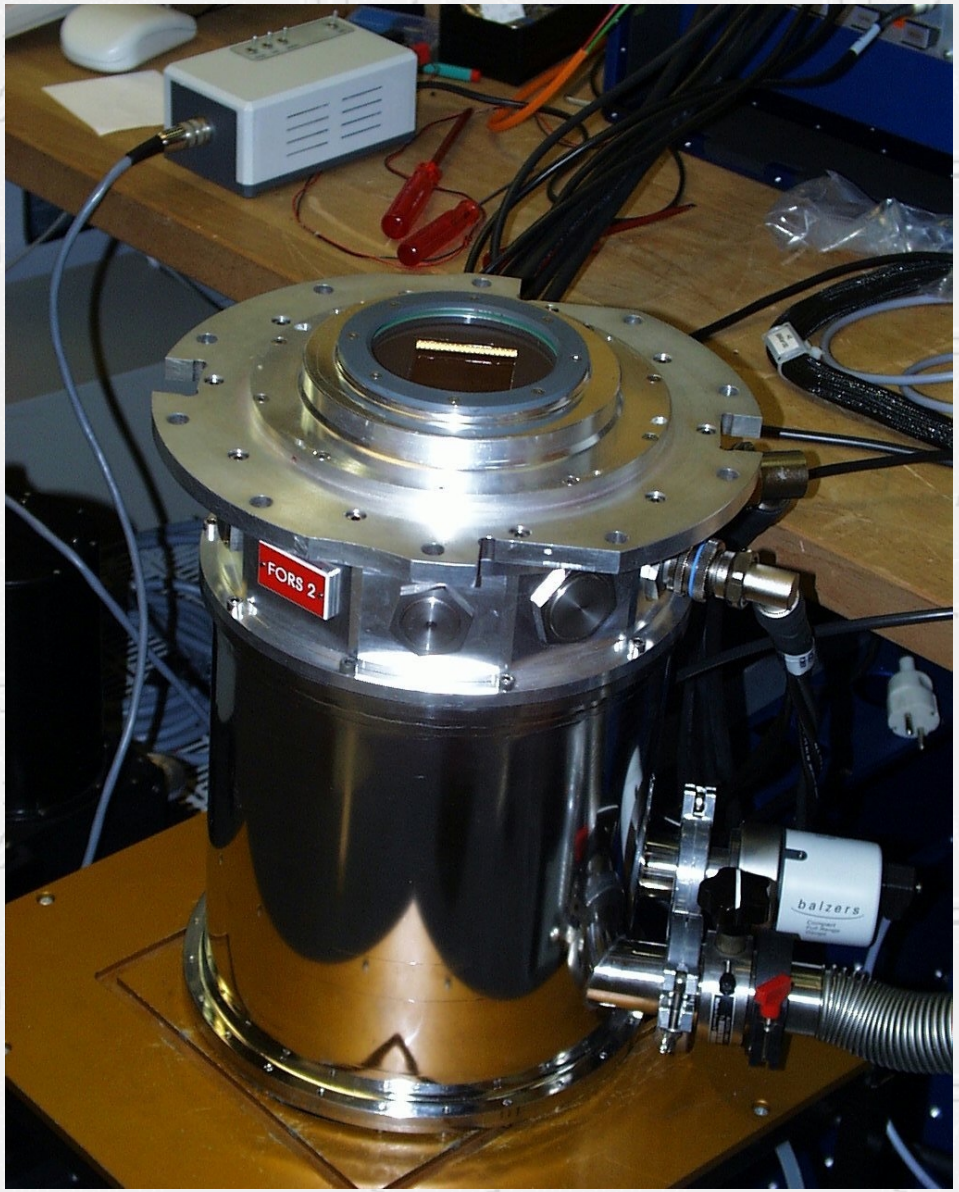


- User friendly CCD readout patterns editor, compiled and code injected from the SUN-Sparc to the FIERA DSP
- No code into the detector head electronics (Fiera A).

ESO's cryostats

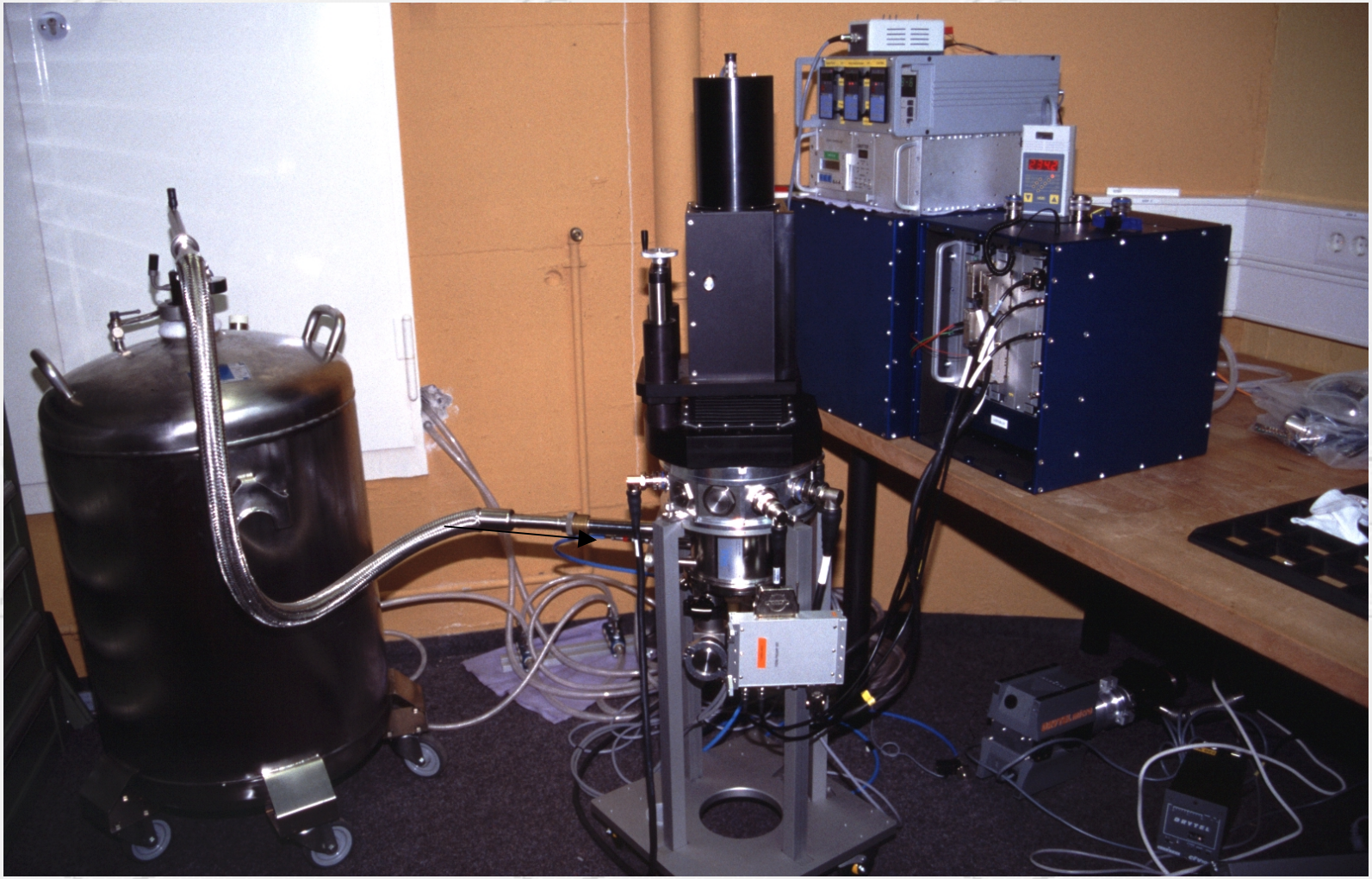
- Able to cool down CCD to -120°C
- Weight is not a issue (2 to 8m telescopes)
- Holding time : 48h
- Vacuum of 1 - 9 x 10^{-6} mB

Bath cryostat, used for Cassegrain

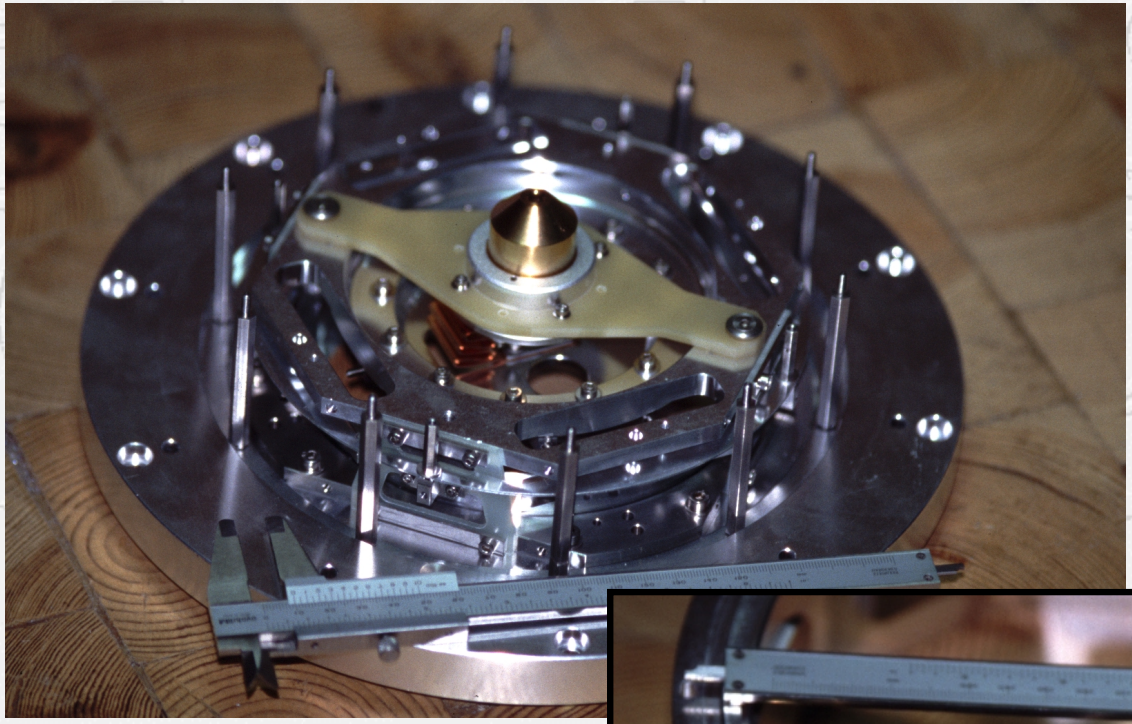


LN2 Continous flow Cryostat

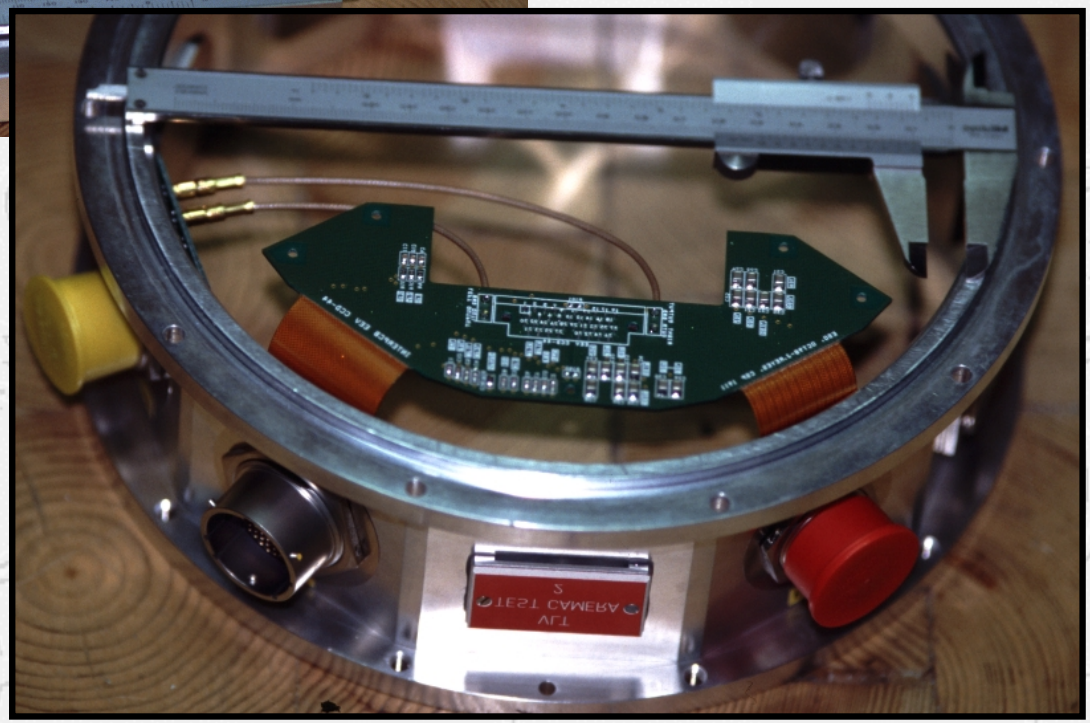
- Holding time : 7 days
- Designed for fixed instruments (spectrograph...) on platforms
- Very compact, fast cooling down



Inner part of the CCD head



Backside and cold finger

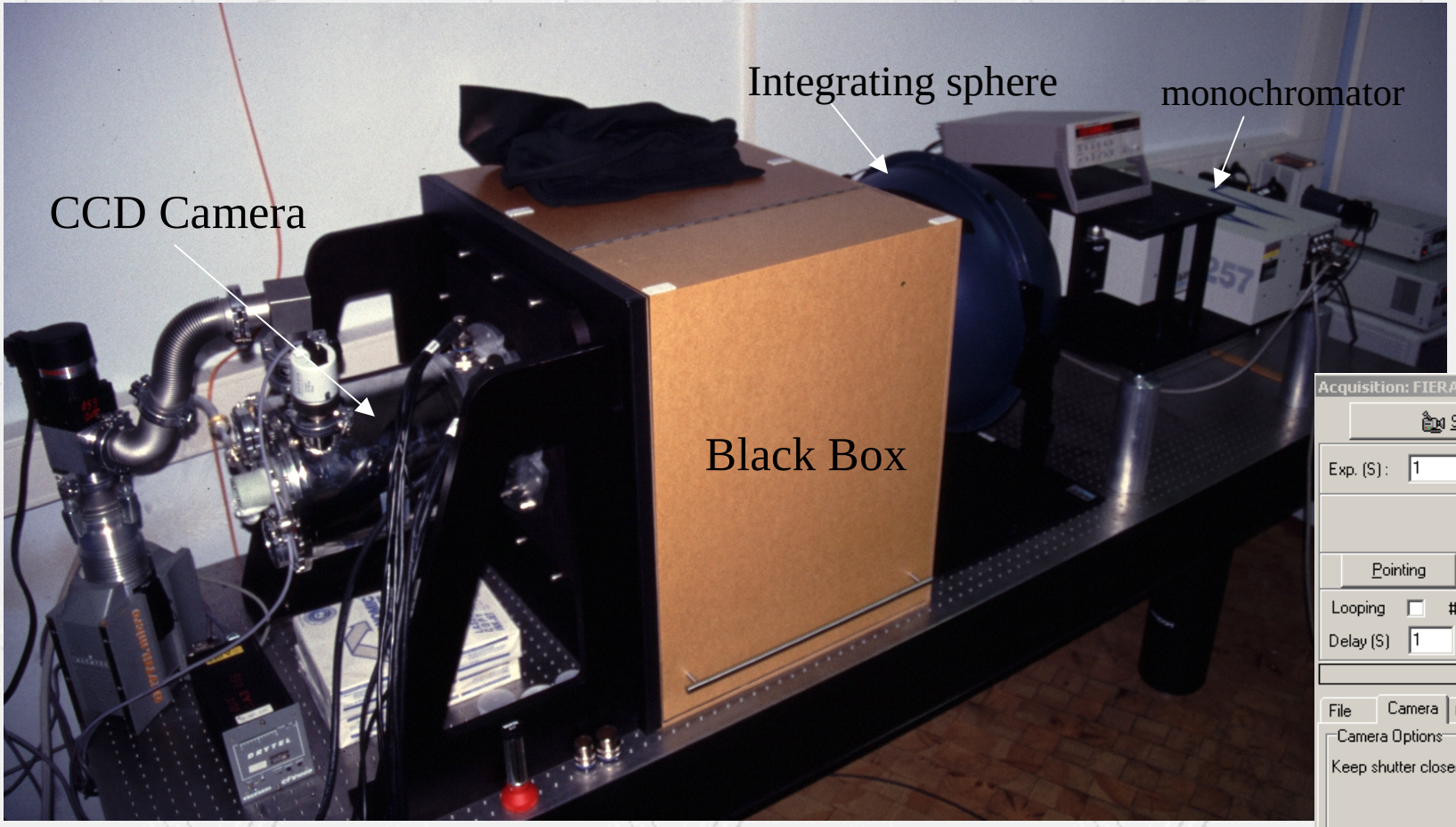


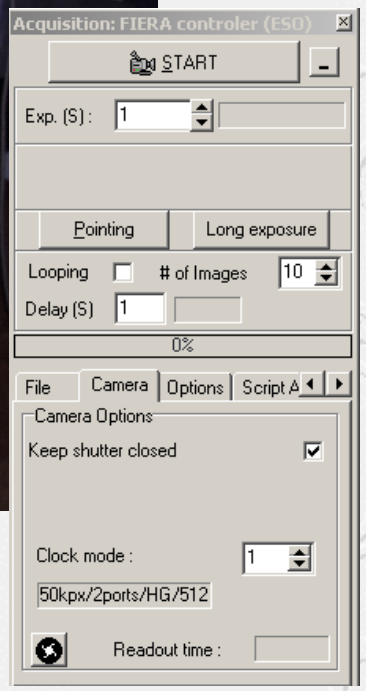
Outer ring :

- SMD boards
- «Flex-rigid »

ESO CCD Test-bench

- Double monochromator, 70cm integrating sphere
- Goal : characterize the whole system before going to the telescope





Automatic measurement software under Win2000

EEV44-82 CCD Performances (1/2)

Noise

- 1.9 e^- @ 50Kpx/s (80s) well suited for spectrographs
- 2.7e^- @ 100Kpx/s (40s)
- 4.7e^- @ 350Kpx/s (12s)
- 5.8e^- @ 625Kpx/s (7s) well suited for imaging

CTE

- Always > 0.999999

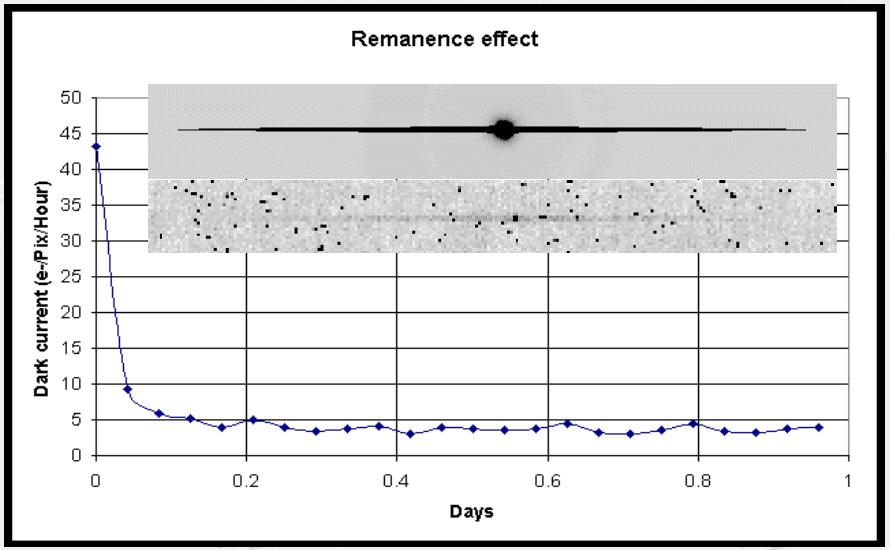
Dark current @-120C :

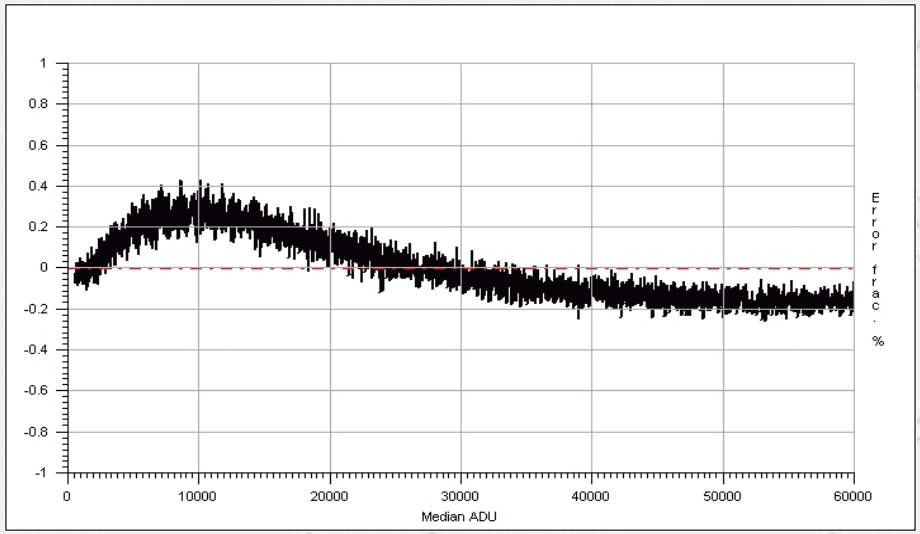
- Less than 5e^- /pixel/hour

(residual image may occur)

Linearity:

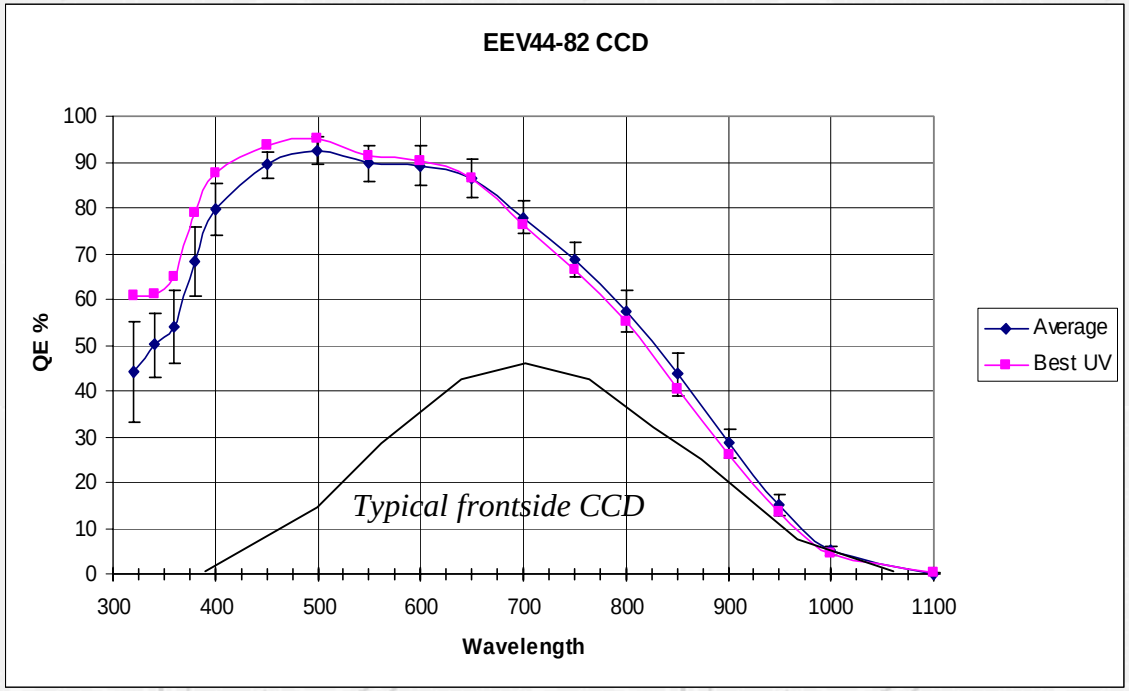
- Optimized by tunning OD, JD voltages





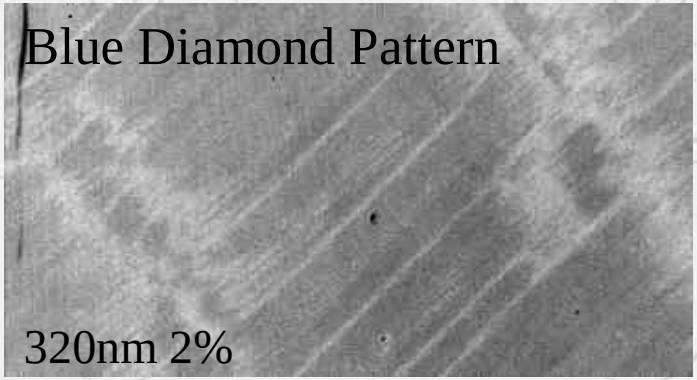
EEV Performances (2/2)

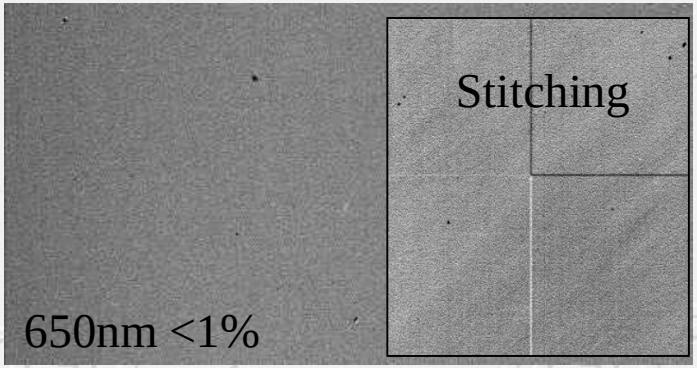
QE

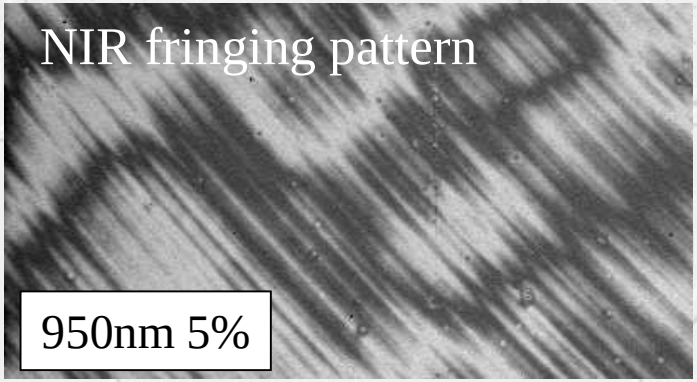


- Visible and blue RQE optimized (AR coating)
- But :
  - IR Fringes
  - Backside passivation -> UV-Blue Non-Homogeneity

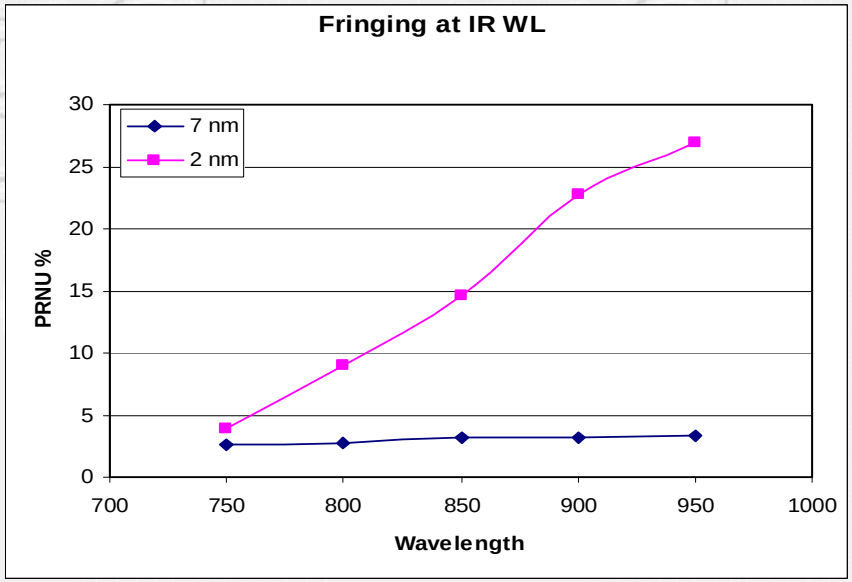
Bandwidth = 5nm, sub-windows of 300x150 pixels

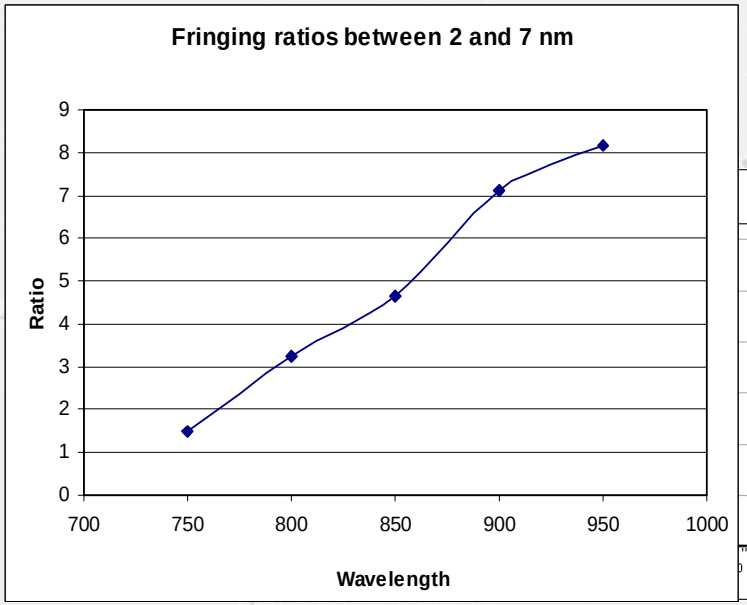


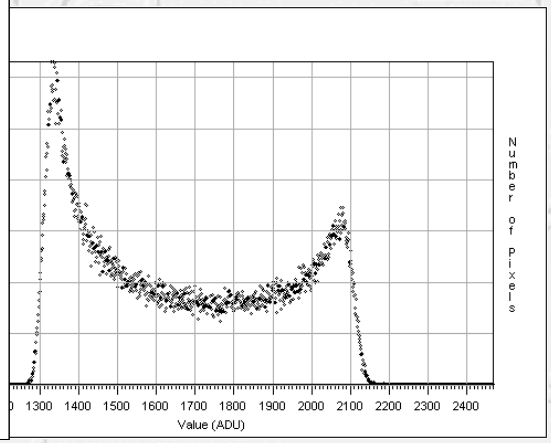




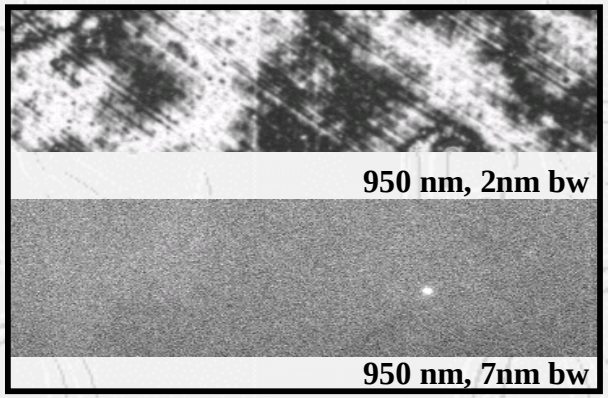
EEV Devices : Fringing

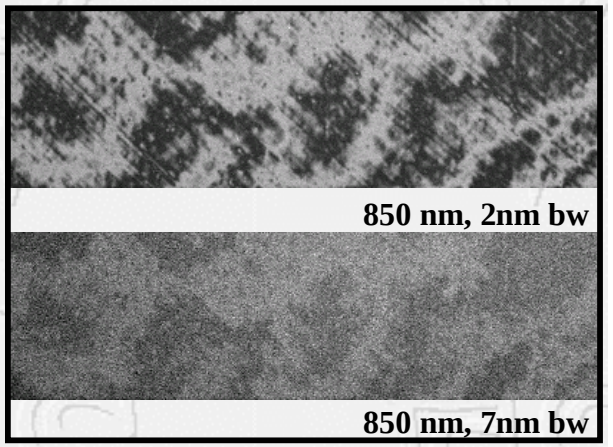


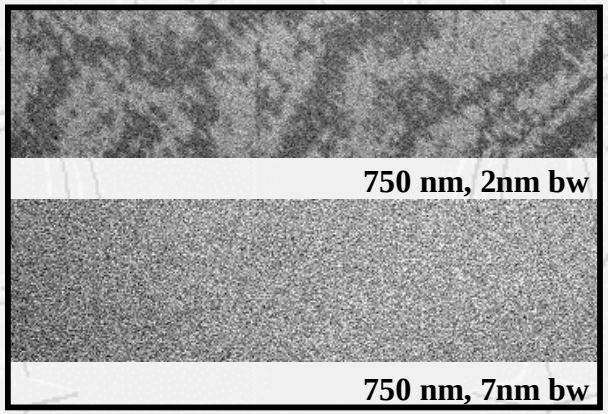




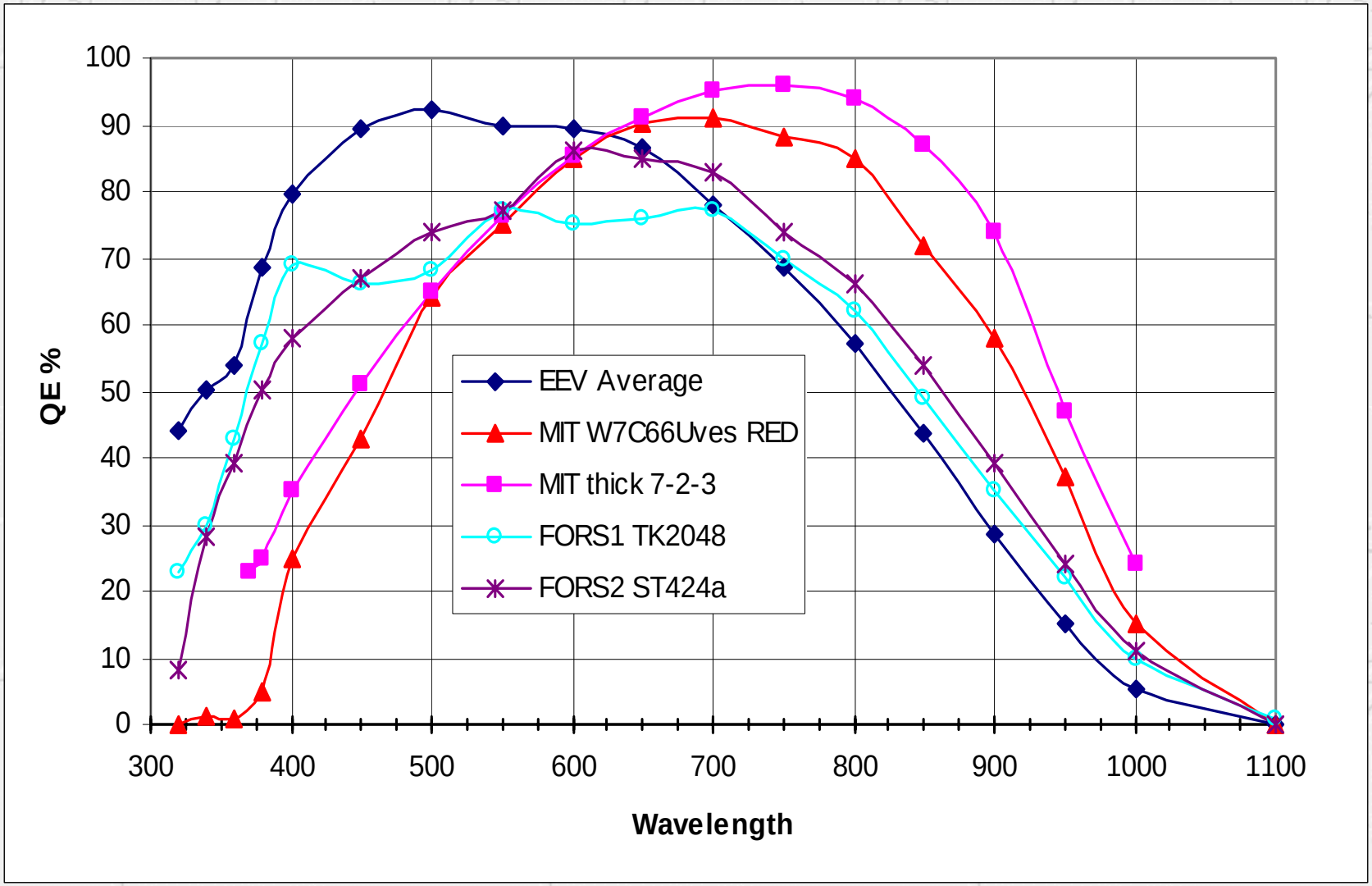
Pixel histogram at 950 nm, 2nm bw







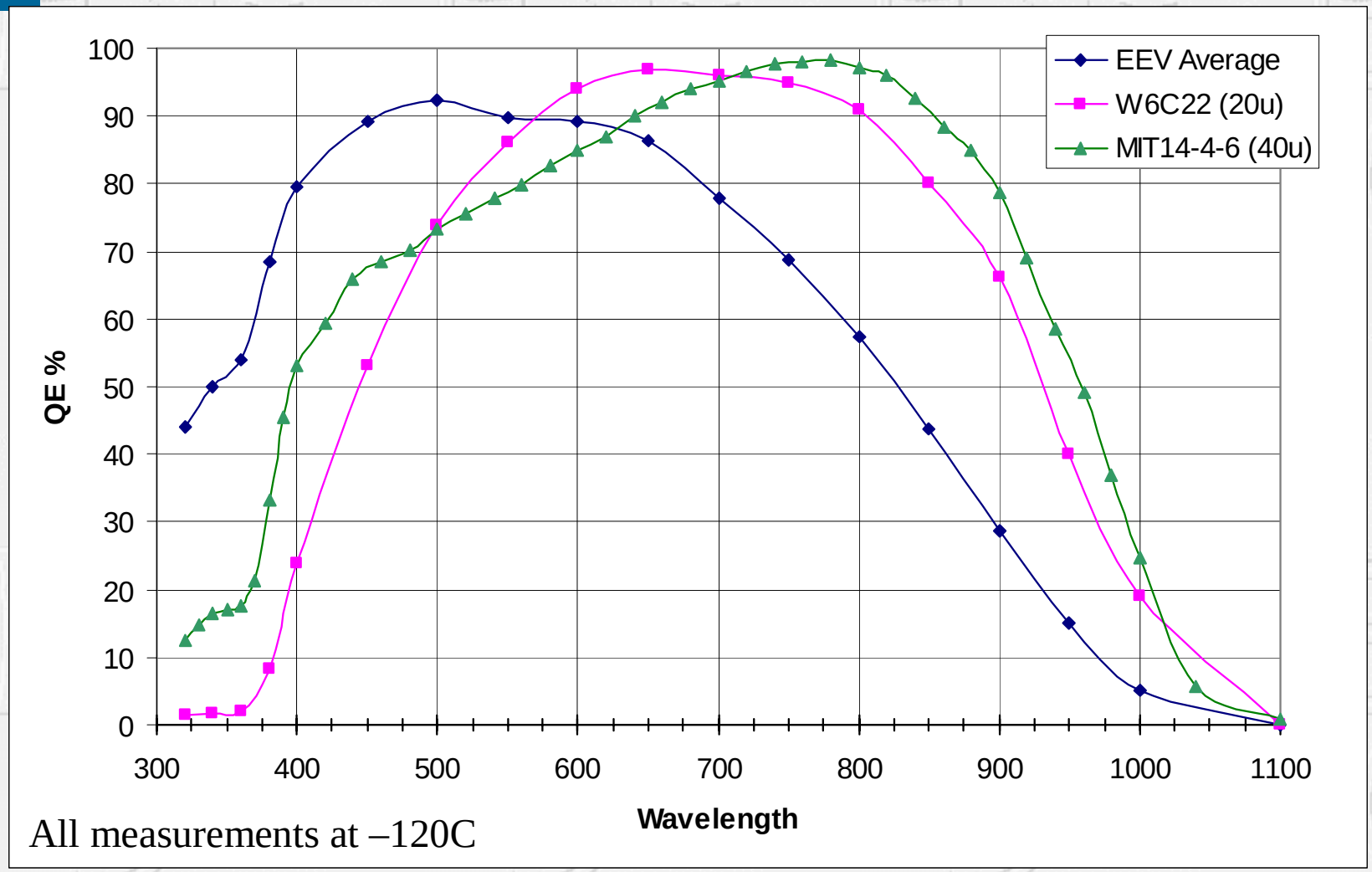
ESO CCDs QE



All measurements at –120C

MIT/LL CCID20

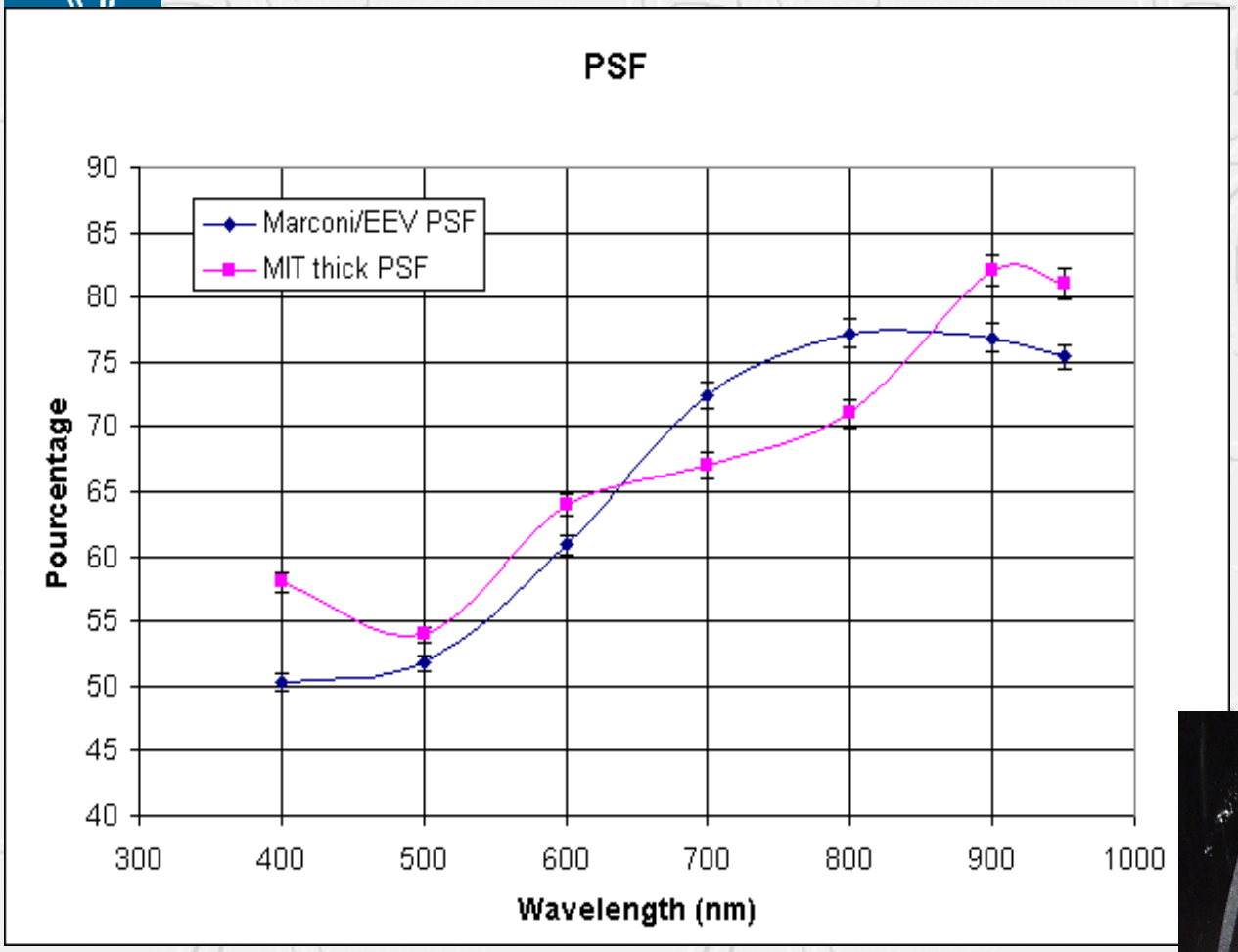
20-40 μm thickness



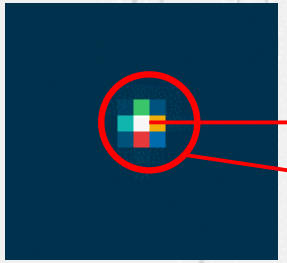
All measurements at –120C

…foreseen for FORS2 upgrade “Red arm”

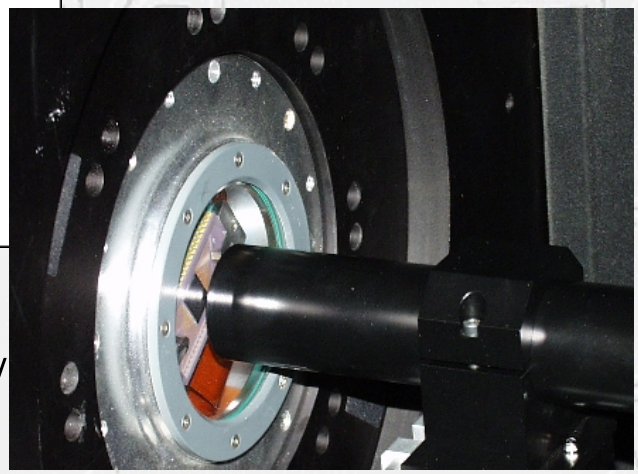
MIT (40µm)/EEV PSF



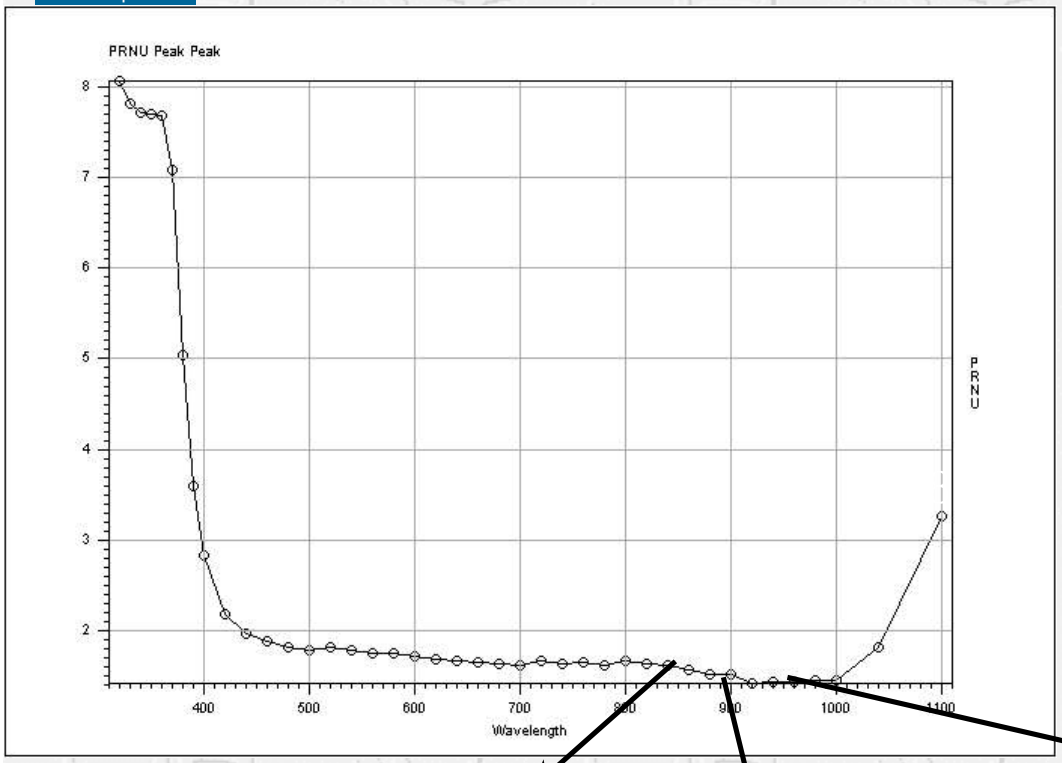
- Single pixel
- 5 µm Spot projector
- F2.8
- best XYZ spot adjustments
- Takes a while…

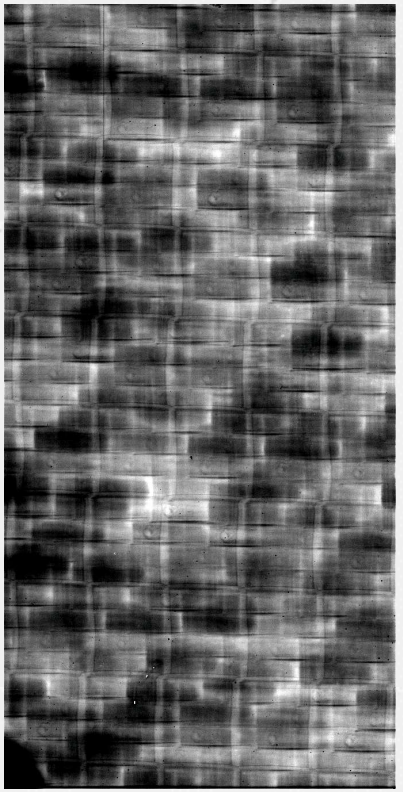


Energy in central pixel /
Total Encircled energy

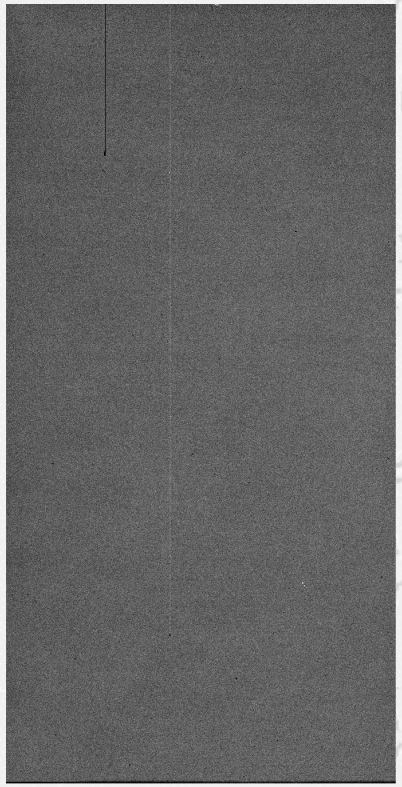


MIT/LL thick
PRNU/Cosmetic

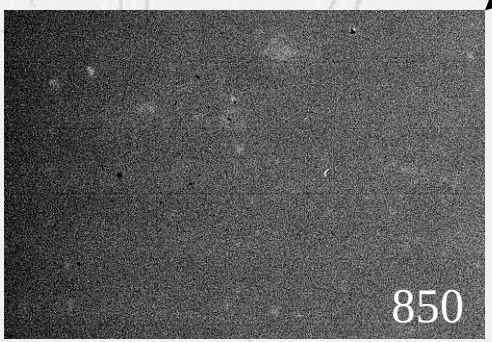




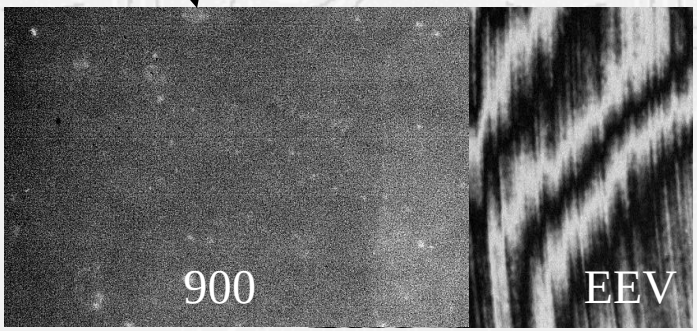
400nm

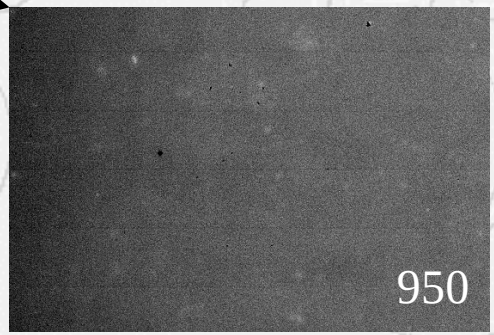


600nm



Bandwidth 2nm





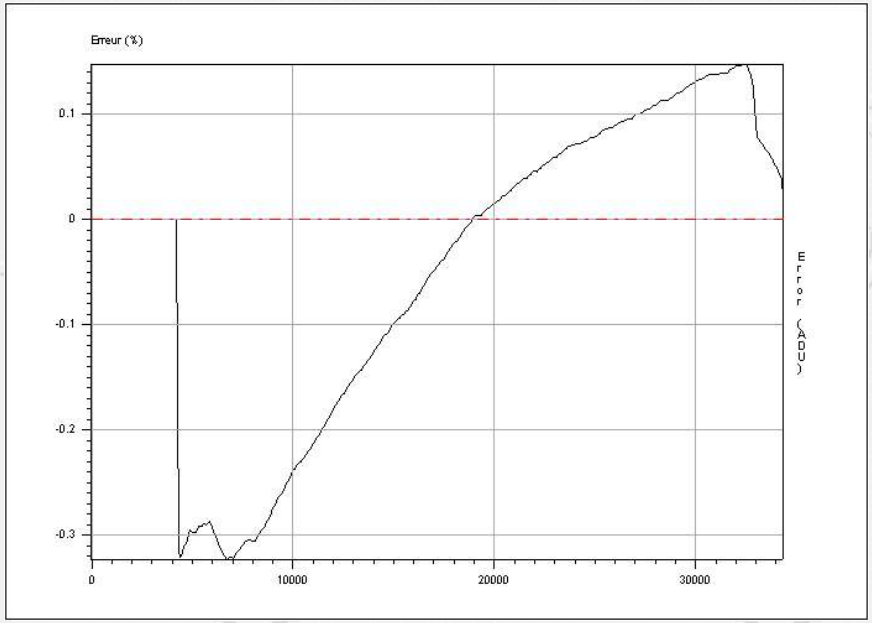
MIT/LL performances

Noise

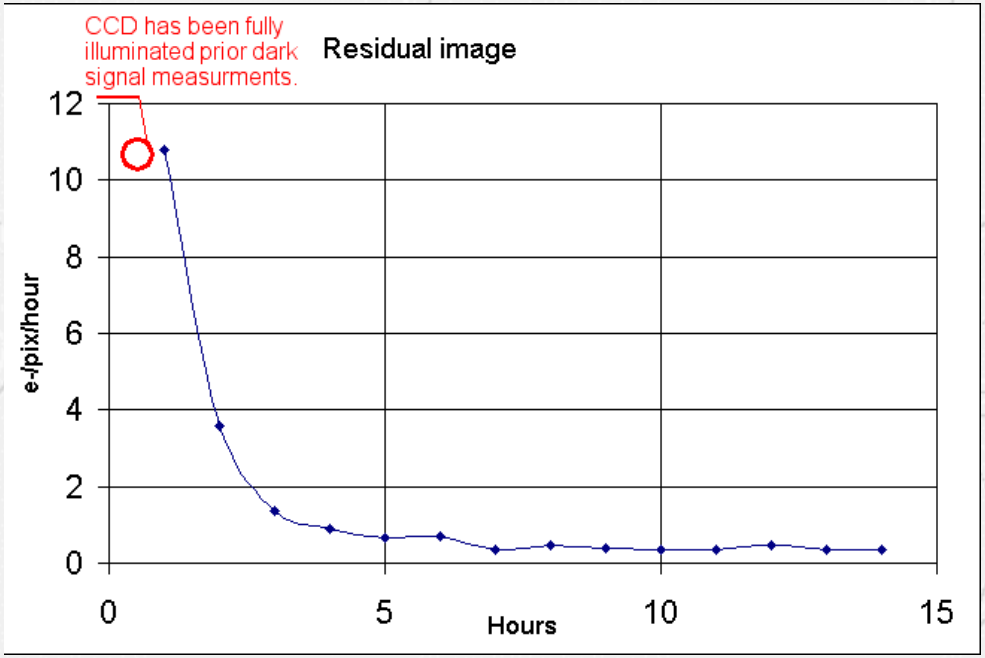
- 2.5 e^- @ 50Kpx/s (80s) well suited for spectrographs
- 3.7e^- @ 225Kpx/s (40s)
- 4.5e^- @ 625Kpx/s (7s) well suited for imaging

Linearity:

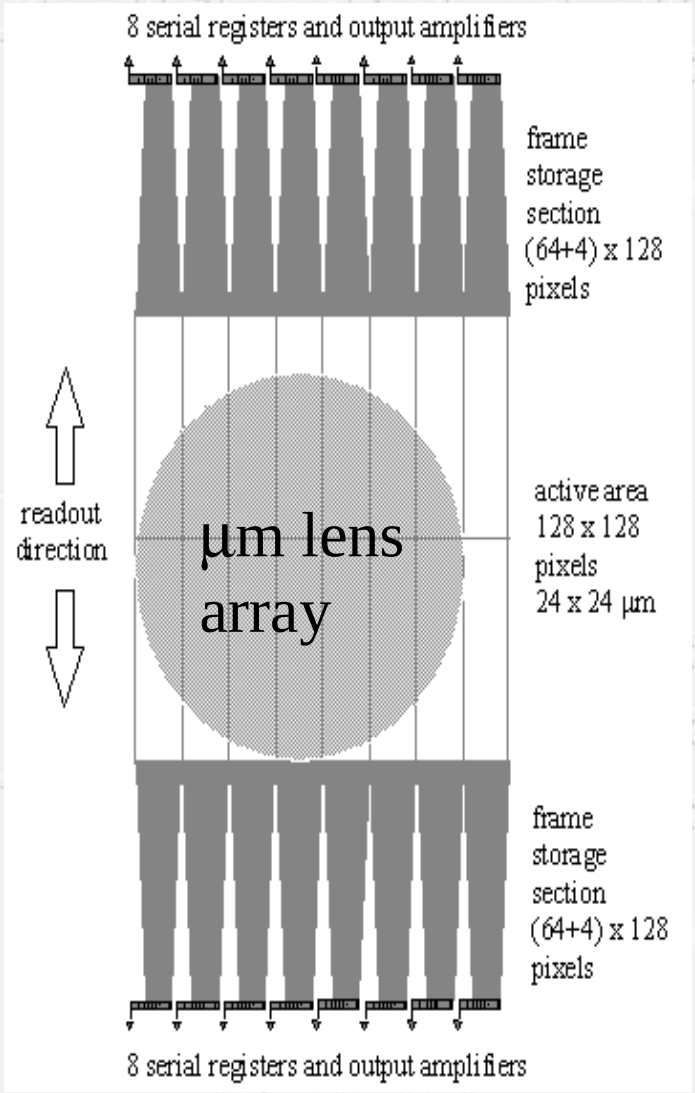
- Optimized by tunning OD, JD voltages
- non linearity kept under 0.5% pp



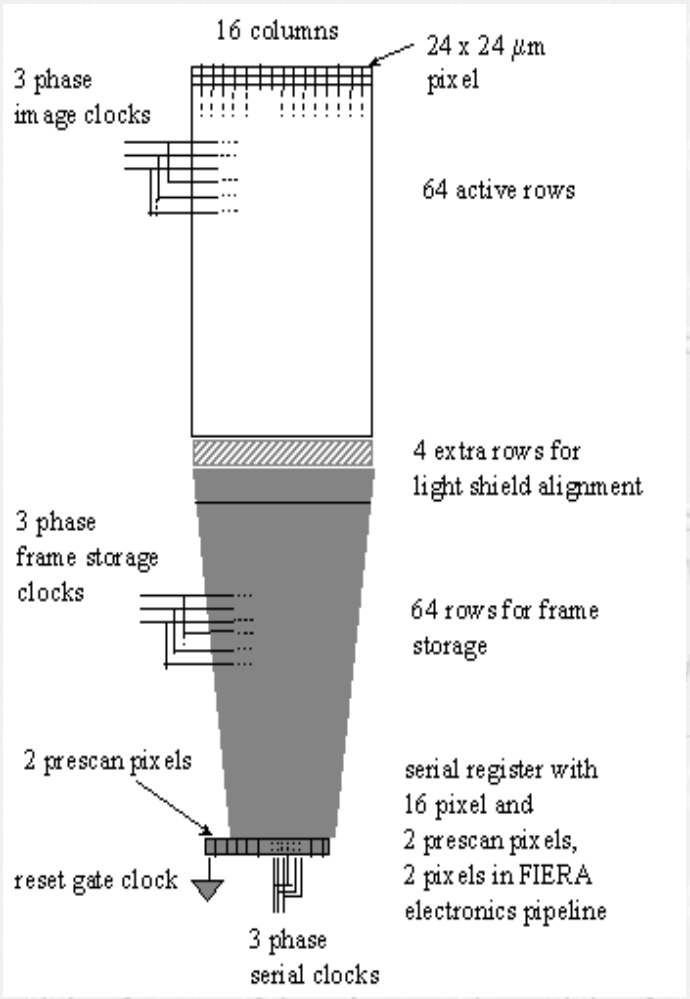
Dark Current @-120C

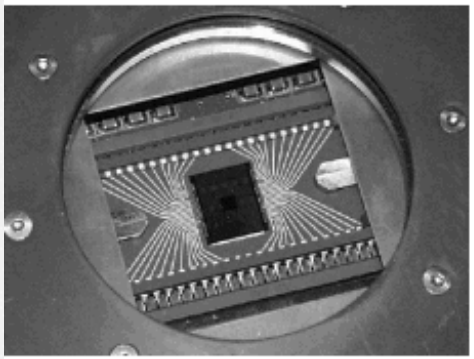


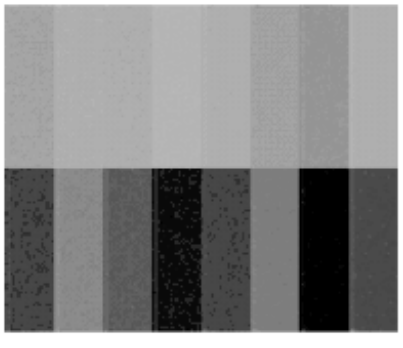
NAOS EEVCCD50 (AO CCD)
S-H Adaptive Optics

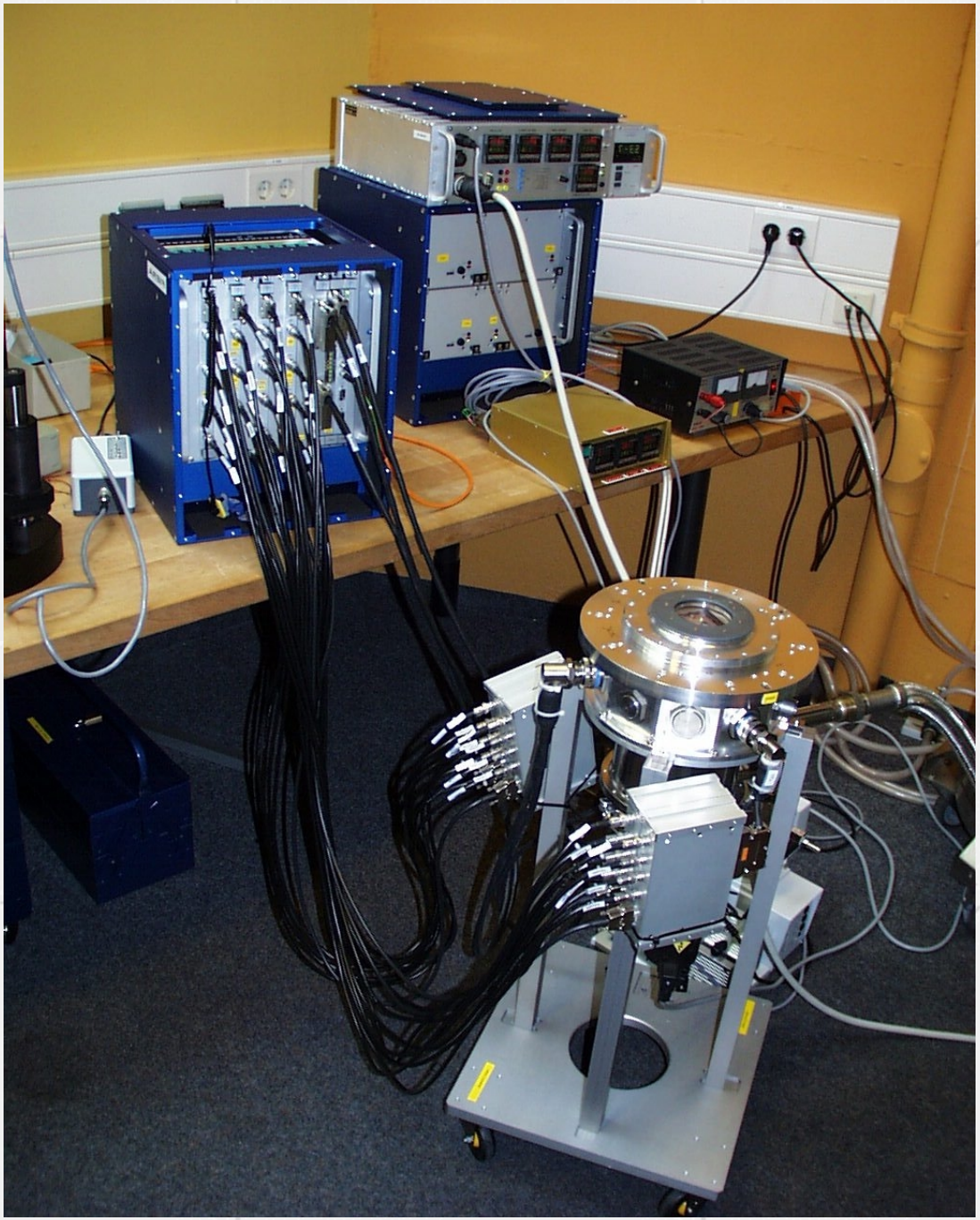


- 16 x 16x64 sub arrays
- 24 µm pixel
- 1000 fps







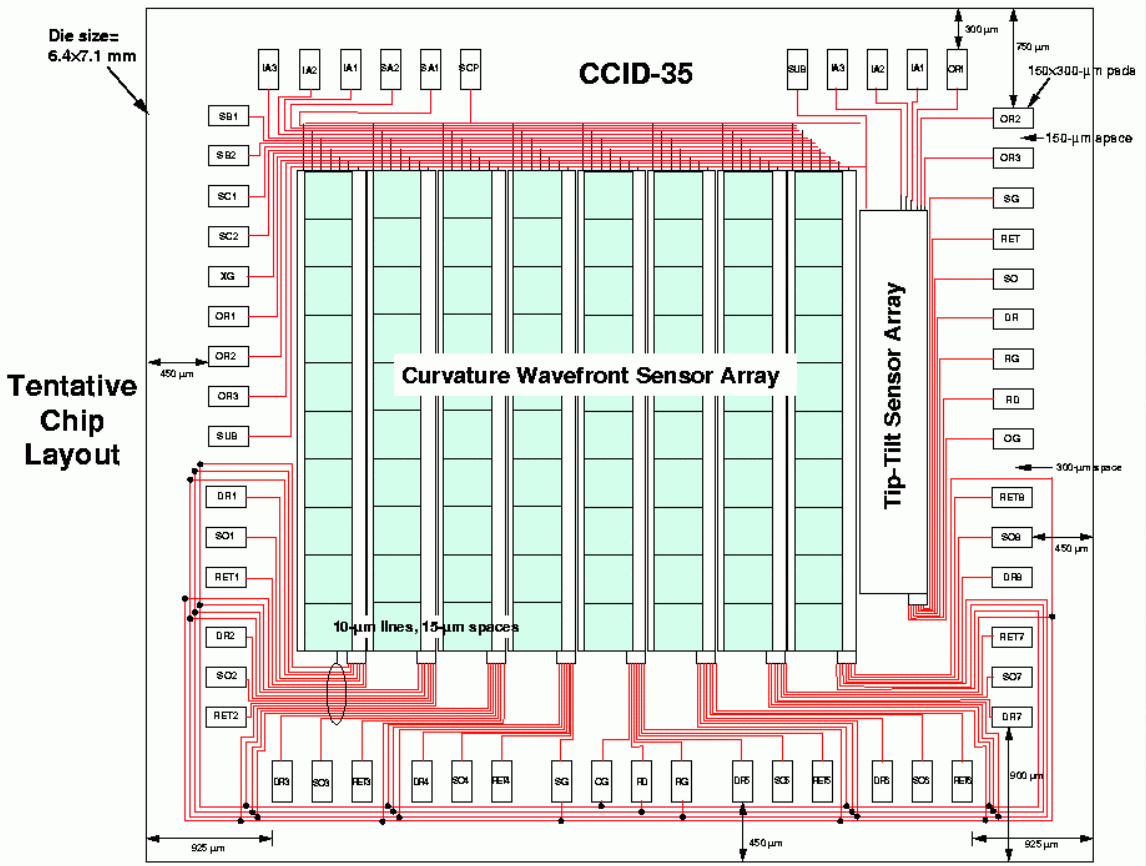


NAOS & FIERA

- 500 frames/sec
- 2.9e- noise @50kpx
- 16 Outputs

To be installed at UT4 in April 2001

New AO CCD developments ongoing at ESO



- Replace the APDs
- 60-element curvature systems for the VLT
- CCID35 : University of Hawaii with MIT/LL
- 2e- RON, 4000 Fps

- 80 superpixel :
  - Imaging section of 20×20 pixels, 18µm pixel size
  - 3 storage sections to allow charge to be added on chip over more integration cycles

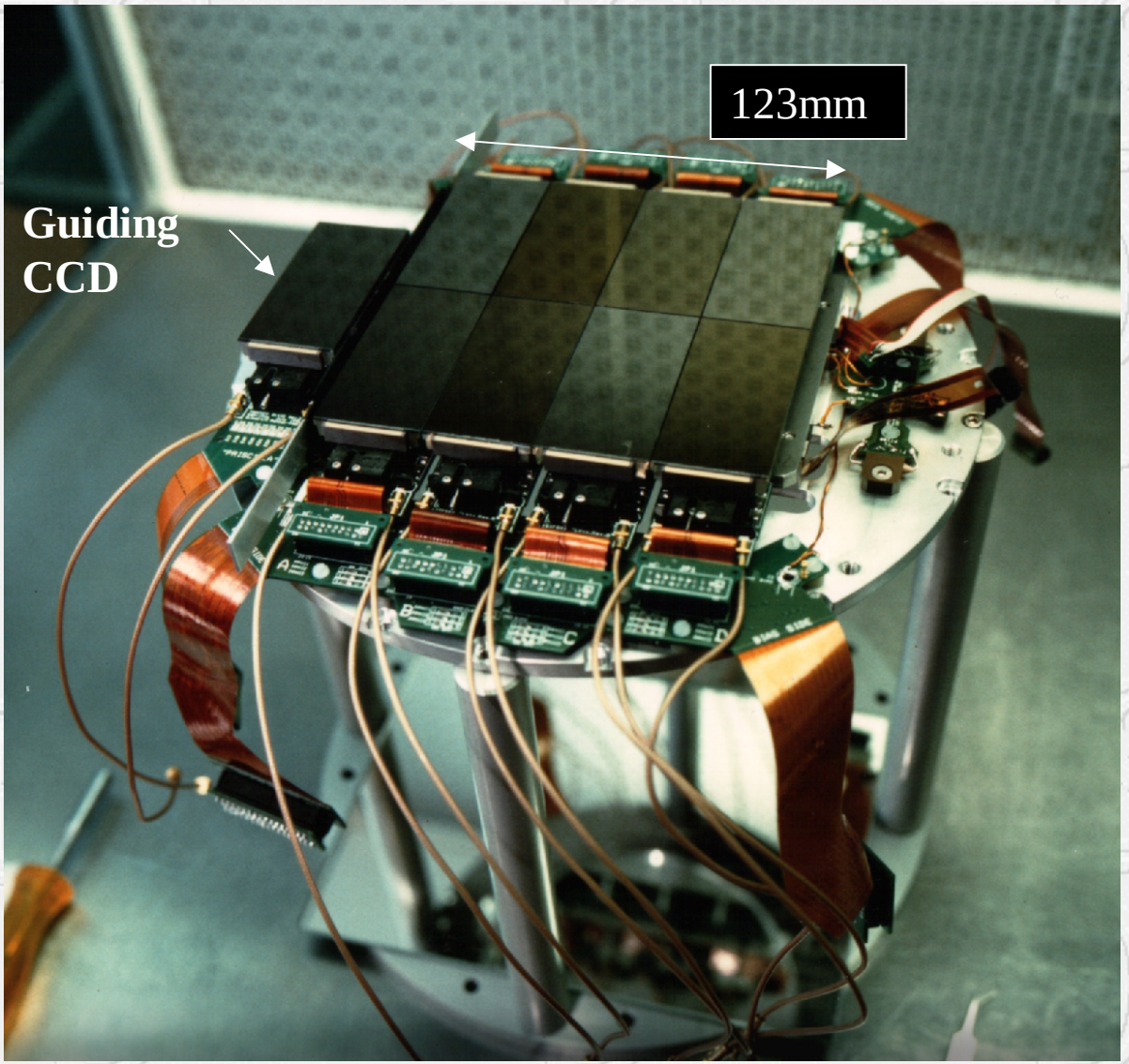
Mosaics at ESO : Wide Field Imager WFI

- 8 EEV CCDs 15 µm 2x4k

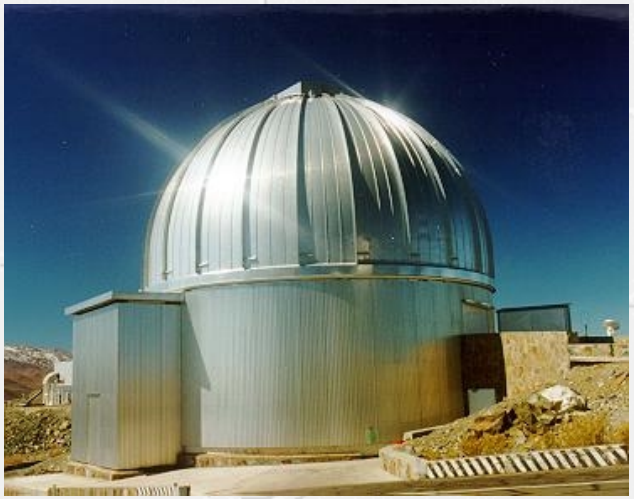
⇨ **8x8 k**

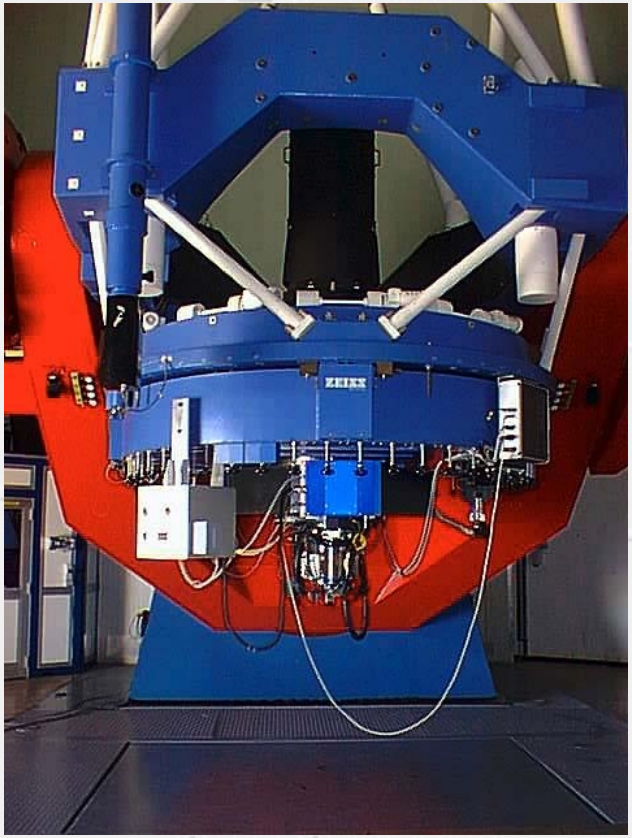
- Overall Flatness +-20µm

- 27sec readout time
- 1 image ⇨ 128Mb
- Noise 4.5e- @357kps
- CCDs at –100C
- Single FIERA to operate it
- Guiding CCD, 1Hz



72 millions of pixels...





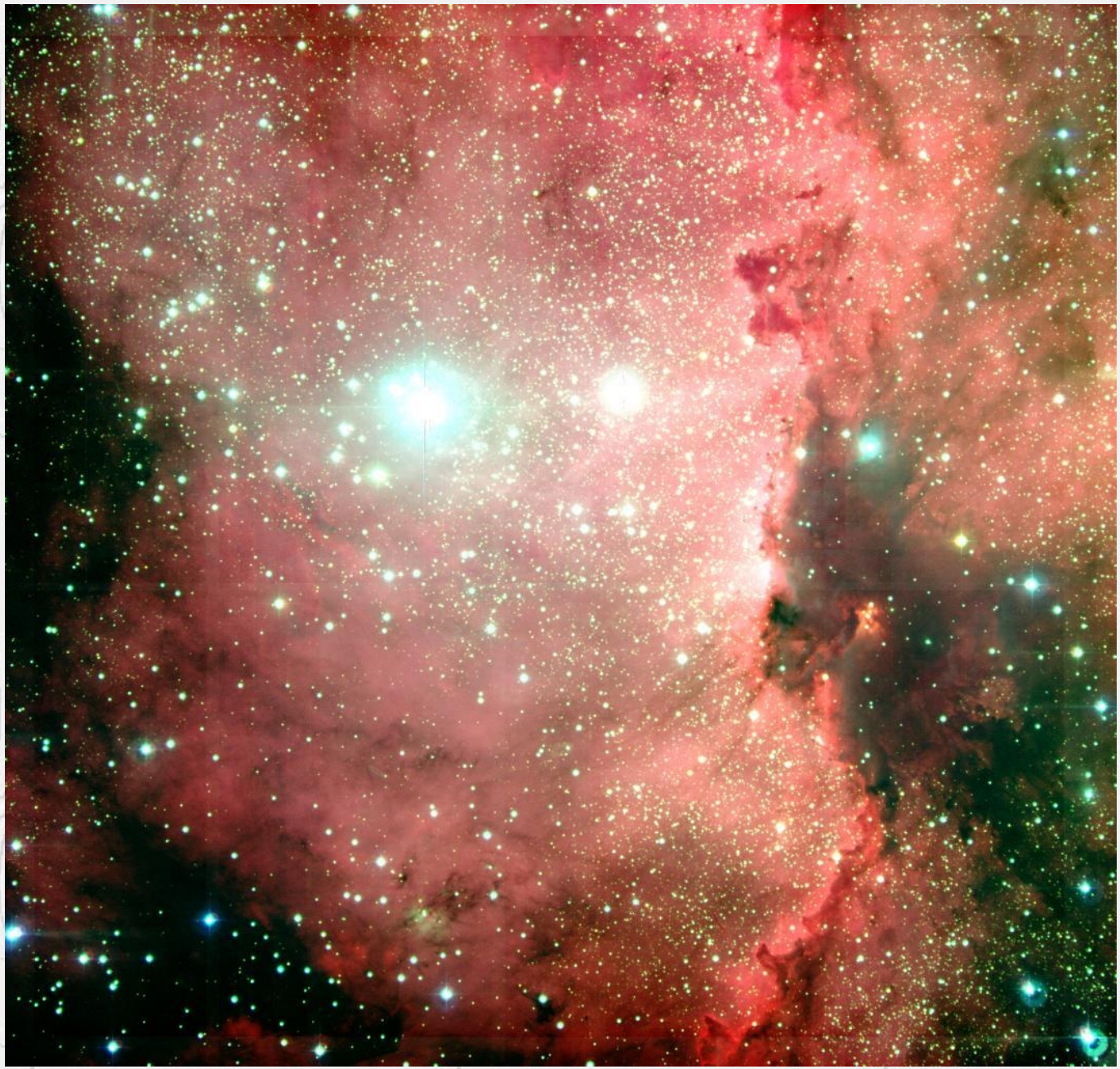
WFI@2.2m

- WFI installed at the 2.2m La Silla (Jan99)
- Field of 34x33', sampling 0.24 arcsec, F/5.9
- 0.6-0.8'' seeing
- 50 filters mounted to « juke-box »
- Polarimetry and Spectrographic (Grism)

Goals

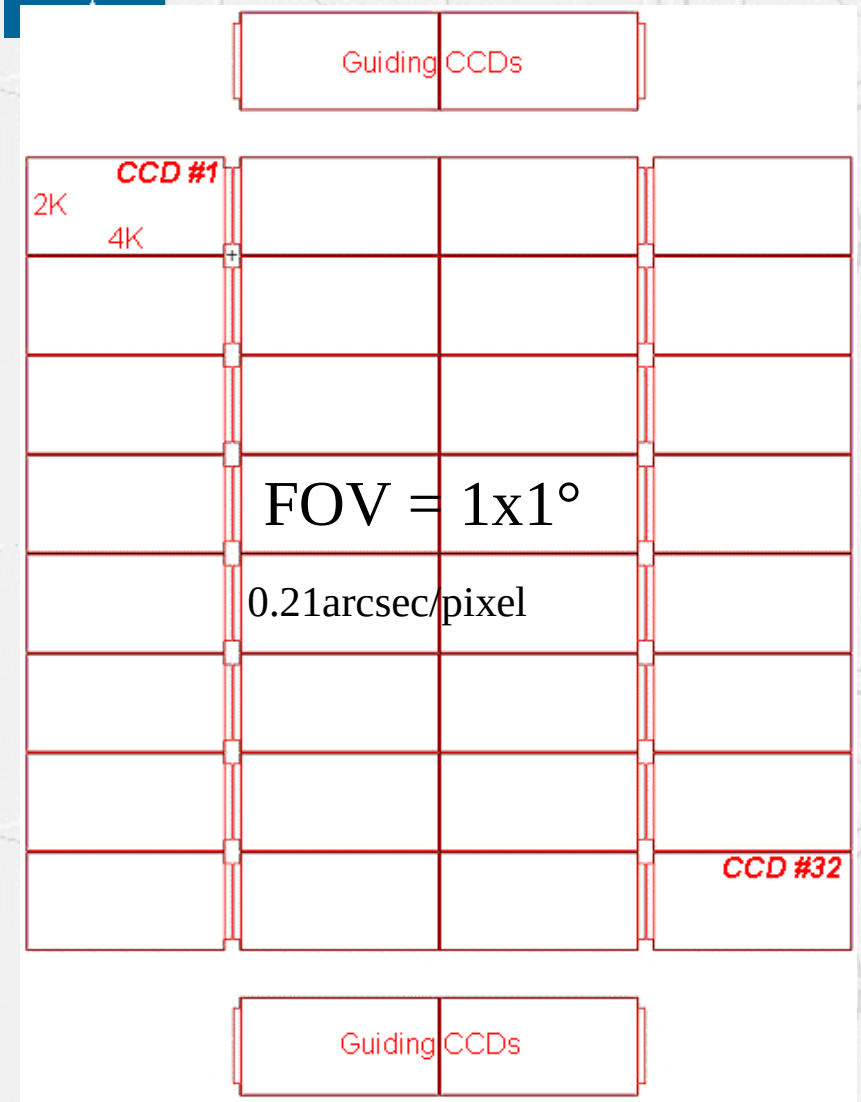
- Solar system : Kuiper belt objects
- UBVRI Deep Survey, resolution<1''
- Galaxy distribution and morphology
- Remote SN z=0.5
- Gravitational lensing induced by dark mater, Large scale effects to Universe
- Target for the VLT
- ….

Some images recorded with WFI@2.2

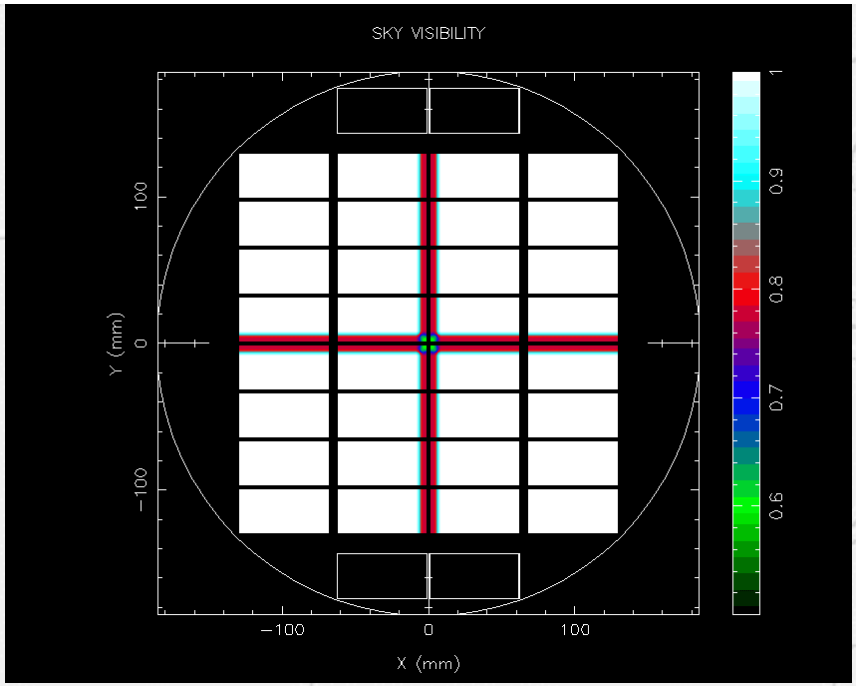


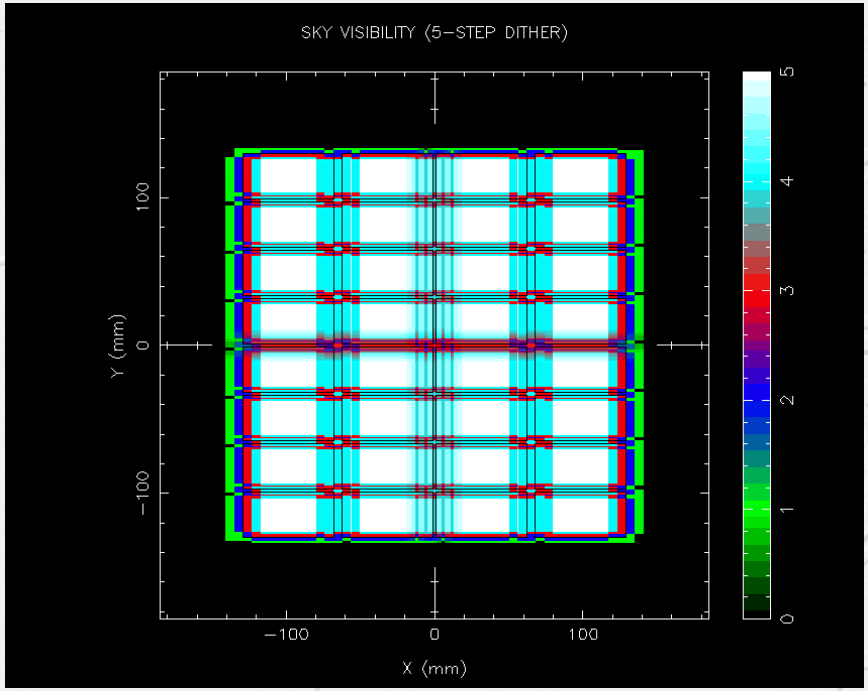
NGC253 WFI@2.2

ESO VST 2.6m
16x16K Omegacam



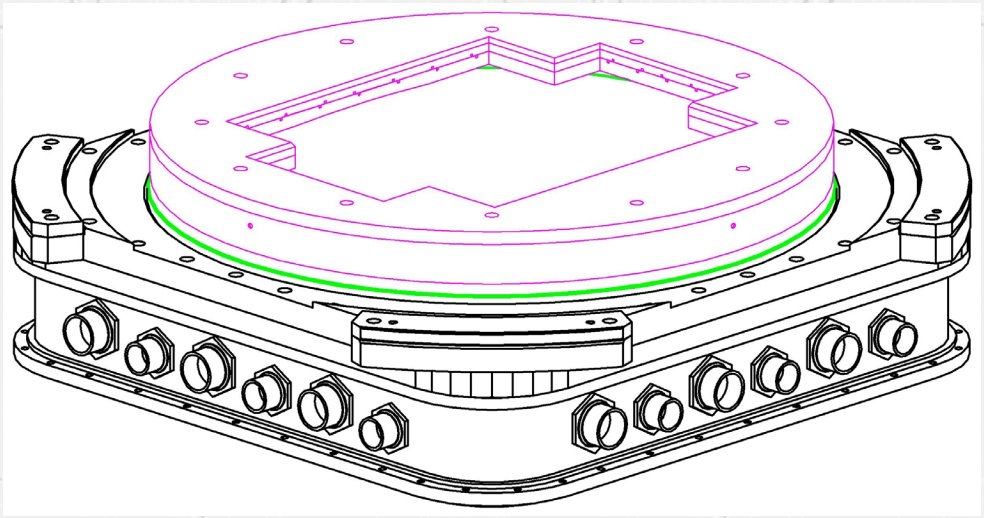
Marconi (ex-EEV) CCDs 2x4K

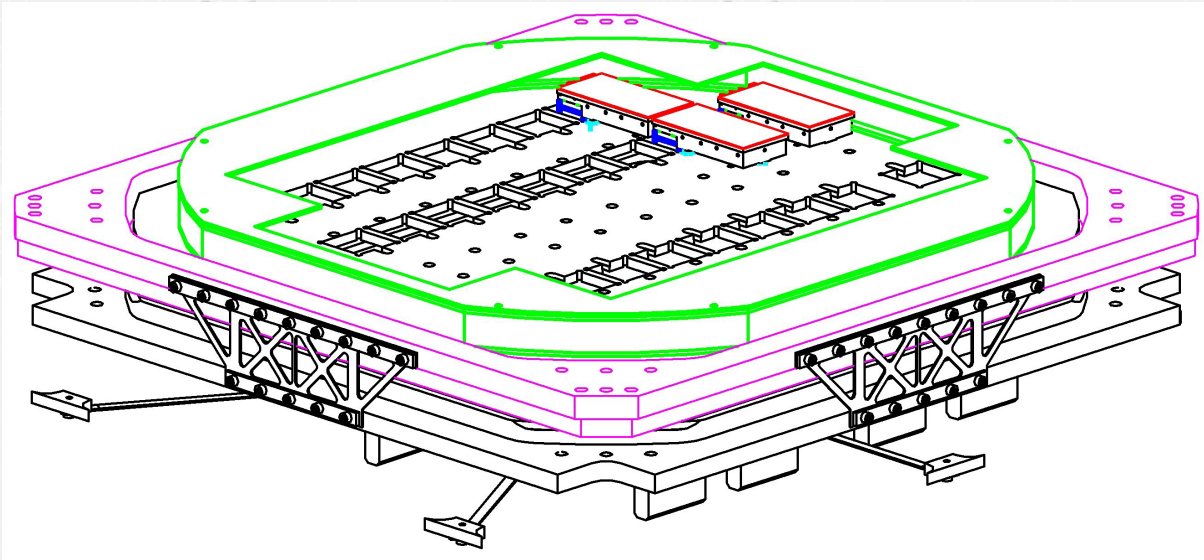


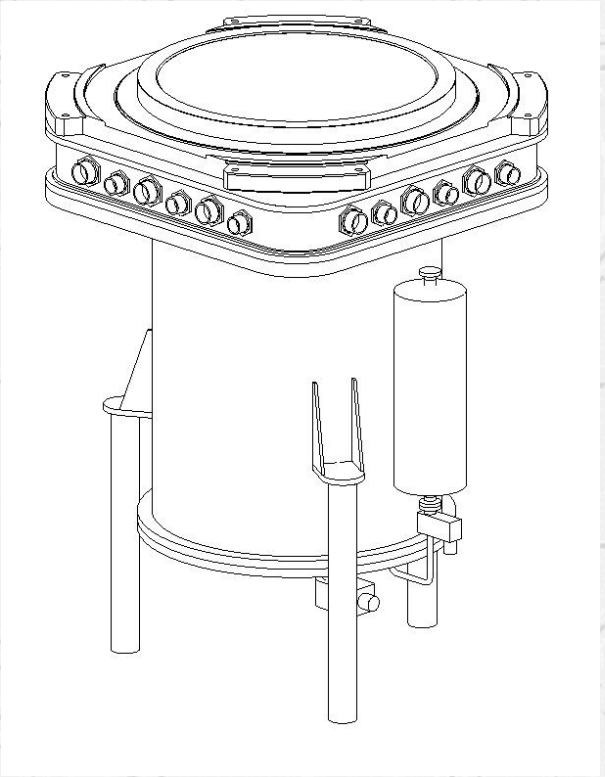


OMEGACAM

Mechanical designs (Preliminary)







CFC-Bath cryostat combination

Futures ODT deliveries

Instrument	CCD	Delivery Expected	Telescope	Application
HARPS	2 EEV 4k x 4k	2001	3.6m - LaSilla	Spectroscopy
GIRAFFE	EEV 2k x 4k	2001	UT2	Spectroscopy
OMEGACAM	16k x 16k, 32 Marconi CCD	2002	VLT Survey Telescope	Imaging
FORS 2 Upgrade	2 MIT/LL CCID20	2001	UT4	Imaging/ Spectroscopy
Emmi Red Upgrade	2 MIT CCID20	2001	NTT – La Silla	Spectroscopy
AVES	?	2003	UT2	Spectroscopy

Summary of systems delivered by ODT between 1998 - 2001

- 16 Systems
- 16 Controllers
- 31 CCDs + 16k x 16k (= 32 CCDs) : 63 devices

⇨ More than 400 M Pix

Conclusion

- In 2002, ODT will provide 18 CCD systems for optical instruments (Paranal-LaSilla)

- Already delivered : Fors1/2 , Uves, Vimos, Wfi, Naos
- Next to come : Omegacam, Giraffe, Harps
- Devices mostly used EEV44 - MIT/LL

- Next generation of optical instruments
- AO CCDs
- Upgrades : Fors,Uves, Giraffe

- Seeking for better CCDs performances
  - QE,noise (1e- @1Mhz ?)
  - Larger monolithic arrays : 4x4K

- Investigate new sensors : APS, STJs