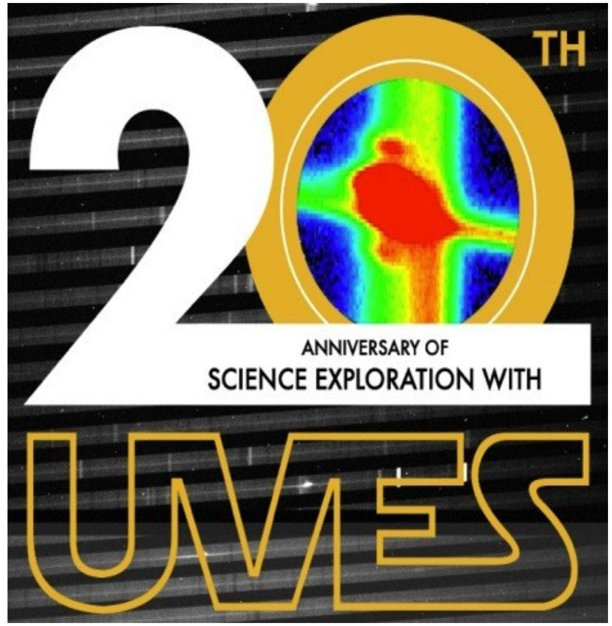
The Ultraviolet-Visual Echelle Spectrograph



UVES from instrument definition to start of operation

Key references, facts and passages (1986- 2000)

Sandro D'Odorico
European Southern Observatory

The framework

TELESCOPES

- *Convergence on the VLT 4 x8m concept (**Cargese&Venice workshops)** 1983 and 1986*
- *Proposal for construction 3.1987*
- *VLT project approved 12.1987*
- *NTT First light 3.1989*
- *10m Keck I- First light 5.1993*
- *Hubble ST +correct.optics 1.1994*
- *UT1 8m First light with TC 5.1998*
- *UT2 8m First light with TC ≈5.1999*

High-Medium resolution spectroscopy (300-1000nm) at large ESO telescopes:

- *CASPEC at 3.6m (1984-1999) – first echelle with CCD*
- *EMMI at NTT (1990-2008)– echelle mode in red arm*
- *UVES kick-off 4.1992*
- *HIRES at Keck –First light 7.1993*
- *First light of UVES 9.1999*
- *UVES Start of Operation 4.2000*

The VLT Working Groups (1985-86)

VLT Working Groups

SITE SELECTION

A. Ardeberg (Lund)
M. Sarazin (ESO)
H. van der Laan* (Leiden)
J. Vernin (Nice)
G. Weigelt (Erlangen)
H. Wöhl (Freiburg)

INTERFEROMETRY

O. Citterio (Milano)
D. Downes (IRAM)
A. Labeyrie (CERGA)
P. Léna* (Paris)
J.E. Noordam (Dwingeloo)
F. Roddier (Nice/NOAO)
J.J. Wijnbergen (Groningen)
R. Wilson (ESO)

HIGH RESOLUTION SPECTROSCOPY

I. Appenzeller* (Heidelberg)
D. Baade (ESO)
L. Delbouille (Liège)
S. D'Odorico (ESO)
D. Dravins (Lund)
P. Felenbok (Meudon)
M. Mayor (Genève)
P.E. Nissen (Aarhus)
J. Solf (MPI Heidelberg)

LOW RESOLUTION SPECTROSCOPY + IMAGING

H.R. Butcher* (Groningen)
J. Danziger (ESO)
M.-H. Demoulin-Ulrich (ESO)
M. Dennefeld (IAP)
S. Di Serego Alighieri (ST-ECF)
B. Fort (Toulouse)
T. Gehren (Munich)
C. Jamar (Liège)
P. Shaver (ESO)

INFRARED ASPECTS

B. Carli (Florence)
E. Kreysa (Bonn)
D. Lemke (MPI Heidelberg)
A. Moorwood* (ESO)
G. Olofsson (Stockholm)
P. Salinari (Florence)
F. Sibille (Lyon)

VLT ADVISORY COMMITTEE

J.P. Swings*
I. Appenzeller
H.R. Butcher
M.-H. Demoulin-Ulrich
P. Léna
A. Moorwood
P. Shaver
H. van der Laan
J. Wampler

WG s and open Venice workshop: first structured involvement of the scientists

**Grouped by obs. technique, not science* **In the 80' out of 50 members, 2 women*

The VLT Proposal to Council (March 87)

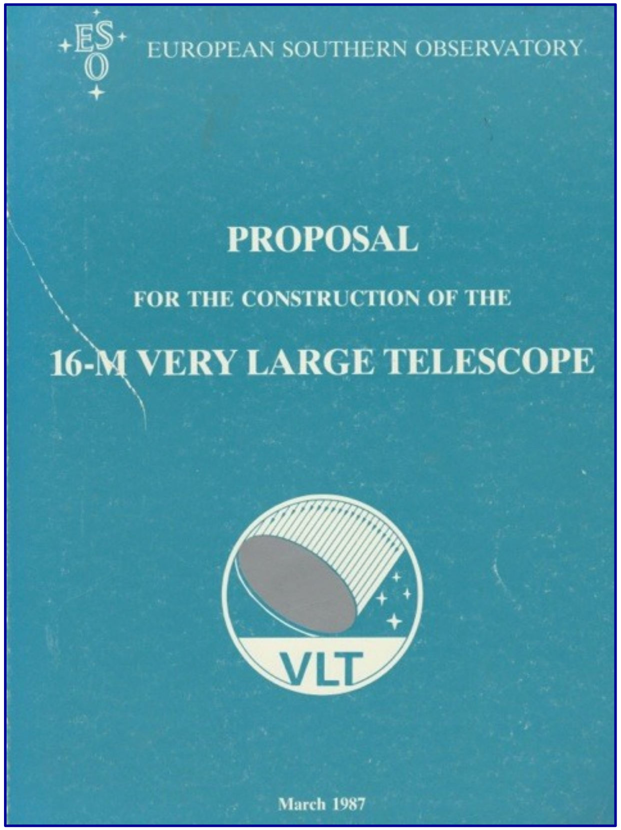


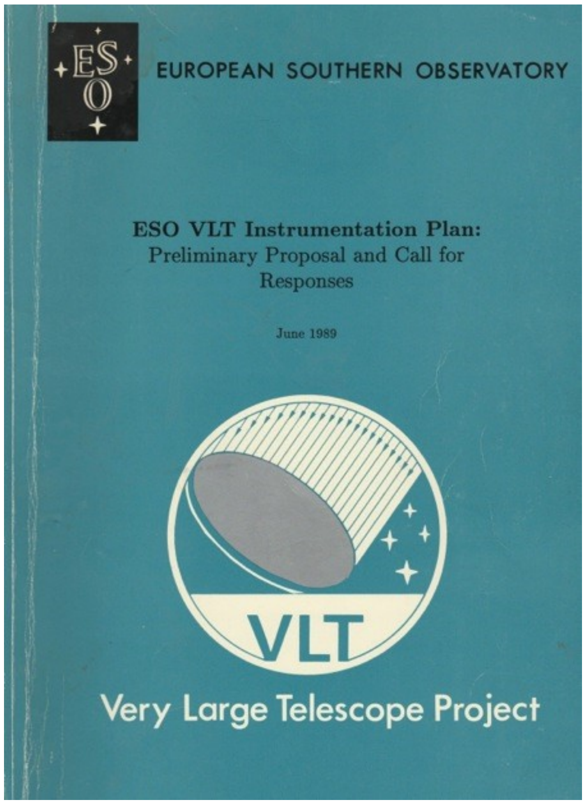
TABLE 10.1

VARIOUS FOCI OF THE VLT

FOCUS	F.O.V.	F/No.	FIELD ROTATION COMP.	ADC	INSTRUMENTS
NASMYTH 1 (Optical)	30 arcmin	F/15	Yes	Yes	Imaging/ Spectroscopy 0.3 - 1μm
NASMYTH 2 (IR)	30 arcmin	F/15	Yes	No	idem 1 - 10μm
(CASSEGRAIN)	15 arcmin	F/13.3	Yes	No	tbd (Later Implementation)
INDIVIDUAL COUDÉ - Visible - Infrared	0.5 2 arcmin	F/74 F/32	Possible Possible	No No	Specific Instruments/ Experiments
COMBINED COUDÉ - Visible - Infrared	30 60 arcsec	F/26 F/18.9	No	No	High Resolution 0.3 - 5μm
INTERFEROMETRY	3 arcsec	tbd	Possible	Yes	Interferometric Set-up

- The 1987 VLT proposal included no instrumentation plan
- Full duplication of the instruments at all telescopes
- Included a few very preliminary instrument concepts

The VLT Instrumentation Plan Proposal, June 89



DISTRIBUTION OF THE DOCUMENT
"ESO VLT INSTRUMENTATION PLAN:
PRELIMINARY PROPOSAL"
(June 1989)

- **To institutes in the member countries**

Belgium:	8	The Netherlands:	16
Denmark:	5	France:	26
Germany:	22	Sweden:	6
Italy:	21	Switzerland:	5

Total: 103

- **To scientists (upon request or unsolicited)**

Belgium:	2	France:	40
Denmark:	14	Sweden:	6
Germany:	13	Switzerland:	2
Italy:	10	U.S.A.:	21
The Netherlands:	12	Others:	14

Total: 134 copies Total:

- **To members of the ESO COMMITTEES (OPSC, USER, STC, FINANCE, COUNCIL) of the board of directors of A & A, of the Instrumentation and Interferometry panels, the Site Selection Committee**

Total: 84 copies

The VLT Instrumentation Plan,ESO-STC 105 (Feb.90)

ESO/STC 105

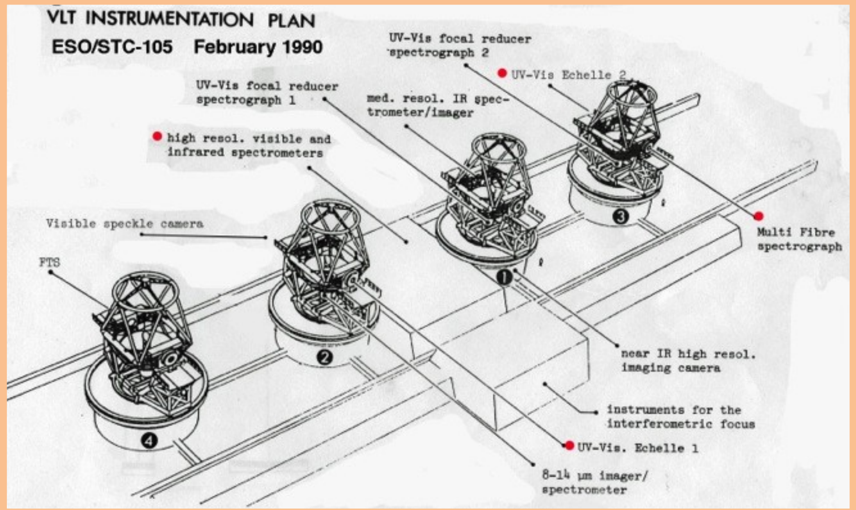
Chapter 4

Implementation of the Instrumentation Plan

4.1 Instruments to be built

The instrumentation plan described in the two preceeding chapters foresees 10 different VLT instruments. These are listed in Table 4.1.

VLT-I 1	Med. Resol. IR Spectrometer/imager	Nasm.	ISAAC
VLT-I 2	UV-Vis. Focal Reducer/Spectrograph x 2	Cass.	FORS1 & 2
VLT-I 3	UV-Vis. Echelle Spectrograph x 2	Nasm.	UVES
VLT-I 4	Near IR High Resolution Imaging Camera	~~Coudé~~ Nasm.	CONICA
VLT-I 5	Multi-fibre Area Spectrograph	Nasm.	FLAMES
VLT-I 6	~~Visible Speckle Camera~~	Nasm.	
VLT-I 7	8-14 μm Image/Spectrometer	Cass.	VISIR
VLT-I 8	High Resolution/Visible Spectrograph	Combined	ESPRESSO
VLT-I 9	~~Multichannel FTS~~	Nasm.	
VLT-I 10	High Resolution/Infrared Echelle Spectrograph	~~Combined~~ Nasm.	CRIRES



What was new:

- Cassegrain focus now in the baseline
- Selection of first 4 instruments (2 duplicated) + 6 being considered, with some preliminary optical design
- Identification of the two ESO-built instruments (NIR Imager-Spectrograph and UV-Vis Echelle Spectrograph)

The VLT Instrumentation Plan, Feb.90

Lively debate within ESO management on the choice of instruments and their procurement

Joe Wampler (scientific advisor to the DG) and Jacques Beckers (head of the high angular resolution group) recommended to ***give higher priority to instruments taking advantage of the diffraction limit and the photon collecting power*** *of the 8 m telescopes (modes with potential higher advantage with respect to 4m class)*

Daniel Enard (Co-leader of the VLT project with Massimo Tarenghi in 1990) recommended to ***cancel the development of the two instrument in house (ISAAC and UVES) to free manpower for the implementation of the coudè path for interferometry at an early stage***

as of memos to the DG in 1990

Participation of external institutes to the VLT Instrumentation

Why we had to: build two instruments at ESO, build the others in the institutes

	INSTRUMENTATION	PROCUREMENT OF INSTRUMENTS	VLT Review January 93

INSTRUMENTS FOR THE VLT (1990 →)

- 2 Instruments to be built initially by ESO to
  - exploit proven capabilities
  - establish standardization aspects in relation to 'real' instruments
  - maintain hands on experience of technical staff required to specify and monitor externally built instruments
  - maintain instrumentation expertise within ESO over the long term
- 7 Instruments to be contracted to Institutes to
  - increase community involvement and identity with VLT
  - exploit unique expertise in the community
  - overcome ESO manpower limitations
  - reduce cost with respect to fully industrial approach

SCIENTIFIC GOALS AND REQUIREMENTS TO THE M-H RESOLUTION SPECTROGRAPH AT THE VLT

From the High Res. Spect. Working Group (Oct 1986)

Chemical composition and atmosphere of stars; Stellar winds, circumstellar mass flows; Stellar rotation; Stellar magnetic fields; composition and kinematics of IM; Radial velocity studies; Kinematics of galaxies and galactic nuclei; IGM from absorption lines to high z QSO.

4 spectrographs at Nasmyth with R≤ 2 x 10^4 with coverage 300-1100nm + a combined focus spectrograph with R≤ 1 x 10^5

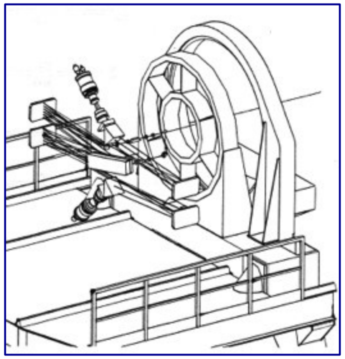
ESO Workshop on HR Spect. with VLT (Feb.1992)

28 scientific talks, 7 extragalactic and on cosmology.
Panel discussion on the different trade-off

Functional requirements/Performance targets in UVES Technical Specifications

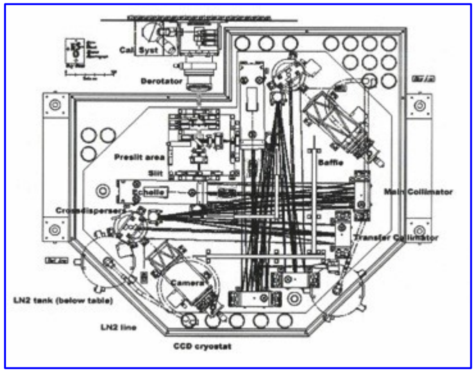
UVES from initial concept to the shipment to Paranal

Feb.1990 *Two M-H Resolution UV-V spectrographs in Inst. Plan. First optical concept (EMMI-like)*



Apr. 1992 *Kick-off, Issue 1 of Tech.Specs: two copies, at UT2 and UT3 , higher R mode to be studied in PD Phase for UVES2*

Apr 1994 *ESO/STC Nr. 151, cancellation of UVES2, higher R in red arm + additional novel features*



April 1996 *Issue 2 of Tech.Specs with final Functional and Performance Requirements*

Sept 1998 *First light of visual-red arm in Garching with solar spectrum*

May 1999 *Test in Europe completed, UVES off to Chile by plane and ship*

Rationale to cancel the second UVES as in ESO/STC 151 (1994)

With the approval of FLAMES, part of the rationale for the duplication, higher speed in the completion of scientific programs which require statistical sample, is no longer valid

High scientific competition for the Nasmyth foci from other instruments

Shift in schedule of UT2 and UT3 in June 93 VLT schedule stretches in time the commitment of staff for the integration and commissioning of UVES, interfering with the work on other instruments

Cancellation implies release of 3.3 MDM which are needed for a timely start of future instruments for UT3 and UT4

UVES design highlights / most difficult passages

- Pupille Blanche spectr. concept by Baranne, skillfully expanded by Delabre
- Two arms to cover optimally the range 310-1000nm, dichroics for parallel operation
- Refractive cameras with external focal plane for easy interfacing with detector
- Use of R4 echelle grating to reach R≈50000 with reasonable beam size (20cm)
- Gravity invariant configuration (derotator + static spectrograph on optical table)

Next talk by Johan on Optical Design!

- Procurement of R4 mosaic grating (largest ever realized, 2 replicas on glass substrate)
- Procurement of CaF2 large blanks for blue camera lenses and their figuring
- Procurement of optimal coatings and dichroics
- Procurement of large, state of the art CCDs for both arms from different sources

The design, construction and commissioning team

THE UVES TEAM

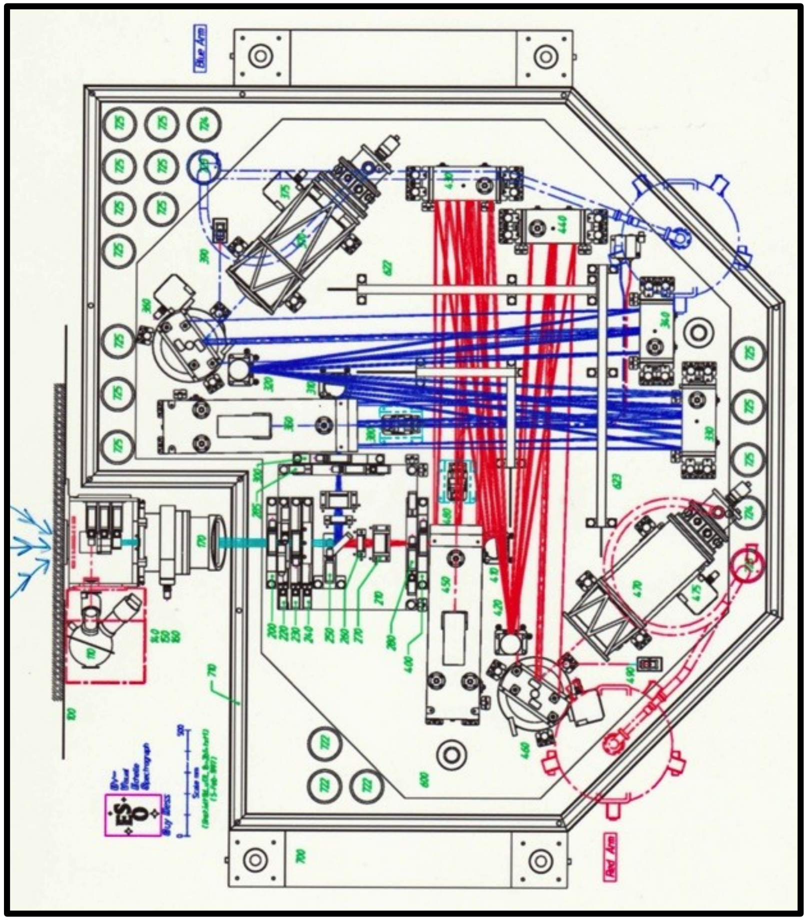
Project Manager, Optical Engineering:	*H. Dekker*
Instrument Scientist , Opt. Ins. Dept. Head	*S. D'Odorico*
Optical Design:	*B. Delabre*
Mechanical Engineering and Design:	*H. Kotzlowski, G. Hess*
Control Electronics:	*S. Moureau*
Control Software:	*A. Longinotti, P. Santin and P. Dimarcantonio (Obs.Trieste), R. Schmutzer* <--
CCD Detector Integration and Testing:	*R. Dorn, C. Cumani*
Opto-mechanical Integration and Testing, Cryogenics:	*J.L. Lizon à l'Allemand, C. Dupuy, A. Silber*
Data Flow System (Pipeline, Instrument Model and ETC, P2PP):	*P. Ballester, O. Boitquin, M. Chavan, A. Modigliani, S. Wolf*
Testing in Europe, Commissioning, Calibration and Operation at Paranal:	*A. Kaufer*
Astronomical Support, Documentation, Data Reduction, Testing of Pipeline:	*S. Cristiani, V. Hill, L. Kaper, T. Kim, F. Primas* <---

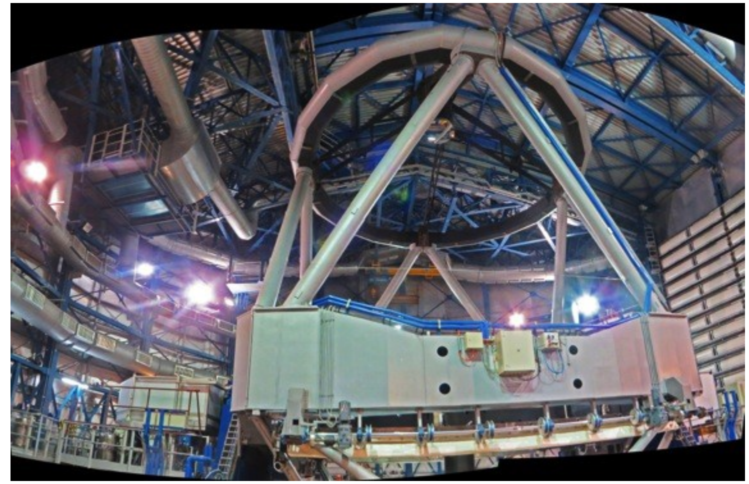
External Advisory Science Team: *B.Gustafsson, H.Hensberge, P.Molaro, P. Nissen*

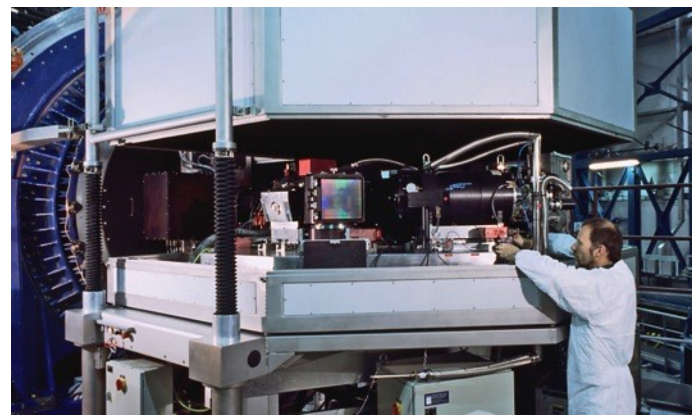
A very effective mixture of Dutch, French, Germans and Italians !

Paranal Engineering : *P.Gray, G.Gillet, G.Rahmer et al.*
Telescope Commissioning Team : *J. Spyromilio, K.Wirenstrand et al.*

UVES as build







➔ *Dekker et al. SPIE 4008 (2000)* ***Design, construction and performance*** *of UVES* 🡐

+ *papers on the* ***CCD systems*** *by Dorn et al.; on the Instrument* ***Control Software*** *by Longinotti et al.; on the* ***Highlights of the first Observations*** *by D'Odorico et al., in the same SPIE Proceed.*

UVES scientific CCD detectors

*The gain in efficiency--> limiting magnitudes for a given S/N provided by the introduction of **efficient, low noise, large size CCD detectors** has been more significant than going from 4m to 8m class telescopes!*

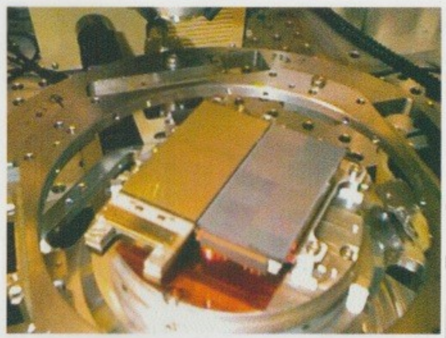
In the 80s-90s ESO had problems in the procurement of competitive detectors. Starting with UVES the ESO detector group was able to acquire state-of-art CCD devices

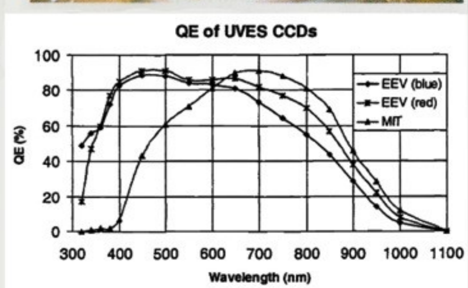
PERFORMANCE OF THE ESO CCD DETECTOR SYSTEM

	Mode	r.o.n (e)	dark current
Blue arm EEV	1x1fast	4	2e/pix/h
	2x2slow	2.1	" "
Redarm EEV	1x1fast	3.4	0.5e/pix/h
	2x2slow	2	" "
Red arm MIT-LL	1x1fast	3.8	1.1 e/pix/h
	2x2slow	3.4	" "

read out time for all modes 40 s

Format: 2k x 4k, 15 μ pixel





SPIE ASTR2000

This was possible through collaborations with USA labs and by working in long term developments with EEV in UK (CCD group led by J. Beletic)

First mosaic of large CCDs assembled at ESO

Integration in Paranal, First light and Commissioning (1)

Integration of instrument on Nasmyth platform in August-September 1999

Extraordinary effort of the Garching and Paranal Engineering and the telescope commissioning team who delivered a working 2nd telescope little more than a year after the 1st, with outstanding performance in terms of pointing, image quality, stability and tracking.

UVES first light on September 27th *(1 month delay w.r.t. date in 1.1994 VLT planning)*

In the 3 weeks of the 1st commissioning in October, a total of ***< 10 hrs lost*** *to telescope or instrument problems.*

Procedures *for target acquisition, secondary guiding, calibration strategy and basic* ***performance parameters*** *-spectral resolution, efficiency, stability with temperature-* ***successfully tested*** *.*

Commissioning, Science Verification, Start of Operation (2)

2nd Commissioning in December1999 dedicated to calibrations, operation testing and training of the Paranal personnel.

*Data flow Paranal-Garching and **first version of the pipeline** was **essential** to assess the performance and carry out **trend analysis of resolution, focus, stability with T and pressure.***

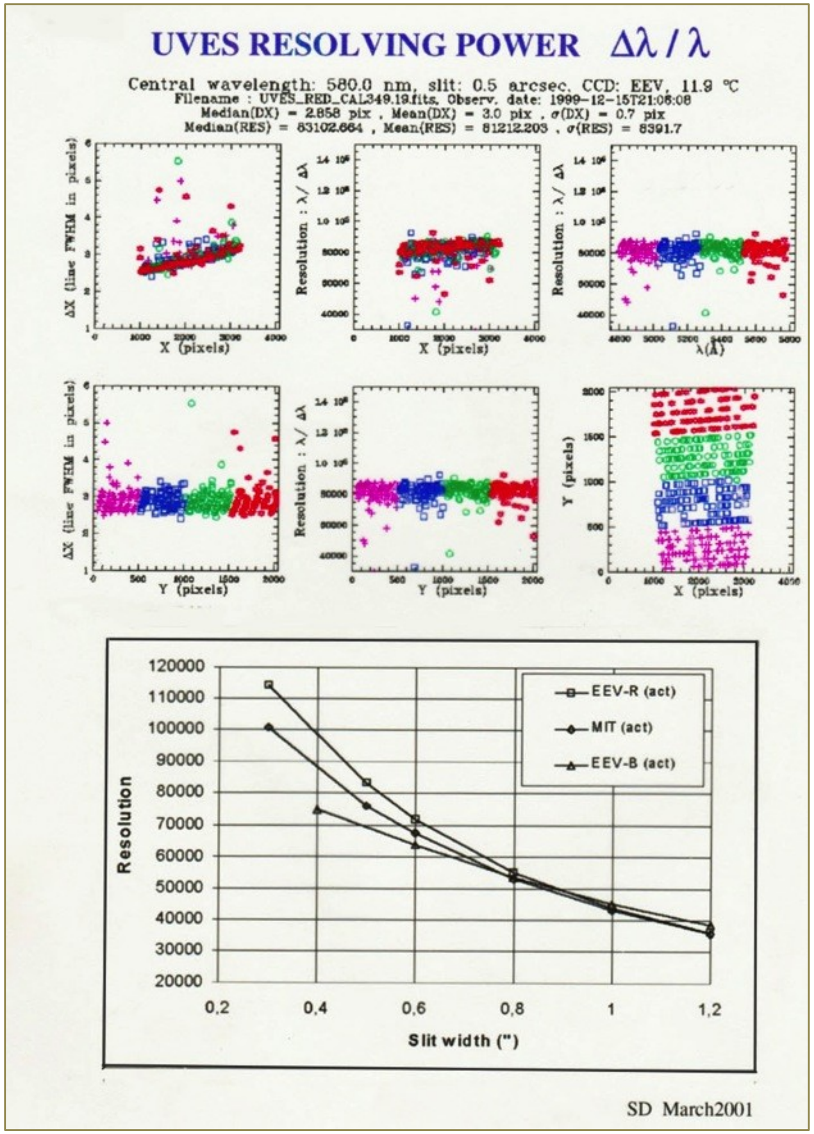
*Thanks to the smooth operation, **we had the possibility to fully explore the scientific capabilities**. 90 hrs of scientific exposures + associated calibrations released by the VLT archive*

***8 nights of Science Verification in Feb 2000**. Average shutter open time >80%. 80 hrs of scientific data released by the VLT archive*

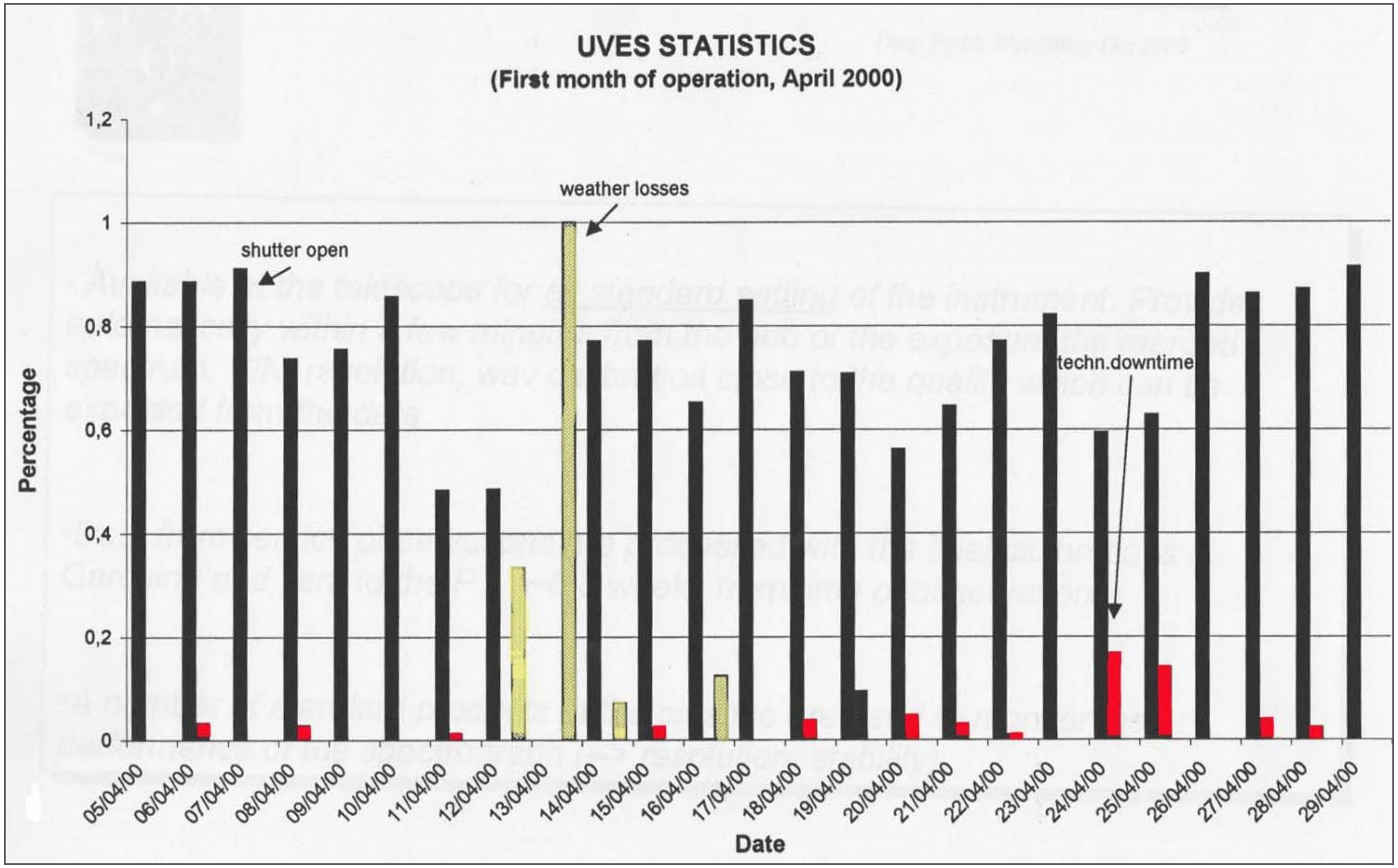
*In the first semester of operation (**P65, Apr-Sept 2000**) 78 nights in visitor mode and 300 hrs in service for a total of **70% of UT2**.*

Thanks Andreas !

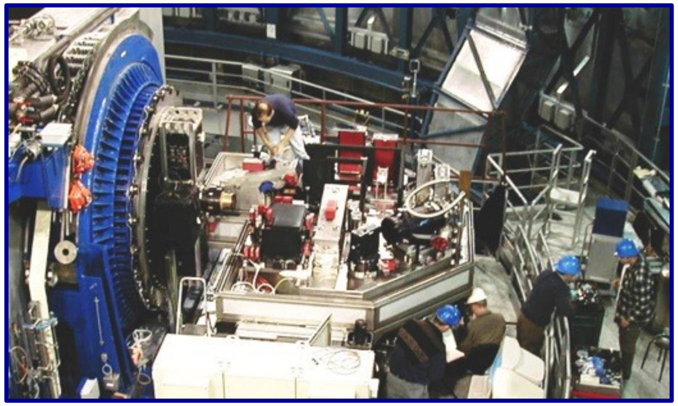
side products of the UVES pipeline



First month of operation of Kueyen and UVES (April 2000)



Integration, First Light, Commissioning Photo Gallery



27th September 1999

UVES Configuration and Performances in 2000

	Blue	Red
Wavelength range	300 - 500 nm	420 - 1100 nm
Resolution-slit product/ Wavelength bin	41400 0.019 Å at 450nm	38700 0.025 Åat 600 nm
Max. resolution	75 000 (0.4" slit)	110 000 (0.3" slit or IS)
Throughput (TEL+UVES,no slit,noatmosphere)	12 % at 400 nm	15 % at 650 nm
Limiting magnitude (90m. exp. time, S/N =10, 0.7 " seeing, slit)	18 (Res = 58 000) at 400nm	19 (R = 62 000) at 600nm
Baseline CCD and pixel scale -disp. direction -along slit	2048 x 3000, 15 μm pixels .215 "/pix 0.25"/pix	Two 4096 x 2048, 15 μm pixels, .155"/pix 0.18"/pix
Echelle	41.59 g/mm, R4, two mosaicked replica on a Zerodur block	31.6 g/mm, R4 ,two mosaicked replica on a Zerodur block
Crossdispersers	CD1: 1000 g/mm, λ_b 380 nm CD2: 600 g/mm, λ_b 380 nm	CD3: 600 g/mm, λ_b 560 nm CD4: 316 g/mm, λ_b 750 nm
λλ/frame (typ.)	700 A in 20 orders	1000 A in 18 orders
Order separation (typ.)	> 15 " ↔ 70 pixels	> 15 " ↔ 100 pixels

SD/March2001

Chasing HIRES performance (1)

With the building of CASPEC and EFOSC for the 3.6m, the quality of the NTT and its main instruments, EMMI and SOFI, ESO had established itself as telescope and instrument builder. European astronomers had access to competitive facilities in different modes of observations

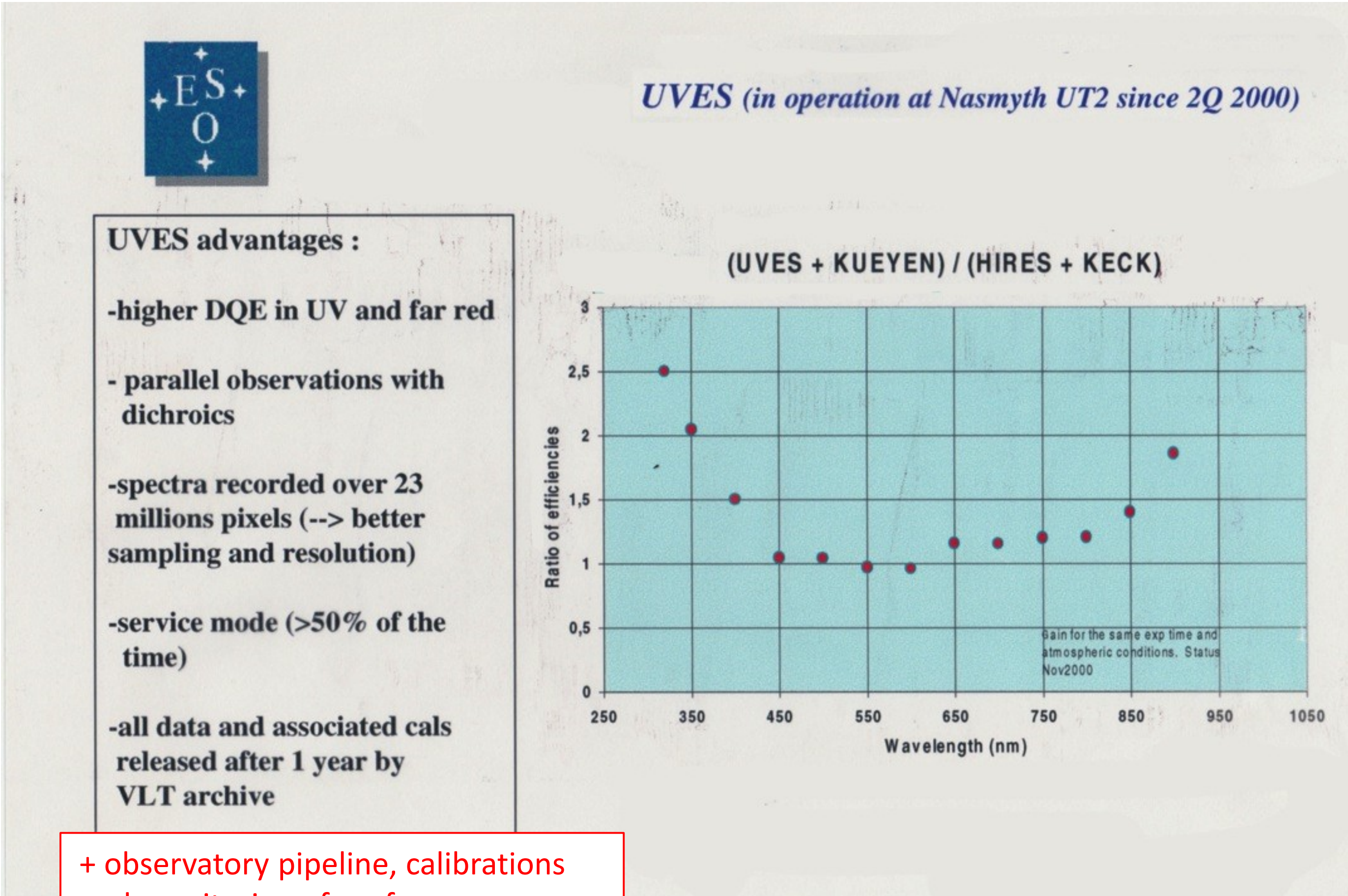
The coming in operation of the 10m Keck in 1994 re-established a "performance advantage" for at least a part of the American community

At Keck, HIRES, the high resolution optical spectrograph, first instr. to come into operation, took full advantage of the large collecting area for not-sky-limited observations

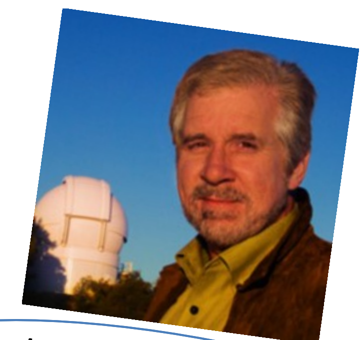
Coming 5 years after HIRES, UVES had to beat its performance to give European astronomy the lead in a field where they traditionally excelled

This goal become a personal obsession and guided many of the design choices and the optimization of the instrument parameters

Chasing HIRES performance(2)



+ observatory pipeline, calibrations and monitoring of performance



Nothing personal, Steve!

Comparison as of November 2000.
*In the following years the HIRES team led by **Steve Vogt** implemented a number of upgrades which filled up most of the performance gap.*

UVES : International Recognition

- *UVES design pioneered different original ideas and components*
- *Many concepts of UVES were duplicated or used as starting points in many (most?) of the echelle spectrographs built later on for large/medium size telescopes around the globe* Next talk !
- *Many astronomers from non-ESO countries noted its competitive performance and applied for observing time*

As an example, here a message by Steve Shectman , Project Manager of the Magellan Telescope of the Carnegie Institution and designer of many successful instruments for the Las Campanas Obs, sent shortly after UVES first light.

-------- Original Message --------
Subject: UVES Cameras
Date: Fri, 22 Oct 1999 14:49:23 -0700
From: "Stephen Shectman" <shec@shadow.ociw.edu>
To: "'hdekker@eso.org'" <hdekker@eso.org>

Dear Dr. Dekker:

I am working on the optical design for a low-resolution double spectrograph for the Magellan 2 telescope. I've become very interested in the optical designs for the UVES cameras. The UVES designs look like they might exhibit some important advantages compared to the designs by Harland Epps which we have been using up to now. (used in Keck's similar instrument)

I wonder if you would be willing to send me some detailed information about the UVES cameras. I would like to try these as starting points for designs which would be specifically adapted to our configuration. Of course I would give full credit to the UVES group for helping with any design based on this information which we might eventually use.

By the way, let me congratulate you on the beautiful spectra which I discovered today when I went to look up more information about your spectrograph on the ESO web site.

Best Regards,

Stephen Shectman
Magellan Project Scientist
Carnegie Observatories

Scientific results from the first year of science with UVES

***A library** of reduced, **high S/N, R= 40000 spectra**, from UV to far red, of **30 high z QSOs with m_V= 17-19**, was made accessible to astronomers in the ESO member states for statistical studies of the Lyα forest and the IMG.*

Publications based on archived comm. and SV data in the years 2000-2001

About 40 papers, each one with 50-150 citations

"The beryllium abundance in the very metal-poor halo star G 64-12 from VLT/UVES observations"; Primas et al., A & A (2000)
"The lithium isotope ratio in the metal-poor halo star G271-162 from VLT/UVES observations"; Nissen et al., A & A (2000)
"First accurate measurements of O and Zn abundance in a DLA at z>3" Molaro et al., Ap.J. (2000)
"UVES observations of QSO 0000–2620 : Molecular hydrogen abundance in the damped Lyα system at z_{abs}= 3.3901"; Levshakov et al., A & A (2000)
"The Cosmic Microwave Background temperature at a redshift of2.33771" ; Srianand et al. Nature (2000)
Molecular hydrogen and the nature of damped Lyman-α systems"; Petitjean et al. A & A (2001)
"The Lyman α forest at 1.4 < z <4"; Kim et al., A & A (2001)
"First results of UVES at VLT: abundances in the Sgr dSph galaxy"; Bonifacio et al., A & A (2000)
"Metallicity in a DLA at z=4.466"; Dessauges et al, A & A. (2000)
"A new deuterium abundance measurement from a damped Ly α system at zabs =3.025"; D'Odorico et al. ,A & A (2001)
"Measurement of stellar age from uranium decay" Cayrel et al., Nature (2001)………………

The Ultraviolet-Visual Echelle Spectrograph

From the S.D.'s contribution in the Proceedings of the VLT 1st Workshop in Cargese (1983) two bold, at the time not properly justified, statements which proved to be correct

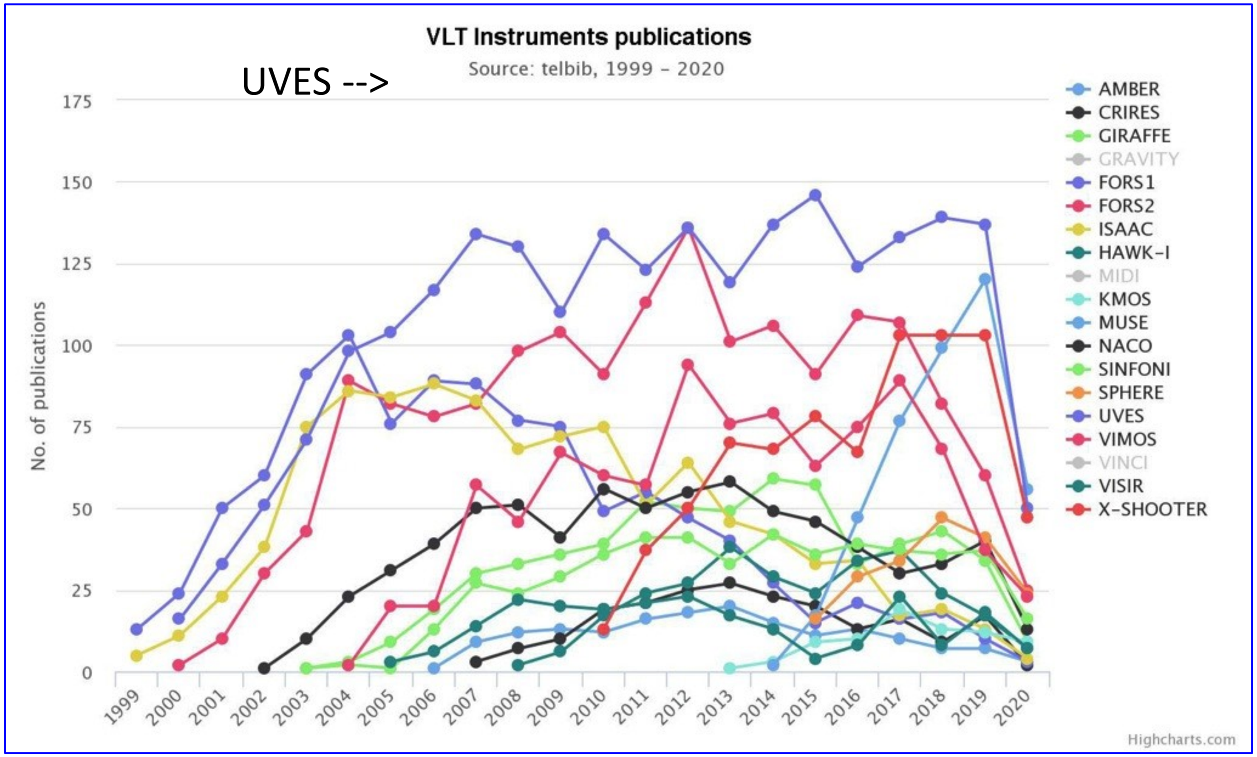
pg.44

An echelle spectrograph which provides a resolution of 50000 and efficiently matches an 8m telescope can be built with a moderate extension of the present technology

The data shown in Fig.4 indicate that an 8m telescope will be able to carry out the systematic spectroscopic survey of QSO between 17 and 20 mag at the required resolution of 50000

Today UVES-based publication statistics

HR spectroscopy one of the domain where the 8m was expected to provide largest gain. UVES has fulfilled the expectations with a rich scientific harvest



Achieved through:

Proper selection of instrument specifications/ outstanding optical concept & design/ sound mechanics, control software/ maintenance at the observatory/ performance understanding & monitoring / working data reduction pipeline/ archive of raw and reduced data

Final thoughts: Looking back and forward

- *UVES is one of the "monuments" to the ingenuity and craftsmanship of the ESO staff. It has contributed to give the organization* ***the knowledge, recognition and prestige which comes from having completed successful projects****, and thus the authority to write specs for and to review the work of partners*

- *UVES has been well maintained but very little time and resources spent to discuss and implement possible improvements.* ***An upgrade is definitely due****…. The changes in the Blue Arm now under consideration (next talk) would bring a significant advantage*

- *As it was the case for the VLT, the largest gain expected from the ELT are in high resolution imaging with AO and in high resolution spectroscopy, but* ***a HRS is not among the planned first generation ELT instruments***