

NEW VLT INSTRUMENTS UNDERWAY

ALAN MOORWOOD AND SANDRO D'ODORICO
ESO, INSTRUMENTATION DIVISION

FOLLOWING POSITIVE RECOMMENDATIONS FROM ESO'S SCIENTIFIC AND TECHNICAL COMMITTEE IN OCTOBER 2003, THE DEVELOPMENT OF THREE NEW VLT INSTRUMENTS - HAWK-I, X-SHOOTER AND KMOS - HAS NOW BEEN APPROVED AND LAUNCHED. ALL THREE HAD BEEN THE SUBJECT OF DETAILED PHASE A STUDIES CONDUCTED OR CONTRACTED BY THE INSTRUMENTATION DIVISION AND WHOSE RESULTS WERE PRESENTED TO THE STC TOGETHER WITH THE VARIOUS REVIEW BOARD REPORTS. WE SKETCH HERE BRIEFLY THE MAIN SCIENCE DRIVERS AND FORESEEN CHARACTERISTICS OF THESE INSTRUMENTS BUT WITH THE CAVEAT THAT NOT EVERYTHING IS YET FROZEN AND THAT COMPLETE IMPLEMENTATION STILL DEPENDS ON RAISING EXTERNAL FUNDING AS WELL AS VARIOUS TECHNICAL ISSUES. MORE DETAILED DESCRIPTIONS OF THESE INSTRUMENTS AND THEIR PROGRESS WILL BE REPORTED IN FUTURE ISSUES.

HAWK-I IS AN INFRARED (0.85–2.5 μm), 'wide-field' (7.5 \times 7.5 arcmin), camera with 0.1" pixels to sample the best Paranal seeing which should go slightly deeper and deliver even sharper images than ISAAC over an order of magnitude larger field. It will be built by ESO with possibly some small contributions from external institutes. HAWK-I's smaller pixels and the larger collecting area of the VLT means that it is scientifically complementary to the VISTA survey telescope. It will also replace and, for some purposes, improve upon the expected infrared imaging capabilities lost following cancellation of the NIRMOS instrument. Some of the specific science drivers identified by a team of ESO and community astronomers prior to the Phase A study are listed in Table 1, and their full report is available on the HAWK-I Web page (<http://www.eso.org/instruments/hawki>).

Naturally, many of the detailed aims are to extend programmes already started with ISAAC. These include a number of surveys e.g. for high redshift galaxies and low mass stars/brown dwarfs where the next step requires at least the same limiting depth but

over a larger field to increase the source statistics and chance of detecting rare objects. As some of these programmes have already involved integrations of > 100hrs/field it is clear that a larger field rather than mosaicing is now necessary! A classic example is the search for galaxies at $z > 7$ where the most promising strategy will probably be to combine infrared photometry and narrow band Lyman α imaging with HAWK-I with follow-up spectroscopy using KMOS. Some of these programmes also exploit the excellent direct imaging capabilities already demonstrated with ISAAC/VLT e.g. to find and study stellar discs. As illustrated by the results of simulations presented in the companion article by Arsenault et al. in this issue the performance, despite the large field, could also be further improved by adaptive optics correction using an adaptive secondary mirror and multiple laser guide stars.

The heart of HAWK-I will be an infrared detector mosaic comprising the four

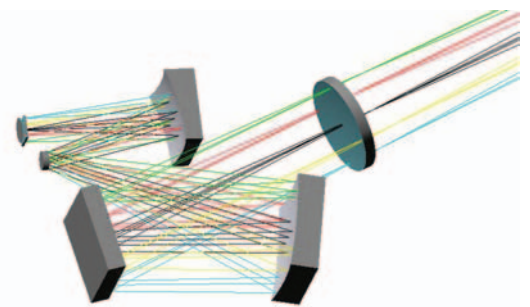


Figure 1: HAWK-I optics comprising only 4 highly reflecting mirrors and an input window/lens designed already for use with an adaptive secondary mirror and 4 laser guide stars.

2048 \times 2048 Hawaii IIRG arrays ordered originally for NIRMOS but with cut-off wavelengths extended from 1.9 to 2.5 μm . The eyes of HAWK-I will be the optical system shown in Fig. 1 which uses only mirrors to achieve the maximum throughput (> 90%). It has also been designed with an input window/lens shaped such that it could be used to reflect light from the laser guide stars into wavefront sensors should the adaptive secondary project become a reality. Figure 2 shows how HAWK-I should look

TABLE 1. HAWK-I SCIENCE DRIVERS

- Galaxy evolution from deep multicolour surveys
- High z galaxy clusters
- Search for high z (> 7) emission line galaxies
- Stellar content of nearby galaxies
- Obscured AGN
- Structure and evolution of nearby galaxies
- Galactic star and planetary formation
- Brown dwarf surveys
- Outer solar system bodies

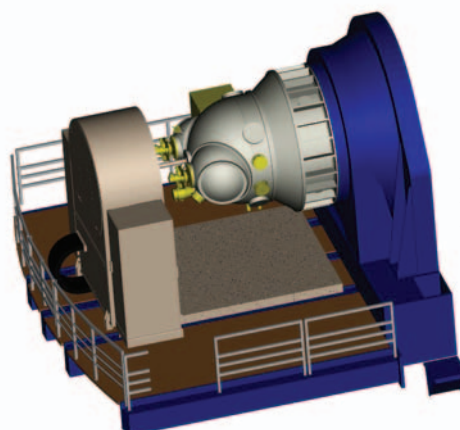


Figure 2: HAWK-I installed at a Nasmyth focus. The large port on this side of the vacuum vessel allows easy access to the detector mosaic and the filter wheels without dismantling the instrument.

Table 2: Science Drivers for X-shooter

- Spectral properties of forming stars
- Properties of cool white dwarfs
- The nature of neutron stars in close binary systems
- Physical processes in the atmospheres of brown dwarfs
- Properties of core-collapse supernovae
- Type Ia supernovae to $z=1.7$
- Gamma-ray bursts as high-energy laboratories and cosmological probes of the intergalactic medium
- The role of faint emission line galaxies in the redshift interval $z = 1.6-2.6$
- Properties of high mass star formation and massive galaxies at high z
- Metal enrichment in the early universe through the study of absorption systems
- Tomography of the Intergalactic Medium through the observations of faint background QSOs

when mounted at a Nasmyth focus of the VLT. Both the cryo/vacuum system and the cable/hose co-rotator are similar to those developed for ISAAC. In contrast, however, its only moving functions will be the two filter wheels carrying 4 broad-band and 5 narrow-band filters. The detailed specification of these filters has recently been discussed at the first meeting of the Instrument Science Team appointed to monitor the instrument development and provide advice as required.

Jeff Pirard is the Project Manager and Markus Kissler-Patig is the Instrument Scientist. As the detectors are expected to be delivered soon and the optics procurement will start immediately after the PDR in March 2004 it is hoped that HAWK-I can be built considerably faster than the more complex VLT instruments and we are aiming for an installation on the VLT around mid-2006.

X-shooter is a single target spectrograph for the Cassegrain focus of one of the VLT UTs covering in a single exposure the wide spectral range from the UV to the H band. It is designed to maximize the sensitivity by splitting the light in three arms with optimized optics, coatings, dispersive elements and detectors. It operates at intermediate resolutions ($R=4,000-14,000$, depending on wavelength and slit width) sufficient to address quantitatively a vast number of astrophysical applications while working in the background-limited S/N regime in the regions of the spectrum free from strong atmospheric emission and absorption lines. The layout and the small number of moving functions (and therefore instrument modes)

make the instrument simple and easy to operate and permit a fast response. The possibility to observe faint sources with an unknown flux distribution in a single shot at the sky limit inspired the name of the instrument.

Four proposals for X-shooter were submitted in response to the ESO Call for Proposals for 2nd generation VLT instruments in November 2001. Following negotiations among the different groups interested in this development and ESO, a Phase A study was carried out by a

Consortium of the Copenhagen University Observatory (P.I. Per Kjærgaard), INAF in Italy (P.I. Roberto Pallavicini), GEPI at the Observatory of Paris-Meudon (P.I. Francois Hammer), ASTRON and the Universities of Amsterdam and Nijmegen in The Netherlands (P. I. Lex Kaper) and ESO (P.I. Sandro D'Odorico). Hans Dekker at ESO acted as Project Manager of the study.

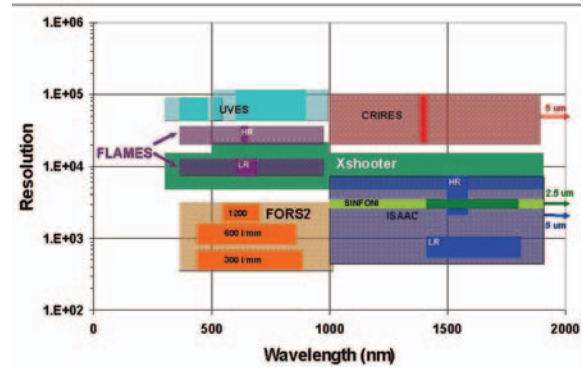


Figure 3: VLT spectrographs in the resolving power versus wavelength plane for the range of operation of X-shooter. For each instrument the light color strip identifies the spectral range of operation, the darker one the spectra coverage in a single exposure (when applicable with different gratings). VIMOS (not shown) approximately overlaps with FORS. Note that by the time X-shooter will be implemented at the telescope the FORSes and ISAAC will be beyond their guaranteed lifetime. X-shooter is unique among instrumentation under construction for 8–10m telescopes in providing full coverage from the UV to the H band in one shot.

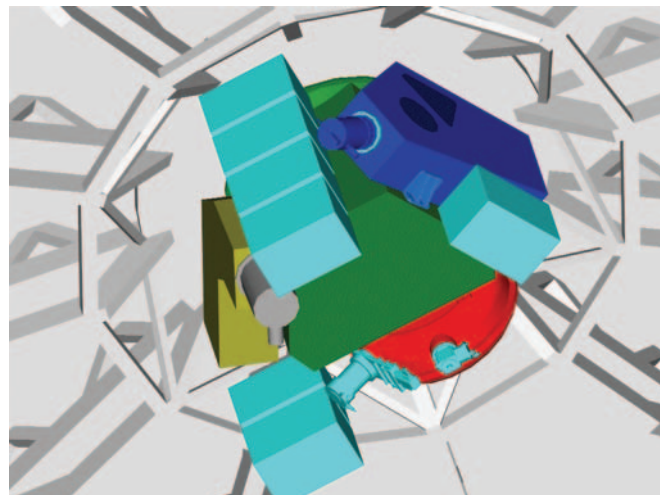


Figure 4: A CAD view of X-shooter attached to the Cassegrain focus of the telescope. While this opto-mechanical layout is likely to be substantially modified in the design of an optimized structure, it conveys the instrument concept based on the parallel operation of three arms operating in the UV, Visual-red and J-H bands.

Table 3: X-Shooter Characteristics

Spectral Format	Prism cross-dispersed echelle (order separation $\geq 12''$)
Wavelength range	300–1900 nm, split in 3 arms by dichroics
Resolutions	4000–7000 for 1 arcsec slit
Slit configuration	long slit (12''); widths: 1''(standard), 0.6''(high R), 5'' (flux cal.); IFU 1.8×4'' input area
Detectors	2K × 4K CCDs (UV and Visual-Red arms), 1K×1K Hawaii LPE MCT(IR)
Auxiliary functions	Calibration Unit; A & G unit with 1'×1' field and filter set; ADC for the UV and Visual-Red arms.

Table 4: KMOS Science Drivers

- The Masses (dynamical) and Growth of Galaxies
- Extremely High-Redshift (>7) Galaxies and Re-ionisation
- Connection Between Galaxy Formation and Active Galactic Nuclei
- Age-Dating of Ellipticals at $z = 2$ to 3
- Stellar Populations in Nearby Galaxies
- Galactic Astronomy (star clusters)

The main scientific objectives of the X-shooter have been elaborated during Phase A by a science team led by Jens Hjorth. With its capability to observe single objects over a wide spectral range at the sky limit, the X-shooter will be a cornerstone facility for the VLT. The scientific programs which were used to set the requirements on the capability of the instrument are listed in Table 2.

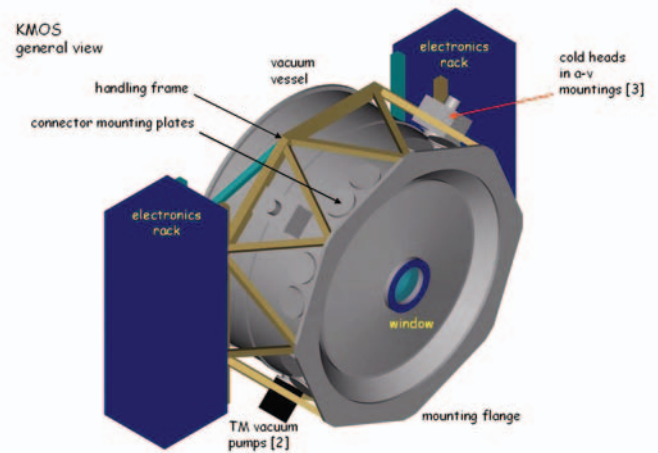
Table 3 summarizes the currently foreseen capability of the X-shooter.

With the project now approved, the Technical Specifications and the Statement of Work are being written together with the agreements between ESO and the four national groups participating in the project. Technical work is advancing toward a Preliminary Design Review in Q4 of 2004. The aim is to meet an installation at the telescope in 2007. The X-shooter is built, as other VLT instruments, with a large contribution of manpower by the national institutes in exchange for guaranteed time. Unlike others, however, the larger share of the hardware cost is also provided by the external sources. This will permit a rapid advancement of the project by decoupling it from the limitations in the cash flow of the VLT instrumentation budget.

The Web page (under construction) can be found at <http://www.eso.org/instruments/>.

KMOS is a near infrared, multi-object, spectrograph for which different concepts were presented at the ESO 2nd Generation Instrument Workshop in 2001 and for which

Figure 5: View of KMOS showing the vacuum vessel and instrument mounted electronic racks.



three Consortia responded to the Call for Proposals issued in Nov. 2001. In response, ESO contracted, and partially financed, competing Phase A studies to both the German/British KMOS1 consortium headed by R. Bender (USM/MPE) and R. Sharples (Durham) and the Italian/French/Swiss/British/Spanish KMOS2 consortium headed by D. Maccagni (IASF, Milan) and J.-G. Cuby (Marseille). In both cases ESO was also involved as the designated supplier of the detector systems. As judged by the review boards, both consortia delivered credible designs and performed an impressive amount of work in the relatively short space of time available to meet the Oct. 2003 STC deadline. After much discussion it was recommended by the STC that ESO continue with the KMOS1 consortium - at least up to PDR.

One of the initial prime science drivers for this type of instrument was the possibility of measuring rotation curves and/or velocity dispersions and hence of estimating dynamical masses for significantly large numbers of $z \sim 1-3$ galaxies to study their mass assembly history. As mentioned above under HAWK-I, such an instrument could also prove invaluable for follow-up Lyman α spectroscopy of $z > 7$ galaxy candidates. These and other science drivers identified by the consortium are given in Table 4.

Table 5 summarizes the overall capabili-

Table 5: KMOS characteristics

Wavelength range	0.9-2.5 μm
Spectral Resolution	$\sim 3-4000$
Field	7.2' diameter
IFU Field	2 \times 2"
Pixel size	0.2"
Number of IFUs	24

ties foreseen currently for KMOS.

Figure 5 shows an external view of KMOS which does not give much away! Inside the vacuum vessel the baseline design uses cryogenic, robotic, pick-off arms to select and feed up to 24 objects to image slicers and then up to 3 spectrographs. More details can be found at http://aig-www.dur.ac.uk/fix/projects/kmos1/kmos_main.html. In parallel an alternative design using steering mirrors, which were also prototyped during the Phase A, is also continuing. In principle, the achievable gain with an adaptive secondary could also be similar to that with HAWK-I as the wavelength ranges and fields are almost the same.

In either case, KMOS will be a relatively complex instrument requiring further development and prototyping and is thus targeted for around 2010, i.e. somewhat later than HAWK-I and X-shooter. At ESO, the Instrument Responsible is Alan Moorwood, Technical Manager is Jeff Pirard and Instrument Scientist is Markus Kissler-Patig.



Three dusty beauties. Images of NGC 613, M 66 (NGC 3627) and NGC 1792 observed with FORS on the VLT. ESO Press Photos 33-03.