Installation and first results of FLAMES, the VLT multifibre facility

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ABSTRACT

FLAMES is the VLT Fibre Facility, installed and being commissioned at the Nasmyth A of UT2 (Kueyen Telescope). FLAMES has been built and assembled at the VLT telescope in about 4 years through an international collaboration between 10 institutes in 6 countries and 3 continents. It had first light with the fibre link to the red arm of UVES on April 1, and with the GIRAFFE spectrograph on July 3. We have not yet enough data to compare the observed vs. expected astronomical performances, although these first data are encouraging in many respects. We aim at proceeding soon with the remaining tests.

Keywords: Spectrograph, optical fibres, multi-object spectroscopy, integral field unit, FLAMES, OzPoz, GIRAFFE, UVES

1. OVERVIEW

FLAMES is the multi-object, intermediate and high resolution fibre facility of the VLT. Mounted at the Nasmyth A platform of UT2 it offers a rather large corrected field of view (25 arcmin diameter) and it consists of several components, developed by several consortia (Australis (AAO and MSO), Paris-Meudon (OPM), Geneve and Lausanne (OGL), Bologna, Cagliari, Palermo and Trieste (ITAL)):

- An optical **Corrector**, providing excellent image quality and telecentricity over the full field of view of 25 arcmin diameter. (Developed at ESO)
- A **Fibre Positioner** hosting two plates. While one plate is observing, the other one is positioning the fibres for the subsequent observations, therefore limiting the dead time between observations to less than 5 minutes. (Developed at AAO and MSO)
- A link to the **UVES** spectrograph (Red Arm) via eight single object fibres / plate. (Developed at ESO and OPM)
- A high and intermediate resolution optical spectrograph, **GIRAFFE** that can be fed by three different types of fibers: MEDUSA, IFU, ARGUS. (Developed at ESO and OPM)
- A coordinating observing software, that allows **simultaneous UVES** and **GIRAFFE** observations. (Developed at ESO and ITAL Consortium)
- As for all VLT instruments, a full Data Reduction Software (**DRS**) package is provided, integrated in the ESO Data Flow Software. (Developed by OGL and ITAL consortium)

Several of the FLAMES components are described in detail elsewhere in these proceedings (cf. e.g. Avila et al. 2002, Gillingham et al. 2002, Mulas et al. 2002, Royer et al. 2002), so we will mostly concentrate here on the aspects not treated in these contributions. Earlier descriptions of FLAMES and its components can be found in the SPIE 2000 proceedings (Pasquini et al. 2000, Blecha et al. 2000, Gillingham et al. 2000, Jocou et al. 2000).
The characteristics of the different observing modes are given in Table 1, which summarizes the general observational capabilities of FLAMES.

Spectro	Mode	Nr. Objects	Aperture (“)	R	Coverage (nm)
UVES8 Red Arm (with sky)		8	1	47000	200, 400
UVES7 Red Arm (with sky)	Simul. Calibration	7	1	47000	200
GIRAFFE	MEDUSA	132 (with sky)	1.2	20500*	λ/22*
GIRAFFE	MEDUSA	132 (with sky)	1.2	7000*	λ/7*
GIRAFFE	IFU	15 (+15 sky)	2X3	33000*	λ/22*
GIRAFFE	IFU	15 (+15 sky)	2X3	11000*	λ/7*
GIRAFFE	ARGUS	1	11.5X7.3	33000*	λ/22*
			Or 6.6X4.2		
GIRAFFE	ARGUS	1	11.5X7.3	11000*	λ/7*
			Or 6.6X4.2		

* The GIRAFFE resolving power (R) and wavelength coverage given here are only average values. They will vary for the different setups by ± ~ 20 %.

Table 1. Observational capabilities of FLAMES

1.1. UVES-Fibre

UVES is the high resolution spectrograph of the VLT UT2. It has been designed for working in slit mode but, thanks to a rather small modification, it has been possible to add a fibre mode on its Red Arm. Each positioner plate has eight fibres connected to the red arm of UVES. With an aperture on the sky of 1 arcsec, the fibres project to five UVES pixels giving a resolving power of ~ 47000.

In addition to the eight fibres per plate, an extra fibre fed by a separate calibration unit is available. This fibre is used for simultaneous calibration to obtain very accurate radial velocities. Only seven fibres can be devoted to astronomical objects when this simultaneous calibration fibre is used. For faint objects one or more fibres can be devoted to the sky. Only the three standard UVES Red setups are offered, with central wavelength of 520, 580 and 860 nm, respectively.

1.1. GIRAFFE

GIRAFFE is a medium-high resolution spectrograph (R = 6000 - 33000) for the entire visible range (370 - 950 nm). It is equipped with two echelles for low and high resolution and uses interference order sorting filters to select the required spectral range within an order. The typical spectral coverage in one exposure is 60-100 nm in low resolution and 20-40 nm in high resolution.

The fibre system feeding GIRAFFE consists of the following components (cf. Avila et al. 2002 for details):

- **MEDUSA** fibre slits, one per positioner plate. Up to 132 separate objects (including sky fibres) are accessible in MEDUSA single fibre mode, each with an aperture of 1.2 arcsec on the sky.
- **IFU** slits, one set of 15 per positioner plate. Each deployable Integral Field Unit (IFU) consists of an array of 20 square micro-lenses of 0.52 arcsec side each, giving a total (almost rectangular) aperture of ~ 3 x 2 arcsec. For each plate there are also 15 IFU dedicated to sky measurements.
- 1 **ARGUS** slit. The large integral unit ARGUS consists of a rectangular array of 22 by 14 micro-lenses. It is fixed at the center of one positioner plate. Two scales are available: one with a sampling of 0.52 arcsec/micro-lens and a total aperture of 12 by 7 arcsec, and one with a sampling of 0.3 arcsec/micro-lens and a total coverage of 6.6 by 4.2 arcsec. 15 ARGUS single sky fibres are also available. These can be positioned everywhere within the 25 arcmin field.

GIRAFFE is operated with 30 fixed setups (22 high resolution + 8 low resolution modes). For performance estimates (based on expected transmission curves and performances) the user is referred to the Exposure Time Calculator (ETC) which is available on the Web at the ESO ETC web page: www.eso.org/observing/etc

1.2. FLAMES observing modes

The FLAMES observing software (OS) is coordinating the operations of the Telescope, the Positioner and the spectrographs in their various observing modes: UVES (either with 8 fibres dedicated to targets or with 7 objects plus simultaneous calibration) or GIRAFFE (either in MEDUSA or IFU or ARGUS modes). In addition, it allows a

COMBINED observations: that is the simultaneous acquisition of UVES and GIRAFFE spectra with the specific observing modes listed in Table 1. During a combined observation the exposure times for UVES and GIRAFFE do not need to be the same, but the longest exposure time will determine the overall length of the observation.

2. LAYOUT

Figure 1 is a view of the main components of the FLAMES facility, the fibre Positioner and GIRAFFE, as seen on the telescope platform. The Corrector support is also visible, attached at the Nasmyth rotator.

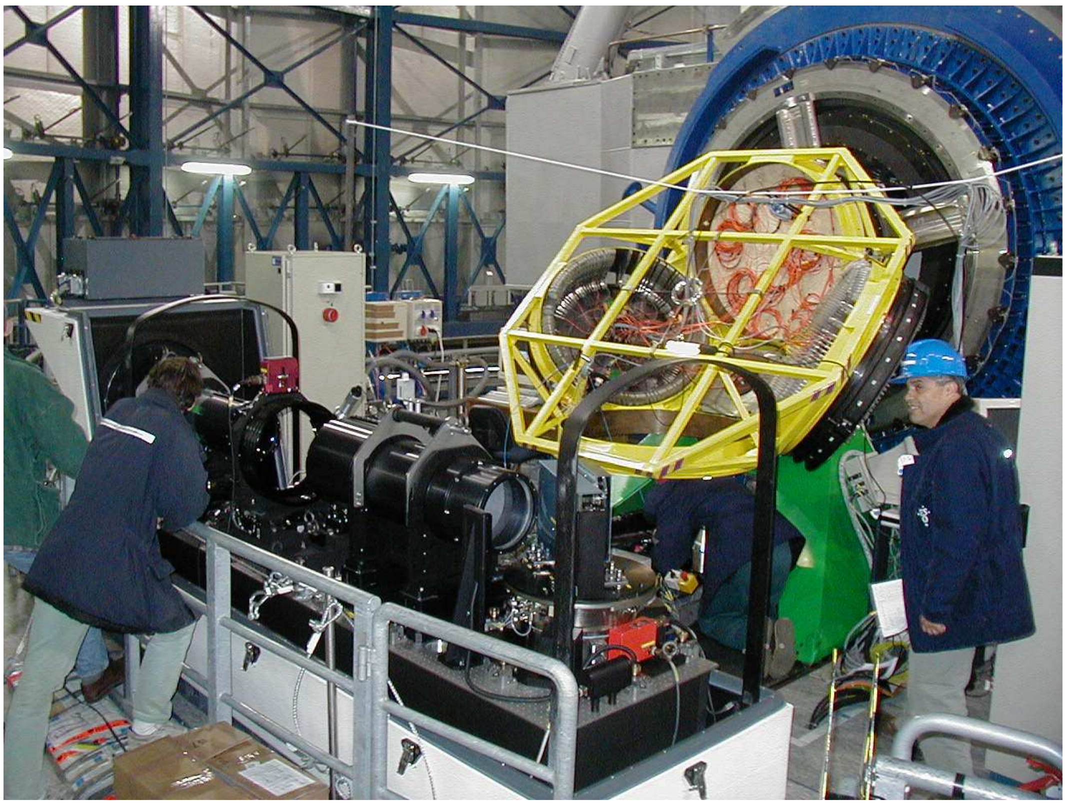

Figure 1: The fibre positioner and Giraffe as seen during the Giraffe integration on the Nasmyth platform. The positioner is looking towards the Nasmyth Focus, where the corrector is placed (only the corrector support is visible). Giraffe is open, and all the optomechanics components are visible.

3. CORRECTOR

The optical corrector is a doublet of 880 mm free aperture made in an equivalent glass of BK7 from a Chinese manufacturer. In order to maintain a good transmission over a large wavelength range, the lenses have been coated with a single layer of Mg2 centered to 530 nm. The function of the corrector is to give an excellent image quality over the whole 25 arcmin FLAMES field of view and to provide a pupil located at the center of curvature of the focal plate, to avoid vignetting for off-axis fibers. The corrector is mounted onto the Nasmyth adapter via a support which has three attaching cones to which the observing Positioner plate is anchored.

When the whole optical train is taken into account (including telescope optics and vignetting), the effective transmission of the corrector depends on the observing wavelength and on the distance of the object to the field center, as expressed in Table 2.

Wavelength	Axis	2arcm	4arcm	6arcm	8arcm	10arcm	11arcm	12arcm
365 nm	0.789	0.788	0.788	0.784	0.776	0.754	0.735	0.692
405	0.894	0.890	0.888	0.888	0.881	0.842	0.848	0.802
486	0.919	0.912	0.906	0.902	0.903	0.900	0.890	0.847
586	0.914	0.905	0.897	0.890	0.889	0.895	0.887	0.856
656	0.898	0.887	0.879	0.871	0.869	0.879	0.872	0.842
800	0.880	0.869	0.858	0.849	0.846	0.854	0.854	0.826
1014	0.843	0.830	0.819	0.809	0.805	0.811	0.816	0.792

Table 2. Measured Corrector transmission as function of wavelength and radial distance of the object from center (in arcmin). It includes as well the (computed) effects of pupil decentering for a MEDUSA aperture.

In order to provide the observers with an accurate Flat Fielding system, meant to obtain the most accurate fibre to fibre transmission measurements, a system of lamps have been installed to illuminate the Nasmyth screen, which is located in the telescope centerpiece, about 2 m in front of the focal plane. A picture of the corrector plus the illuminated screen is given in Figure 2.

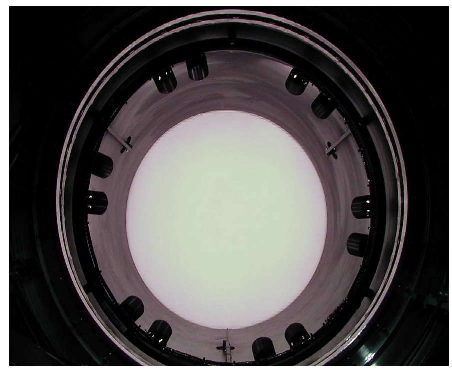

Figure 2: Picture of the illuminated Nasmyth screen. This system has been built to provide the users with a very accurate system to measure fibre to fibre relative transmission without the need of moving the fibres from their observing position.

4. FIBRE POSITIONER (OZ POZ)

The Fibre Positioner (Oz Poz) is at the core of the FLAMES facility. OzPoz is a rather large and complex system equipped with four plates, two of which are currently in use (cf. Gillingham et al. 2002). The Positioner can be subdivided into the following subsystems:

- Plates: Two metallic disks, on which the magnetic buttons holding the fibres are attached. Each of the plates has a hole in the center. In one plate this hole hosts ARGUS. Each plate has a curvature of 3950 mm to match the curvature of the corrector focal surface.
- Retractors: Mechanical systems maintaining the fibres in constant tension. Each fibre is equipped with one retractor. The retractors are the same for all fibres.
- Exchanger: Main structure holding the plates. The exchanger can perform two main movements: it can retract (or approach) the Nasmyth adapter to engage the plate (or disengage it). Furthermore it can rotate the upper part in order to perform the plate exchange.
- r-θ system and Gripper: This unit grips and releases the magnetic buttons at the positions reached via the r-θ (polar) robot. The gripper requires a back-illumination system, that means a brief light flash shining from the spectrograph towards the plate. A camera records this back-illumination light and performs an image analysis. The backillumination light is used for three purposes: to reach the required high positioning accuracy and to detect if the magnetic button was properly released on the plate and also to detect possible problems with fibre buttons (i.e.button accidentally displaced or fibre broken). The measured fibre polar coordinates are stored in the internal NVRAM and used for the next pick-up operation.
- Oz Poz is equipped with a calibration box, which moves in theta with the gripper. This calibration box hosts an optical system which can direct the light either from a tungsten lamp, from a Th-Ar lamp, or from a Ne lamp into a fibre. In this way FF, Th-Ar and Ne calibrations can be obtained for GIRAFFE and for UVES. The procedure to acquire these calibrations is to first position the fibres to be calibrated on the plate in a given pattern (typically along a spiral) and then to sweep with the gripper over the buttons, illuminating one fibre after the other, one by one. For FF calibration the procedure is to sweep continuously over the buttons, illuminating them several times,

while for the Th-Ar calibrations the gripper stops over each fibre for a number of seconds specified by the user. The calibration unit has also space to host an additional lamp.

- Field Acquisition Bundles (FACBs): Four magnetic buttons on each plate are equipped with a system of 19 coherent fibres each. This bundle of fibres is used to obtain images of fiducial stars, one per button. The four images are viewed by an ESO technical CCD; the image centroids are computed and the proper offsets are calculated to center the fiducial stars into the bundles. Each FACB bundle has an effective diameter of 2.4".
- Positioning Software: It is written around the so-called delta-task program which was developed initially for the 2dF system at AAO. This program allows crossing between the fibres and it determines the button movements sequence.

4.1. Positioner Performances

The main performance characteristics of the fibre positioner can be summarized as follows.

1) Mechanical Positioning accuracy: better than 0.08 arcsec
2) Positioning time: 6 seconds/move. The whole configuring time also depends on the number of move necessary to re-configure the plate, that is, the number of moves/fibre needed to re-position one button, as well as by the number of attempts/button needed to achieve the required positional accuracy.
3) Possibility to configure the next observation while observing.
4) Plate Exchange time: less than 180 seconds (w/o considering field acquisition).
5) Calibration unit: less than 2 minutes per calibration, either for FF or Th-A exposures.
6) Secondary offsets with FACBs.
7) Minimum button distance 11 arcsec (button diameter: 10 arcsec).

5. BUTTONS AND FIBRE SYSTEMS

FLAMES is equipped with different types of fibres for UVES and for the different modes for GIRAFFE (Avila et al. 2002). At the output of the fibre system, individual fibres have been arranged in different sub-slit systems depending on the fibre type. It is worth mentioning that, in addition to the object or sky fibres coming from the Positioner, each GIRAFFE fibre slit has five fibres devoted to **simultaneous wavelength calibration**. These fibres provide five calibration spectra for each observation acquired with GIRAFFE..

The histogram distribution of the transmission is given in Figure 3 for the different fibre types. The FLAMES fibres have been proven very robust so far that out of more than 1000 fibres, only a few have been found broken (and replaced) at the end of the whole process. The first tests of photometric stability with respect to torsion have been so far very positive, showing variations below 0.5% after a full rotation of 360 degrees of the Nasmyth adapter.

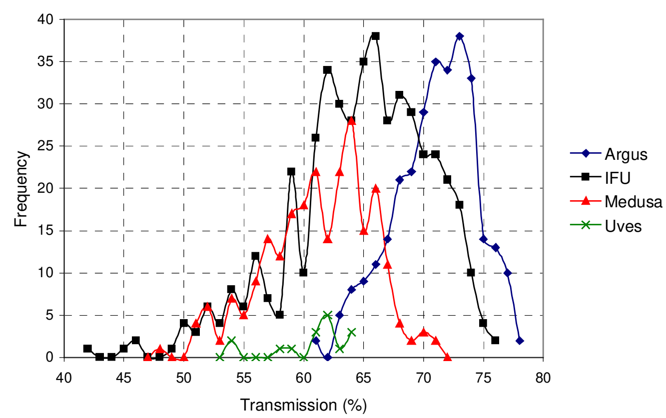

Figure 3: Transmission distribution of all GIRAFFE fibres, as measured in laboratory

5.1. UVES fibres

Each of the positioner plates hosts eight 55-meters fibres which guide the light to the UVES spectrograph located on the opposite Nasmyth Platform. Two fibre bundles are present (one per plate), each with eight buttons. Every button hosts one fibre. From the UVES simultaneous calibration box, one additional 5-meter fibre reaches the UVES-Fibre slit. Each of the two UVES-fibre slits (one per plate) consists of 9 fibres, but only eight fibres can be used simultaneously to avoid order overlap. The fibres have a core/cladding/buffer of 120/144/180 microns respectively.

The UVES system works at the optimal F/3 aperture, to minimize the focal ratio degradation . The exit is also at F/3; each fibre has an aperture of 1 arcsec on the sky. A micro-lens in front of the fibre convert the F/15 focal of the VLT to F/3. The transmission of the UVES fibre at several wavelengths is given in Table 3; they include the losses due to FRD, micro-lenses and fibre-micro-lenses coupling.

Fibre	370 nm	400 nm	450 nm	600 nm
UVES	0.36	0.41	0.52	0.61

Table 3: UVES fibre transmission. These values include all losses, focal ratio degradation, optics and coupling. For wavelengths redder than 600 nm the transmission is constant. Variations of several percent are present (cf. Figure 3) among the fibres.

The fibres of each plate are arranged in one sub-slit. The nine fibre centers are separated by 1.7 fibre core, implying that there is some degree of contamination between adjacent fibres. This contamination can be largely reduced by extracting the spectra on the central six or seven pixels; the UVES-Fibre Data Reduction Software (Mulas et al. 2002) has been developed to obtain a complete de-blending of the spectra.

5.2. MEDUSA fibres

Each plate also hosts 132 MEDUSA fibres. Each button includes a single fibre and its construction is similar to that of UVES, except that in the case of MEDUSA, the focal aperture is F/5. The core of each MEDUSA fibre is 230 microns, which corresponds to an aperture on the sky of 1.2 arcsec. The fibres have a cladding of 253 micorns and a protection buffer of 280 microns.

The MEDUSA fibres are 13 meters long and their typical overall transmission is given in Table 4.

Fibre	370 nm	400 nm	450 nm	600 nm
MEDUSA	0.47	0.52	0.55	0.61
ARGUS	0.52	0.58	0.62	0.70
IFUs	0.49	0.55	0.58	0.66

Table 4. GIRAFFE Fibre Transmission. The values given here include all losses, focal ratio degradation, optics and coupling. For wavelengths redder than 600 nm the transmission is constant. Variations of a few percent between different fibres are measured (cf. Figure 3)

The fibres are organized in a slit composed of several sub-slits.. They are arranged on a long slit that is curved to follow the curvature of the GIRAFFE focal plane. The separation between each of the MEDUSA fibres in a sub-slit is 2.26 x the fibre core; our measurements show that this ensures a fibre-to-fibre contamination below 0.5 percent.

During our tests we have experienced some (about 2%) increased stray light due to reflections from the filter and the (polished) exit slit. We will attempt to reduce this with a stray light mask that reduces the width of the reflecting exit slit viewed from the side of the filter.

5.3. IFU fibres

Each Integral Field Unit (IFU) button is composed of twenty micro-lenses arranged in a rectangular shape. The micro-lenses are 0.52" squares. They convert the F/15 VLT beam to an F/7 aperture. Due to the FRD in the fibres, the effective focal aperture at the fibre exit is F/5. The movable IFUs are a unique characteristic of GIRAFFE. These devices can be placed all over the FLAMES field of view, with the exception of a small fraction of the center annulus. Below the micro-lenses, a totally reflecting LLF1 prism sends the light to the fibres. Each IFU has twenty associated single fibres and each plate hosts fifteen IFUs.

In addition, fifteen Sky IFUs are present on each plate. They are indentical to the object IFUs, with the exception that only 1 fibre takes the light from the central micro-lens. The fibres of each IFU are organized in such a way on the micro-lens array, that fibres adjacent on the exit slit are also adjacent on the input side.

The separation between the fibres center is only 1.47 times the fibre diameter core, which implies that the contamination between adjacent fibres is rather high (about 10 percent). With the chosen arrangement of the fibers this is acceptable since in normal seeing conditions an even higher level of contamination will be present at the fibre entrance level.

5.4. ARGUS fibres

The Argus system is a fixed array of 15 x 20 micro-lenses, similar to the IFUs, located in the middle of Plate 2. Argus is also equipped with a lens allowing to switch between a scale of 0.52 "/micro-lens to a finer scale of 0.3 "/pixel. A permanently mounted ADC ensures that the object images at different wavelengths are maintained in the same locations up to a Zenithal distance of 70 degrees. In addition to the object fibres, fifteen ARGUS sky fibres are present on the plate; they are built as IFU sky fibres. The ARGUS slit is organized along the same principle as the IFU slits.

6. GIRAFFE

GIRAFFE is a fully dioptric spectrograph. The fibers are arranged in 5 long slits (IFU 1/2, Medusa 1/2, Argus, each one 76.8 mm) at the curved focal plane of the collimator. One of these fiber slits is placed in the working position by a translation stage. The other slits are masked. After leaving the fibres at F/5, the light first passes through one filter out of a set of 30 order sorting filters before it is directed to the collimator by a 45 degree mirror. The collimator has a focal length of 900 mm to produce a 180 mm beam; in the first pass it is used at the edge of the field. The collimated beam is dispersed by one of the two echelle gratings that are mounted back to back on the direct-drive grating turret. After passing through the collimator again, this time on axis, an intermediate spectrum is produced. Finally, a re-imaging system ("camera") produces a 2.5-times demagnified image on the 2K*4K CCD at F/2. A view of GIRAFFE is give in Figure 1. GIRAFFE has been conceived to minimize maintenance and night calibrations; special requirements have been introduced to reduce setup shifts and to obtain accurate re-positioning. We expect to be able to use wavelength calibrations and flats obtained in the afternoon, so this time-consuming operation does not have to be done during the night using the OzPoz internal calibration system. To be able to monitor instrument drifts, five fibres are always used to obtain simultaneous calibration spectra.

A summary of the most relevant GIRAFFE characteristics is given in Table 5

Fiber slit height	76.8 mm
Type	Echelle + Order selection Filters
Collimator aperture	F/5
Collimator beam	18 cm
H-R Echelle	204X408 mm, 316 lines/mm, 63.4º Blaze
L-R Echelle	156X204 mm, 600 lines/mm, 33.7º Blaze
Reimager demagnification ratio	2.5
Effective Camera Focal Length	360 mm
Detector	2048 x 4096, 15 um EEV CCD
Scale	0.20 arcsec/pixel

Table 5 Summary of GIRAFFE construction characteristics

GIRAFFE is operated with 30 fixed setups; 22 are used to cover the whole spectral range with the high resolution grating, 8 with the low resolution grating. The different GIRAFFE sub-units are described in more detail in the following sections.

6.1. Slit Unit

The slit unit contains six slots: five are occupied by the GIRAFFE fibres and one is occupied by the long slit which can be illuminated by an internal calibration unit. The slit unit is the most complex GIRAFFE mechanical subsystem, because it needs a very high stability and reproducibility. It has two linear movements: one to exchange the fibre slit, the other one is used for focusing and to press the non-used slits against a baflle that is also used for back-illumination. Each movement has a resolution of 130 nm per step (equivalent to 50 nm on the CCD).

The slit unit is equipped with a number of back-illumination LEDs. These LEDs are powered and controlled by the fibre positioner. They are switched on for typically 10 msec before pick-up and after placing a fiber, to allow the gripper camera to view the fibre output. For Medusa with its 132 fibers, the total LED ON time needed to configure a plate will be minimum 5.2 sec, usually somewhat longer since sometimes a fiber button must be repositioned.
Since the back-illumination LEDs are lit during the GIRAFFE exposures, special attention was paid to light-tightness. The measured level for a total LED ON time of 20 sec is not measurable (< 1 e/pix) so while one slit is observing, any slit on the other plate can be prepared by OzPoz.

6.2. Filters

After the fibre slit, an order sorting interference filter is placed in the beam. These filters must have excellent transmission and steep bandpass edges and out-of-band blocking, in order to avoid pollution from adjacent spectral orders. This is very critical, especially in the blue where the orders are rather short. One example of filter transmission is given in Figure 4. The transmissions of all filters, averaged over each setup, are given in Figure 5. This figure shows also the efficiencies of other Giraffe components, as well as overall DQE of Giraffe. The thirty GIRAFFE filters are mounted on a cylindrical wheel that is rotated and translated to select a filter. The number of available filter positions is 48, arranged in 4 layers, each with 12 filters positions.

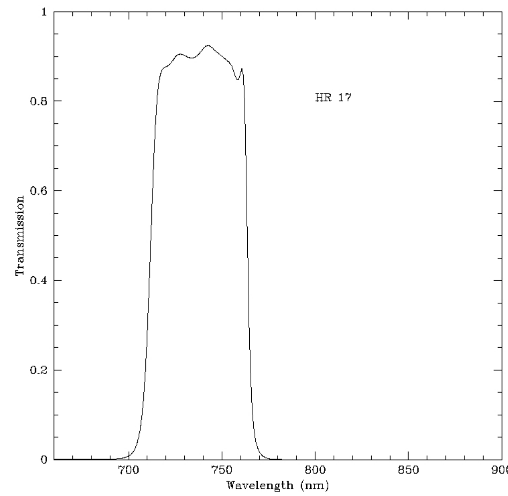

Figure 4: Transmission of order sorting filter HR 17

6.3. Optics and gratings

After it passes the filters, the light is reflected by a 45 degree mirror towards the collimator, which works in double pass, i.e. the light passes through it again after being dispersed. The incident beam is 6 degrees off axis.

The gratings are placed back to back on a direct-drive turntable The high dispersion grating is the Spectronics MR-112, a MgF_2/Ag coated, 204 x 408 mm 63.6 degree echelle with a large groove density (316 lines/mm) in order to have long orders also in the blue. The 370-950 nm spectral range is covered by twenty-two setups in grating orders 15 to 6. Silver was selected because of its good VIS/NIR efficiency and the low polarization it produces on this grating. While the efficiency on one edge of the grating is good though the used spectrum, the efficiency degrades below 500 nm as one approaches the other edge. This is due to inhomogeneity in the MgF_2 layer which is too thick on this side of the grating due to non optimal geometry during the application of the MgF_2 flash coat. We are working with Spectronics to find a replacement before the instrument is released.

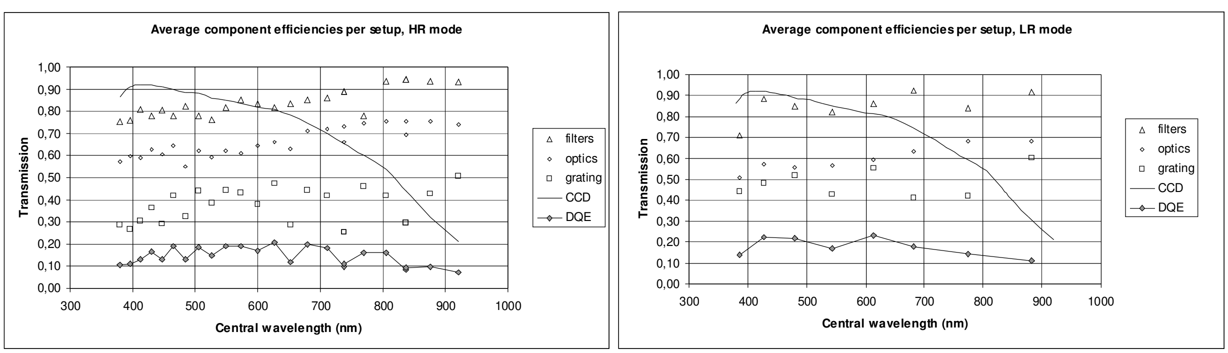

Figure 5: Component efficiencies per setup and the resulting overall DQE (slit to detected photoelectrons) of GIRAFFE. All reported values are averages; note that grating efficiencies can vary by up to a factor of two within a setup. The optics efficiency includes vignetting at the grating, this is why the reported LR values are slightly lower than HR values at the same wavelengths.

The low resolution grating is the MR5328ZD-660 coated with MgF_2/Al, 600 lines/mm. Its first-order blaze lies at 1.96 um so in the range 370-950 nm it works in orders 5 - 2; eight setups are needed to cover the full range. The grating ruled area is 155 x 204 mm, which implies that some 8% of the 18-cm beam is vignetted. In the future, the aim is to provide a grating with the same characteristics but a larger size.

After being dispersed, the light passes again through the collimator, forms a real image at an intermediate focal plane and is finally imaged by an F/2 reimaging camera with 7 elements. Because we do not maintain a constant temperature, the effect of refractive index changes must be compensated. To maintain a good image quality within the operational temperature range (typically 0-20 deg C on Paranal), two conditions must be satisfied: (1) the fiber slit must remain conjugated to the CCD plane and (2) the beam must remain collimated on the grating, which would otherwise introduce astigmatism. This implies two mechanisms: expansion bars move a lens inside the camera to maintain collimation, the slit focus position is controlled using the signal of temperature sensors inside the spectrograph.

6.4. Spectral Format and Efficiency

In GIRAFFE the spectra are parallel in dispersion along the long side of the detector (readout direction), while the short side is along the slit direction. Spectra are slightly curved due to optical distortion and lateral chromatism, with the central part closer to each other than the edges. As is the case in any long-slit spectrograph, the lines of constant wavelength are arranged on low curvature arcs. An example of Th-A spectrum taken with a pinhole mask is given in Figure 6, red is towards the left.

Although any wavelength can in principle be selected, standard GIRAFFE setups have been identified to facilitate operation, calibration and management of the calibration database. Use of these is mandatory for service observing and is strongly encouraged also for observing in Visitor Mode.

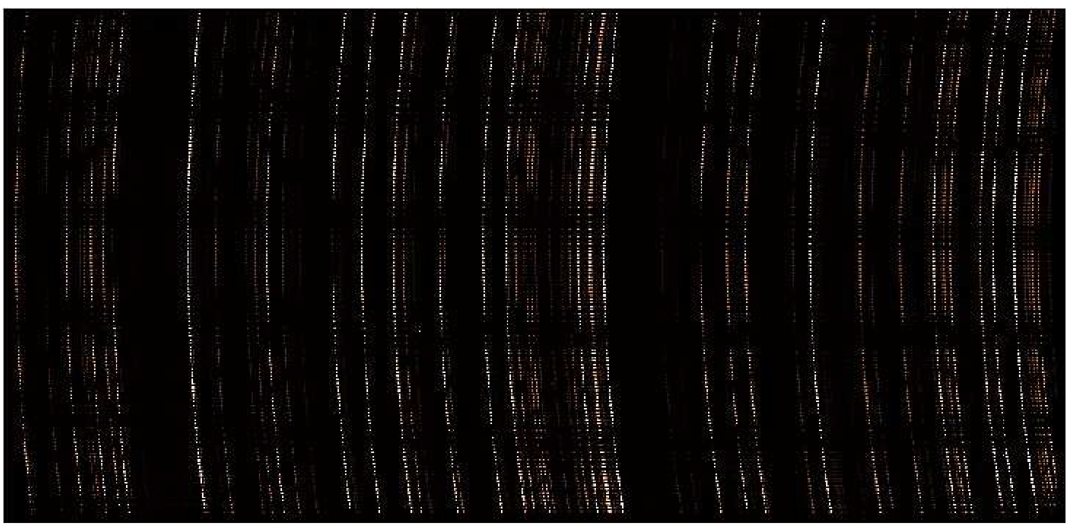

Figure 6: Th-A spectrum taken during system test with the internal long slit, equipped with a pinhole mask to simulate a Medusa fibre slit. The fibres in the center of the slit have lines moved towards the blue; e.g. fibres corresponding to the central fibres will have a slightly bluer wavelength coverage than the ones at the CCD edges.

The resolving power and coverage are both a function of the grating angle. It is determined by the central wavelength and grating order for the chosen setup: two or three different grating angles are required per grating order, which causes the differences in resolution and spectral coverage between the different setups. A higher angle leads to a higher resolution and to smaller wavelength coverage. The setups have also been chosen to guarantee a 10% overlap between consecutive setups. This enables an easy connection between the different spectral slices of the same object.

The higher resolving power of the IFU and ARGUS modes (compared to the MEDUSA mode) is due to the smaller size of the fibres, which projects to 2-2.4 pixels instead of 3.8-4.8 pixels of MEDUSA (differences caused by grating anamorphosis.

The spectral coverage for a given setup is the same in the MEDUSA, IFU and ARGUS modes. For a given spectral format, the spectral resolution is very uniform along the chip. Tests on Medusa fibres show a variation of the resolving power along the chip of less than 4.4% rms. In general, the telescope plus spectrograph is expected to deliver a peak efficiency of 10%, uniform in the 450-700 nm range, which degrades towards the blue (mainly due to lower grating and fibre transmission) and towards the red (due to CCD efficiency).

It is important to recall that the efficiency can change up to a factor of two within a setup especially if it has an off-blaze central wavelength. The efficiency may be improved in the future if a new red sensitive detector becomes available and UV-blue performance could be improved with a new HR echelle.

7. FLAMES: INTEGRATION AND FIRST RESULTS

FLAMES components have been installed between October 2001 and April 2002 on UT2. The integration sequence has roughly followed the light path: Corrector, UVES fibres, Positioner, GIRAFFE. Since all these components have been assembled separately in the home institutes and followed separate development schedules, this sequence was chosen to allow the use of UVES-fibre in case of delays in the schedule of GIRAFFE. Actually, GIRAFFE had first light in Europe in December 2001 and was re-assembled in Paranal in April 2002 without major inconveniences, after the re-integration of the positioner and in perfect timing with the rest of the project.

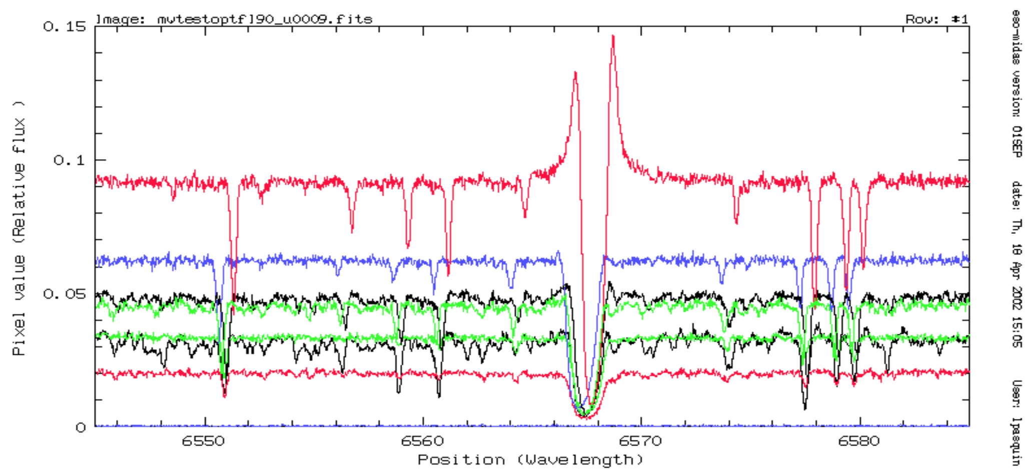

Figure 7: Reduced spectra of 7 giants in the globular cluster Omega Cen taken with UVES-fibre around the alpha line.

During the first run at the end of March 2002 the Positioner was integrated and tested and we could gather the first light with UVES-Fibres. Three 10 minutes spectra were obtained for 7 stars (one fibre was dedicated to sky) belonging to the Globular cluster Omega Cen. The seven giants were chosen to have different metallicity and three of them were previously observed with UVES in long slit mode (Pancino et al. 2002). A small portion of the spectra around line H-alpha line is shown in Figure 7. The stars had magnitude varying between V=11.5 and 12.9. A crude analysis of the data shows that the fluxes recorded are in good agreement with what was expected when considering the limited astrometric accuracy of the system at that stage and the atmospheric conditions at the moment of the observations.

During these tests the team experienced with malfunctions in the positioner Teta air-bearing and the encoder, due to the lower temperature at Paranal compared to those prevailing during the tests in Australia and in the Assembly Hall in Paranal. We temporarily fixed this by the installation of 3 heaters of 2 kW each - clearly not a suitable permanent solution. The robot mechanics were corrected during a second commissioning period in June 2002, but new mechanical problems, related to the interface with the telescope rotator-adapter were encountered.

Finally, on July 3, first GIRAFFE spectra could be obtained. Two sets of spectra of stars in an astrometric field were acquired, each of 10 minutes. The setup used was LR4, Low Resolution centered at a wavelength close to the V filter. 66 MEDUSA fibres were positioned (some in sky positions), and the reduced spectra of some of them are shown in Figure 8. (Note that the slope in the reduced spectra is not the original one, because they have been divided by the Flat Field). The stars have R magnitudes between 13 and 14. In all spectra the Magnesium triplet at 518 nm is clearly visible, as well as the 5576 sky emission line. Also in this case the observed fluxes are in reasonable agreement with what expected, when considering seeing and the still limited astrometric accuracy of the system (e.g. slightly better than 10^{-3}).

The stability and repeatibility on the telescope, measured by taking a ThAr spectrum every 4 hours over a period of 2 weeks during which the telescope was observing with UVES, is shown in Figures 9 and 10.

A further commissioning took place in August 2002; enabling us to advance the commissioning tests and to decide whether the FLAMES facility will be released to observers on the planned date: April 1

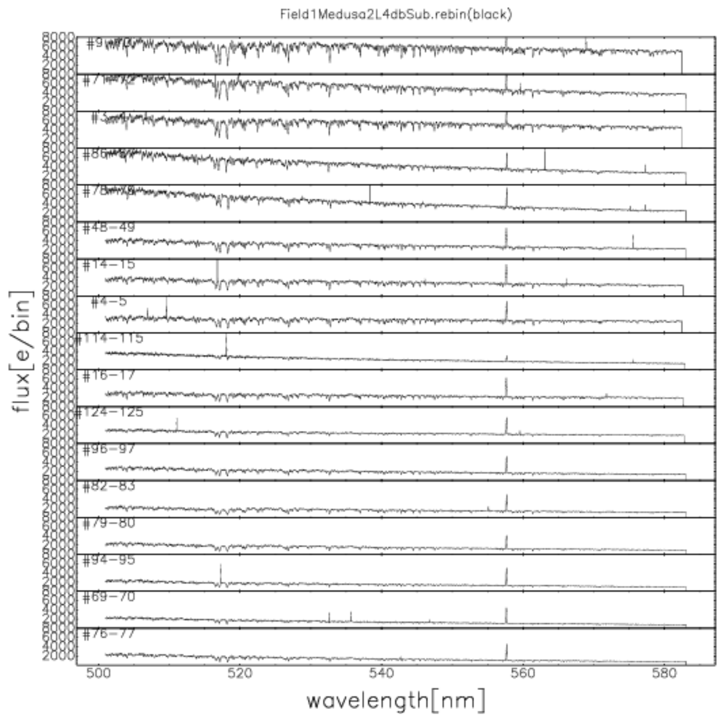

Figure 8: Reduced spectra of GIRAFFE: the stars belong to an astrometric field. The Mg triplet and the 5576 sky emission line are clearly visible in all spectra

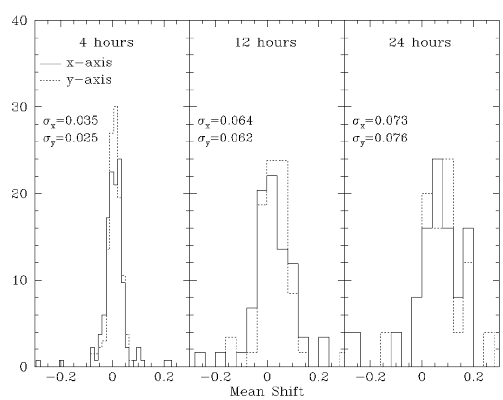

Figure 10: Histogram of relative shifts after 4, 12 and 24 hours, using the time series of figure 12. In HR mode, 0.1 pixel corresponds to about 300 m/sec. These plots show the intrinsic stability of Giraffe and will be helpful to plan the frequency of calibrations. Note that we expect to obtain higher radial velocity precision by using the simultaneous calibration fibres.

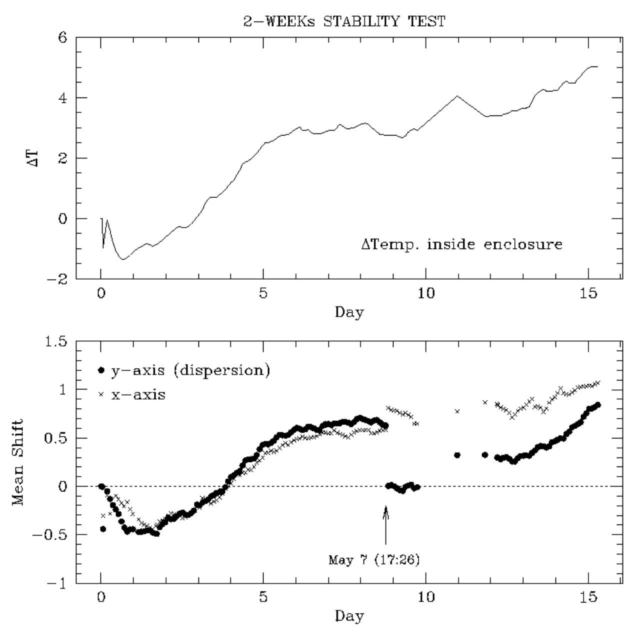

Figure 9.: the average position of ThAr lines in a time series that was taken at 4 h intervals over a period of 2 weeks. Shifts are given in pixels relative to the first exposure. These exposures were taken in Medusa HR mode, with configuration changes between exposures. The jump on May 7 cannot be correlated to any known event like an earthquake.

2003.

8. FINAL REMARK

We believe that the development of FLAMES, which has been recommended by the ESO STC in 1998, presented some remarkable aspect, in particular showing the feasibility of the development of a complex, multi-institute facility in a short time. This could not have been possible without appropriate structures but mostly without the dedicated work of a very large number of people, which are not appearing in this author list. We would like to thank all the persons at ESO (Garching and Paranal) and at the different institutions (Anglo Australian Observatory, Mount Stromlo, Paris-Meudon, Geneve, Lausanne, Bologna, Cagliari, Palermo, Trieste) who have contributed to the realization of this ambitious project.

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