FLAMES Integral Field Unit ARGUS commissioned

A.Kaufer, L.Pasquini, R.Schmutzer, and R.Castillo

Introduction

The FLAMES multi−fibre facility at the VLT (Pasquini et al. 2002) is equipped with two different types of integral field units (IFUs): 15 deployable mini−IFUs per plate, each consisting of a rectangular array of 20 square microlenses with an aperture of 3 x 2 arcsec. The mini−IFUs are complemented by15 single−fibre IFUs for measurements of the sky background. The second type is the stationary **ARGUS**−IFU with a 22x14 microlens array feeding 300[1] fibres to the GIRAFFE spectrograph and a maximum aperture of 11.5x7.3 arc sec² on sky. Only a single ARGUS−IFU is available and is fixed to the centre of Plate 2 of the Fibre Positioner. 15 deployable single−fibre IFUs are available for sky measurements in the ARGUS mode. All FLAMES IFUs have been developed as part of the FLAMES project by the Observatoire de Paris−Meudon (Jocou et al. 2000).

While the deployable mini−IFUs have been offered to the community from the beginning of the FLAMES operation in January 2003, the ARGUS mode had to be postponed to Period 72. This paper reports on the results of the successful 3−day commissioning of the ARGUS mode in last July and provides the users with some detailed information which is considered useful for the preparation of their Period 72 observations, the preparation of future proposals, and the analysis of their ARGUS data.

ARGUS characteristics

Table 1 summarises the characteristics of the ARGUS−IFU and the corresponding ARGUS mode of the GIRAFFE spectrograph.

The pre−optics of the ARGUS−IFU offer two different magnifications of the focal plane. The scale 1:1 projects 0.52x0.52 arcsec² on each microlens resulting in a total aperture of the IFU of 11.5x7.3 arcsec²; with the scale 1:1.67 each microlens corresponds to 0.3x0.3 arcsec² and the total aperture is 6.6x4.2 arcsec². To change between the two scales, the Fibre Positioner Plate 2 has to be swapped to the configuration position. Therefore, the selection of the ARGUS scale is part of the fibre configuration process.

The rectangular ARGUS−IFU is oriented with its long axis along the North −

1 Which is 3 times more than Αργος had eyes on his body.

South direction on the sky for a position angle of 0 degrees. The position angle of the ARGUS−IFU is counted in the usual sense, i.e., increasing from North over East.

The ARGUS−IFU is not perfectly centred on the optical axis of the telescope but is located at an offset position of −1.25 arcsec in right ascension and −0.9 arcsec in declination for a position angle of 0 degrees. This offset is taken into account during the preset of the telescope and the acquisition of the field so that the user−specified target coordinates are centred on the ARGUS−IFU.

The detailed configuration of ARGUS during the observation is recorded in the header of the FLAMES FITS extension named `OzPoz_Table` using the following keywords:

```
ARGPOSAN    45.          Position Angle of ARGUS on sky (Degrees)
ARGSCALE    '1:1'        ARGUS Scale
CENRA       269.05162    17:56:12.39 ARGUS Centre mean RA
CENDEC      −0.025166    −00:01:31.6 ARGUS Centre mean DEC
```

In the original design and installation of the ARGUS pre−optics a zero−deviation Atmospheric Dispersion Corrector (ADC) was foreseen to compensate the differential, wavelength dependent shifts of the images due to the atmospheric dispersion. The two counterrotating ADC prisms have been removed at the beginning of the ARGUS commissioning and were replaced by a corresponding pupil stop. This decision was taken after a careful reconsideration of the benefits of the ADC over the increased complexity and the inevitably reduced efficiency of the ARGUS mode.

The GIRAFFE observing modes which are affected most by the differential atmospheric dispersion are the bluest wavelength settings with the largest wavelength coverage, i.e., with the lowest resolution. In the most extreme LR1 setting with a wavelength coverage of 360−410 nm the images are shifted by 0.9 (0.6) arcsec along the parallactic angle for an airmass of sec z = 2 (1.5). More critical than the absolute image shifts which can be easily modelled and corrected for in the data reduction, may appear the differential shifts during a long exposure at high airmasses: while the image centre of the ARGUS−IFU is always maintained by the telescope guiding for the central wavelength, the extreme wavelengths of the setting would suffer in the above example from a *smearing* of the image of ±0.15 arcsec along the (changing) parallactic angle over an exposure running from airmass 1.5 to 2. However, considering that the smallest available ARGUS pixel scale is 0.3 arcsec, the differential effect appears negligible even for the most extreme wavelength settings. In general, observations at such blue wavelengths at high airmasses have to be avoided anyway because of the high extinction losses.

The arrangement of the microlenses in the 22x14 array and the resulting geometry of the ARGUS−IFU are shown in Figure 1 together with the organisation of the 300 IFU fibres in the ARGUS−slit of GIRAFFE. The 300 fibres are organised in 15 subslits of 20 fibres each. The order of the fibres in the microlens array and in the corresponding subslit is indicated by arrows in Figure 1. Each of the 15 subslits is complemented with an additional ARGUS sky fibre which is mounted first in the subslit followed by the 20 IFU fibres; in the subslits 1, 4, 7,10, and 13 a simultaneous calibration fibre is mounted last in the subslit. In total, the GIRAFFE ARGUS slit is fed by 300+15+5=320 fibres. The FLAMES FITS extension table named `FLAMES_Fibre_Table` contains the correspondence between the position of the individual fibres in the GIRAFFE slit (table column `FPS`) and the subslits (column `SSN`). The columns `X` and `Y` eventually record the position of the respective fibre in the microlens array. If the IFU image is reconstructed using the given x,y positions, the long x−axis of the array is oriented in North direction while the short y−axis is oriented in East direction for a position angle of 0 degrees.

Preparation of Observations

All ARGUS observations in FLAMES Service Mode must be prepared using the Fibre Positioner Observation Support Software FPOSS (Shortridge et al. 2003). In addition to the selection of the VLT guidestar and the detailed assignment of the ARGUS Sky and the Fiducial fibres (FACB) fibres, FPOSS allows to define the ARGUS position angle and the ARGUS scale. The coordinates of the field centre as specified in the input target file (*.fld*) with the keyword `CENTRE` will be centred on the ARGUS−IFU during the acquisition process. If the field centre is given in the same astrometric system as the fiducial stars, the ARGUS−IFU can be positioned with very high precision on the target. However, in general the required accuracy for the relative astrometry of the target and the fiducial stars can be relaxed to 1 arcsec rms for the ARGUS mode (for MEDUSA and IFU mode, astrometry of better than 0.3 arcsec rms is required).

In FLAMES Visitor Mode a simplified so−called *fast* ARGUS acquisition procedure is offered which does not require the use of FPOSS for the preparation of the observations and allows to preset from one target to the next without reconfiguration of the fibres. In the fast acquisition mode, the accuracy of the centring of the target relies on the pointing accuracy of the VLT which is better than 3 arcsec. If in addition to the target coordinates the VLT guide star is provided by the user in the same astrometric system, almost the same pointing accuracy as with the fiducial fibres can be achieved. In the fast acquisition the FACBs are not used at all, the ARGUS sky fibres can either be parked or placed on a constant radius in the 25 arcmin field of view. Once the sky fibres are configured and the ARGUS scale is selected, the ARGUS field can be presetted from one target to the next without reconfiguration of the plate. This reduces the overheads between two subsequent ARGUS observations from 30 minutes for the reconfiguration and reattachment of Plate 2 down to 6 minutes as needed for a regular telescope preset. Therefore, the fast acquisition is of great importance for ARGUS−only observations in Visitor Mode. In Service Mode two queued ARGUS observations have to (and can) be interlaced with a regular MEDUSA / IFU / UVES observation on Plate 1 to avoid extensive overheads.

The fast acquisition template is complemented by a fast observation template, which allows to offset the telescope between consecutive exposures. This additional feature provides the user with the possibility to raster larger areas of the sky with defined offset patters to create e.g. mosaics of extended objects (for an example of such an observation cf. below).

Calibration Plan

Standard FLAMES calibrations for the science data are provided by the observatory (cf. Kaufer 2003 for details on the FLAMES calibration plan) and include flatfield and wavelength calibrations as taken during daytime with the calibration system of the Fibre Positioner robot by illuminating each individual fibre with a fibre projector fed by calibration lamps. The ARGUS−IFU cannot be illuminated homogeneously because of the limited beam size of the fibre projector. To enlarge the illuminating beam, all robot−flatfields and wavelength calibrations of the ARGUS−IFU are taken with the enlarged scale of 1:67 which allows to illuminate all microlenses of the array. The robot−flatfields can mainly be used to trace the location of the fibres on the detector. For this purpose in addition to the ARGUS−IFU, all ARGUS sky fibres and the simultaneous calibrations fibres are illuminated as well during the flatfield exposures.

In addition to the daytime calibrations, observations of spectrophotometric standard stars with the ARGUS−IFU will be automatically provided by the observatory corresponding to the ARGUS and spectrograph setups used for the science observations. Each observation of a spectrophotometric standard will be followed by a set of flatfields taken with the Nasmyth screen. Contrary to the robot−flatfields, the screenflats do provide a homogeneous illumination of the IFU and can be used to calibrate the relative response of the ARGUS−IFU. The ARGUS screenflats reveal a slight vignetting of <10% at the edges of the array due to the decentering of the ARGUS head w.r.t. the central hole of the plate.

First 'Science' Observation

To test the newly created fast acquisition and observing templates and to demonstrate the capabilities of the ARGUS mode of FLAMES, the extended equatorial region of the eta Carinae Homunculus was observed with five overlapping pointings of the ARGUS−IFU as indicated in Figure 2. At each offset position, a 300 second exposure was taken in the GIRAFFE high−resolution setting around the Halpha line (HR14 with a resolving power of R=47000 and a wavelength coverage of 638−663 nm). For the central pointing, the exposure time was reduced to 1 second because of the extremely strong Halpha emission of the central region of eta Carinae.

Figure 3 shows 4 out of the 14 available wavelength−X planes as extracted from the combined data cube of the 5 ARGUS pointings and nicely demonstrates the power of 3D −spectroscopy: in the presented example the complex spatial, dynamical and physical structure of the eta Carinae Homunculus is revealed to the observer in a single, quite spectacular view.

From our first experience with the ARGUS mode of FLAMES during this successful commissioning run we conclude that the comparatively large size of the ARGUS−IFU paired with the high resolution of the GIRAFFE spectrograph indeed provides the ESO community with a unique new observing capabilities at the VLT.

Acknowledgements

We would like to thank the OzPoz team at the Anglo−Australian Observatory and Gerardo Avila at ESO/Garching for their active support during the ARGUS commissioning.

References

Pasquini, L., et al., 2002, *Installation and Commissioning of FLAMES, the VLT Multifibre Facility,* The Messenger 110, 1

Jocou, L., Guinouard, I., Hammer, F. , Lenoir, H., 2000, SPIE 4008, 475

Kaufer, A., Pasquini, L., Zoccali, M., Dekker, H., Cretton, N., 2003, *FLAMES User's Manual,* Version 1.1

Shortridge, K., Zoccali, M., Primas, F., Kaufer, A., 2003, *FPOSS User's Manual*, Version 1.9

Kaufer, A., 2003, *FLAMES Calibration Plan,* Version 0.4

Table 1: Characteristics of the ARGUS IFU and Mode

ARGUS−IFU	
Microlens Array	22x14 x (0.3x0.3mm²)
Pre−optics Scales	1:1 = 0.52x0.52 arcsec²/microlens
	1:1.67 = 0.3x0.3 arcsec²/microlens
Aperture on Sky	11.5x7.3 arcsec² (scale 1:1)
	6.6x4.2 arcsec² (scale 1:1.67)
Location	Centre Fibre Positioner Plate 2
Orientation	long axis N−S (Position Angle 0)
	long axis N−S (Position Angle 90)
Efficiency (incl. Fibres, spectrograph, detector)	3.9 (3.3) % at 400nm for HR (LR)
	6.4 (9.4) % at 600nm for HR (LR)
	4.8 (4.8) % at 900nm for HR (LR)
Fibre−to−Fibre Transmission Variation	<10 %
Atmospheric Dispersion Corrector	none
GIRAFFE−ARGUS	
Slit Geometry	300 ARGUS fibres
	15 ARGUS Sky fibres
	5 Simultaneous Calibration fibres
Resolving Power	~ 33000 (HR grating)
	~ 11000 (LR grating)
Wavelength Coverage	~ λ / 22 (HR grating)
	~ λ / 7 (LR grating)

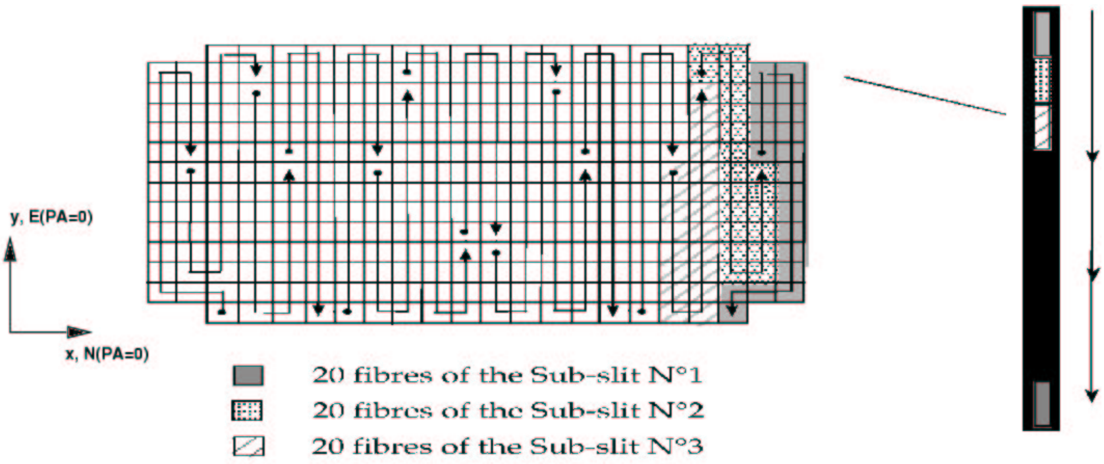

Figure 1: ARGUS−IFU and ARGUS−Slit geometry.

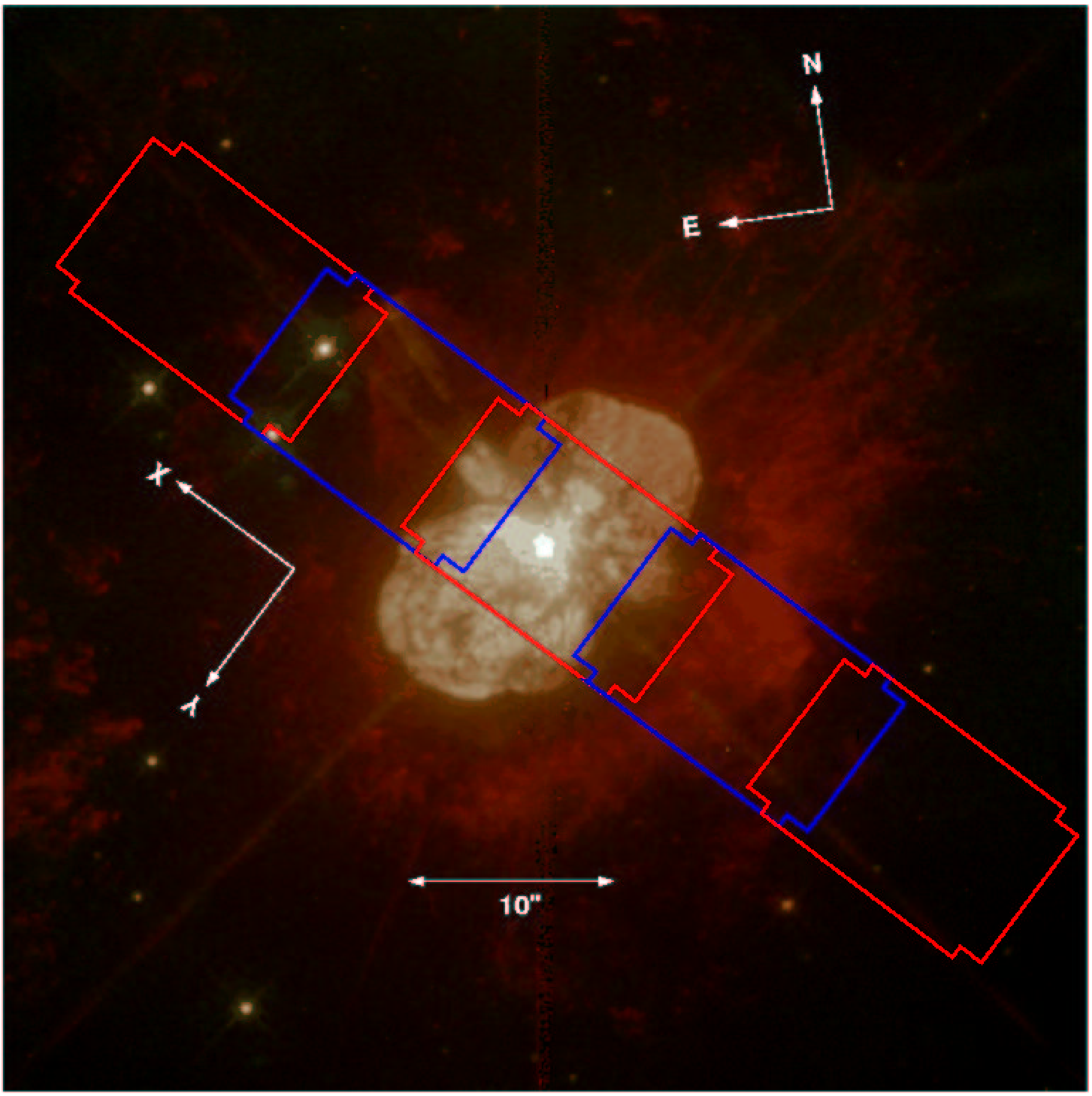

Figure 2: Position of the 5 ARGUS pointings on eta Carinae superimposed on a HST WFPC−2 image (from HST Press Release STScI−1994−09).

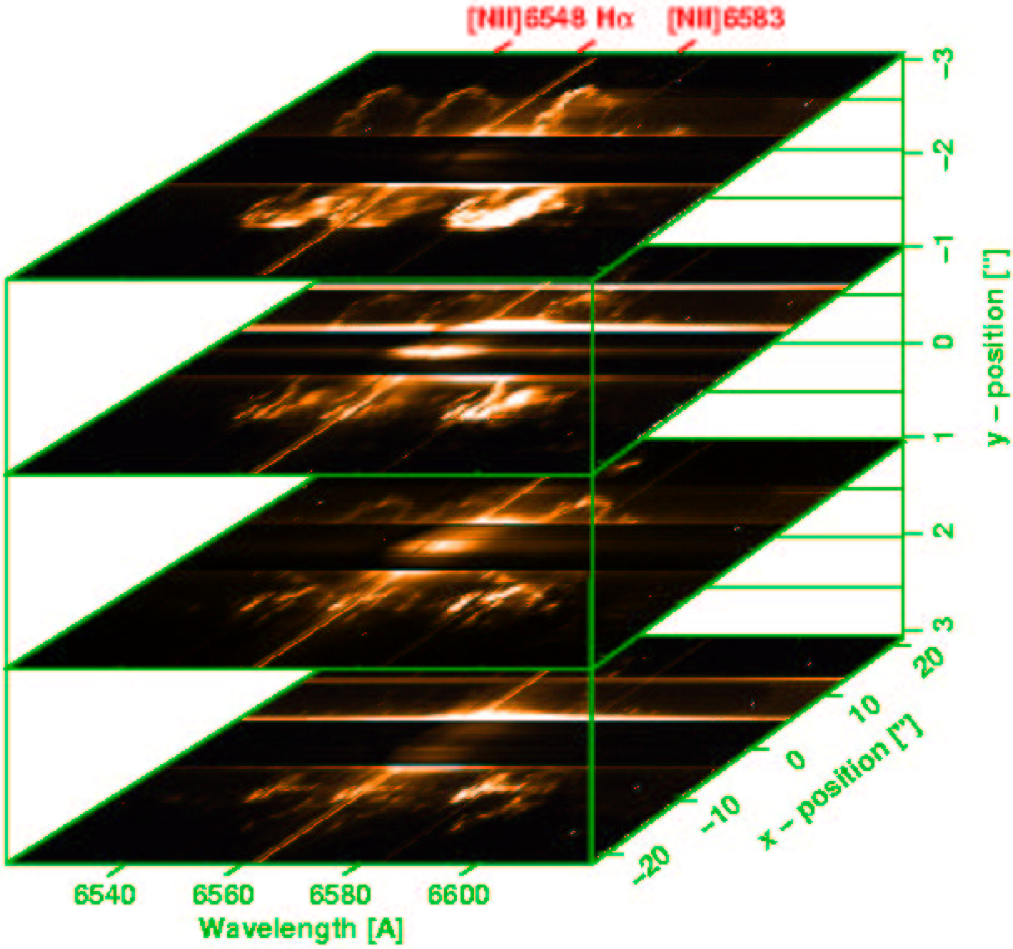

Figure 3: Four out of 14 slices from the eta Carinae ARGUS data cube around the Halpha and the [NII] lines. The horizontal lines in the back indicate the positions of the 10 slices which could not be shown.