Processing IFU data from VLT instruments

Running title: Processing IFU data from VLT instruments

R. Hanuschik[a], P. Sartoretti[a]

[a]*European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching, Germany*

Correspondence to: rhanusch@eso.org

Abstract

Currently three ESO/VLT instruments employ IFUs: FLAMES/GIRAFFE, VIMOS, and SINFONI. As all other VLT data, the IFU data from these three instruments are fed into a data flow system that provides, as main functions, archiving and pipeline processing. On Paranal *quick-look* data reduction is performed, while at Garching Headquarters *quality-controlled* calibration solutions and science products are produced. The pipelines also extract quality information from the data, which is fed into a database and is available for long-term performance monitoring and trending.

This article focuses on the data processing and quality control processes of GIRAFFE and VIMOS data.

Key words: instrumentation: spectrographs; techniques: spectroscopic; methods: numerical

PACS: 95.55.Qf, 95.75.Fg

VLT instruments with IFUs

Three ESO/VLT instruments have presently an IFU mode: FLAMES/GIRAFFE, VIMOS, and SINFONI. GIRAFFE is a medium to high-resolution optical spectrograph and has two different IFU modes: one mode with 15 deployable IFUs of 20 square microlenses each, and one mode (called ARGUS) with a single 22x14 array of microlenses.

The VIMOS optical imager/spectrograph uses 4 CCDs and has among other operational modes an IFU mode, which uses up to 6400 (80x80) microlenses feeding fibres and offering a resolving power of up to 2000.

SINFONI is a near-infrared dedicated IFU spectrograph and employs a 32-element image slicer to map 64 x 32 spatial pixels onto a pseudo-long slit. SINFONI is supported by adaptive optics and operates in the 1.1-2.45 micron range. SINFONI data processing is covered in detail by Hummel et al. (2005).

Like for all other VLT and VLTI instruments, data from GIRAFFE and VIMOS are processed by data reduction pipelines, both on-site, and off-line in Garching. The *on-line* processing is done to provide quick-look results and give feedback about the instrument performance and the scientific usefulness of the data acquired. The *off-line* processing, done by the Data Processing and Quality Control group in

Garching, has the goal to provide certified calibration solutions, and to extract quality information to assess and monitor the status of the instrument. Furthermore all science data in Service Mode are processed and delivered to the PI, along with the associated calibrations.

FLAMES/GIRAFFE

The instrument

FLAMES is the **F**ibre **L**arge **A**rray **M**ulti-**E**lement **S**pectrograph mounted at the Nasmyth A platform of the 8.2m Kueyen (UT2) telescope, which is part of the Very Large Telescope (VLT) of the European Southern Observatory (ESO) situated on Cerro Paranal (Pasquini et al. 2002). It has fibre links to two spectrographs, UVES and GIRAFFE. The GIRAFFE instrument has one EEV 2k x 4k CCD and uses two gratings which provide high (R=48,000) and intermediate (6,000) spectral resolution. It has two fiber-fed IFU modes (plus one MOS mode, Medusa, with deployable fibres). One mode is called just '**IFU'** and consists of 15 deployable integral field units of 20 micro-lenses each, with a field of view of 3x2 arcsec each. There are two identical positioning and fibre systems ('plate 1' and 'plate 2'), one of which is typically used for observing while the other one is being configured with the next set of fibre positions, to avoid positioning overheads.

The other IFU mode, **Argus,** is a single rectangular IFU of 22x14 micro-lenses (12x7 arcsec). Both the IFU and the Argus mode use a total of 300 object fibres, 15 sky fibres and 5 fibres reserved for simultaneous calibration with an arc lamp.

GIRAFFE data processing

All calibration and science data are pipeline-processed. The main goal of processing is to extract QC information about the instrument, to provide certified master calibrations, and to process the science data in a way which provides a good starting point for science analysis. The pipeline algorithms have been written by the Observatoire de Genève (Blécha et al. 2000; Royer et al. 2002) and have been integrated into the ESO data flow system. More details about the processing of GIRAFFE data is found in Hanuschik et al. (2004).

The processing of *calibration data* follows a cascaded scheme and involves:
- bias frames are processed to a master bias;
- fibre flats are processed to deliver the fibre localization, the width of fibre signal, a gain map, to record the fringing and to provide a measurement of the relative fibre transmission;
- an arc-lamp exposure is used to derive the dispersion solution (Figure 1);
- for ARGUS data, a standard star is measured to record the fibre transmission more precisely than a flat can do.

<insert here Figure 1>

The science data reduction uses the products of the calibration processing, in order to:
- debias the raw frame;
- extract the fibre signal;
- wavelength-calibrate and rebin the spectra;

- correct for transmission (both in spectral direction and relative, fibre to fibre) using the extracted flat field;
- reconstruct the spectro-image by collapsing the extracted spectra (Figure 2). This is useful for real-time quick-look. It is planned to provide the full data cube in Euro3D format.

<insert here Figure 2>

VIMOS: low to medium resolution, large FoV multi-object spectrograph

The instrument

VIMOS has 4 identical arms arranged in a mosaic, with 4 CCDs (2k x 4k each). It has three modes: imaging, multi-object spectroscopy, and IFU. The IFU has a field of view of up to 1'. There are six grisms available. In low-resolution mode, 80x80 = 6400 fibres are coupled to a micro-lens array of 54x54 arcsec (0.67”/fibre) or 27x27 arcsec (0.33”/fibre) field of view. The fibres are re-arranged into 4 subslits per quadrant. The spectral resolution is about R = 250.

In medium and high-resolution mode, the field of view is 27x27 arcsec (0.67”/fibre) or 13x13 arcsec (0.33”/fibre). 40x40 = 1600 fibres are mapped into one subslit per quadrant. The resolving power is R = 700 (MR) and 2500 (HR), respectively.

IFU science reduction

The VIMOS IFU data are processed by a pipeline, with the following steps:

- debias;
- fibre tracing with the solution obtained from the flat frame, updated by an incremental shift of the reference fibre;
- the cross-dispersion fibre profile for the extraction is determined from the first and last fibre per block;
- the wavelength calibration is performed with the solution from the arc frame, updated by sky line solutions
- presently there is no flat-fielding and no defringing.

<insert here Figure 3>

The data products are delivered as data cubes, with all 4 quadrants recombined. It is foreseen to deliver a Euro3D data cube.

The purpose for the incremental updates of the trace and the dispersion solution is to compensate for potential flexure of the instrument. For that reason, also a set of flats and an arc lamp exposure is taken immediately after the science observation.

<insert here Figure 4>

GIRAFFE and VIMOS Quality Control

Like for all VLT data, quality information is extracted from the GIRAFFE and VIMOS data, in order to know as precisely as possible the instrument status and the quality of the data. Find more information and results of the QC process under the URL http://www.eso.org/qc/ >> VIMOS or GIRAFFE >> Quality Control.

Acknowledgment. We would like to thank Carlo Izzo and Ralf Palsa for many stimulating discussions about the data processing pipelines.

References

Blecha, A., Cayatte, V., North, P., Royer, F., Simond, Gilles, Proc. SPIE Vol. 4008 (2000), p. 467-474

Hanuschik R., Smoker J., Kaufer A., Palsa R., Kiesgen M., Proc. SPIE Vol. 5493 (2004), pp. 564-573

Hummel W., Modigliani A., Szeifert Th., Dumas C., these proceedings (2005)

Pasquini L., Avila G., Blecha A., Cacciari C., Cayatte V., Colless M., Damiani F., De Propris R., Dekker H., Di Marcantonio P., Farrell T., Gillingham P., Guinouard I., Hammer F., Kaufer A., Hill V., Marteaud M., Modigliani A., Mulas G., North P., Popovic D., Rossetti E., Royer F., Santin P., Schmutzer R., Simond G., Vola P., Waller L., and Zoccali M., The ESO Messenger 110 (2002), p. 1-9

Royer F., Blecha A., North P., Simond G., Baratchart S., Cayatte V., Chemin L., Palsa R., Proc. SPIE Vol. 4847 (2002), pp. 184-194

Captions

Figure 1. Arc-lamp calibration. **Left**: Raw arc-lamp exposure with curved spectral format. **Middle**: Product after extraction (the curvature is still present). **Right**. Calibrated and rebinned arc-lamp spectrum, with strictly horizontal emission lines. Fibre index is growing towards right, dispersion upwards

Figure 2. Reconstructed spectro-image for the ARGUS mode of GIRAFFE. Each spaxel has been collapsed in spectral direction. Relative differences between fibre transmission have been corrected for. The left bright spot is due to a bad column. The dark gap comes from fibres falling onto the edge of the CCD, hence being truncated by the pipeline.

Figure 3. VIMOS: Science reduction, extracted fibre spectra. Single spectrum (top) and 2D set of spectra (below).

Figure 4. VIMOS spectro-image, combined mosaic from all four quadrants. Dark spots are caused by dead fibres.

Figures

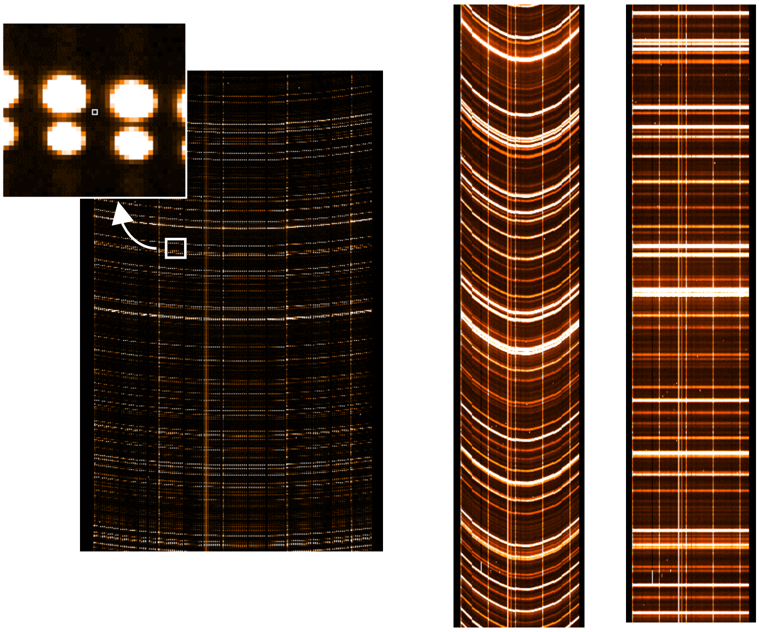

Figure 1

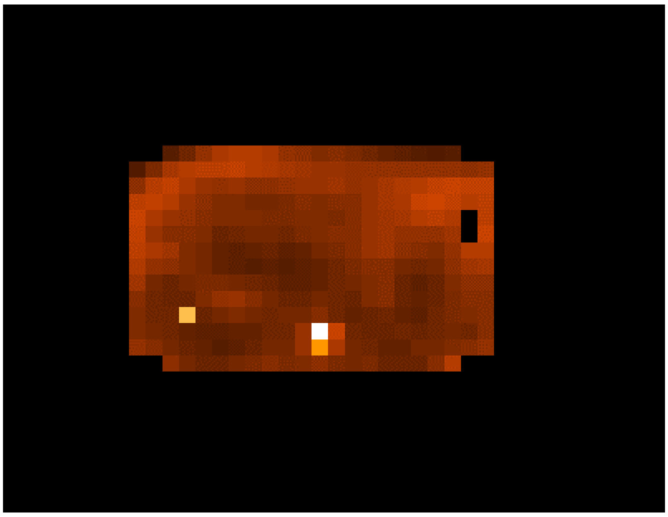

Figure 2

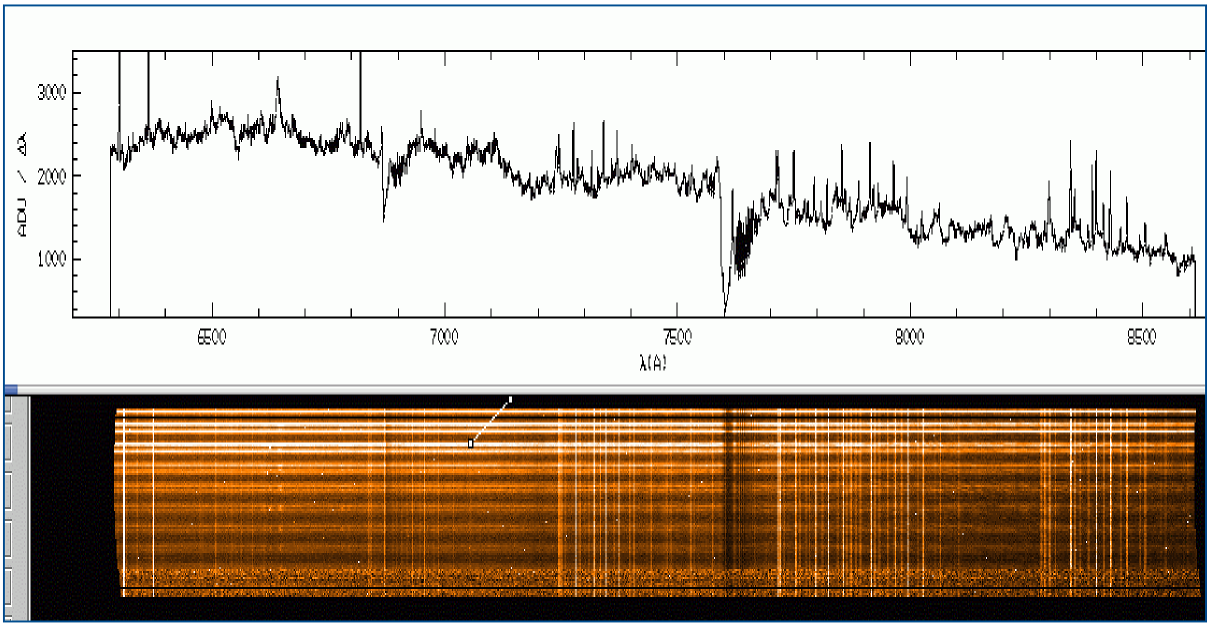

Figure 3

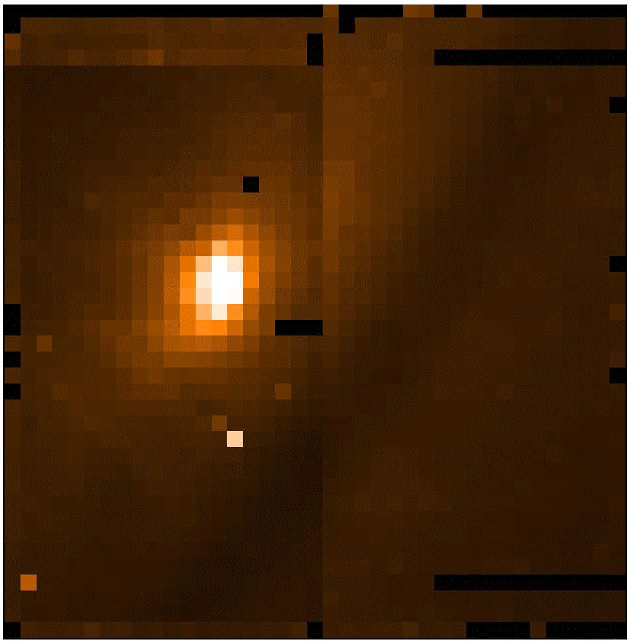

Figure 4