Gasgano & ESO VIMOS Pipeline Released

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In collaboration with instrument consortia, the Data Flow Systems Department (DFS) of the Data Management and Operation Division is implementing data reduction pipelines for the most commonly used VLT/VLTI instrument modes. These data reduction pipelines have the following three main purposes:

- Data quality control - pipelines are used to produce the quantitative information necessary to monitor instrument performance.
- Master calibration product creation - pipelines are used to produce master calibration products (e.g. combined bias frames, super-flats, wavelength dispersion solutions).
- Science product creation - using pipeline-generated master calibration products, science products are produced for supported instrument modes (e.g. combined ISAAC jitter stacks; bias-corrected, flat-fielded FORS images, wavelength-calibrated UVES spectra). The accuracy of the science products is limited by the quality of the available master calibration products and by the algorithmic implementation of the pipelines themselves. In particular, adopted automatic reduction strategies may not be suitable or optimal for all scientific goals.

Even though the main focus of the pipeline recipe development has been, and remains, VLT science operation support, ESO is endeavoring to release all operational instrument pipelines to the community as rapidly as possible. Instrument pipelines consist of a set of data processing modules that can be called from the command line, from the automatic data management tools available on Paranal or from *Gasgano*.
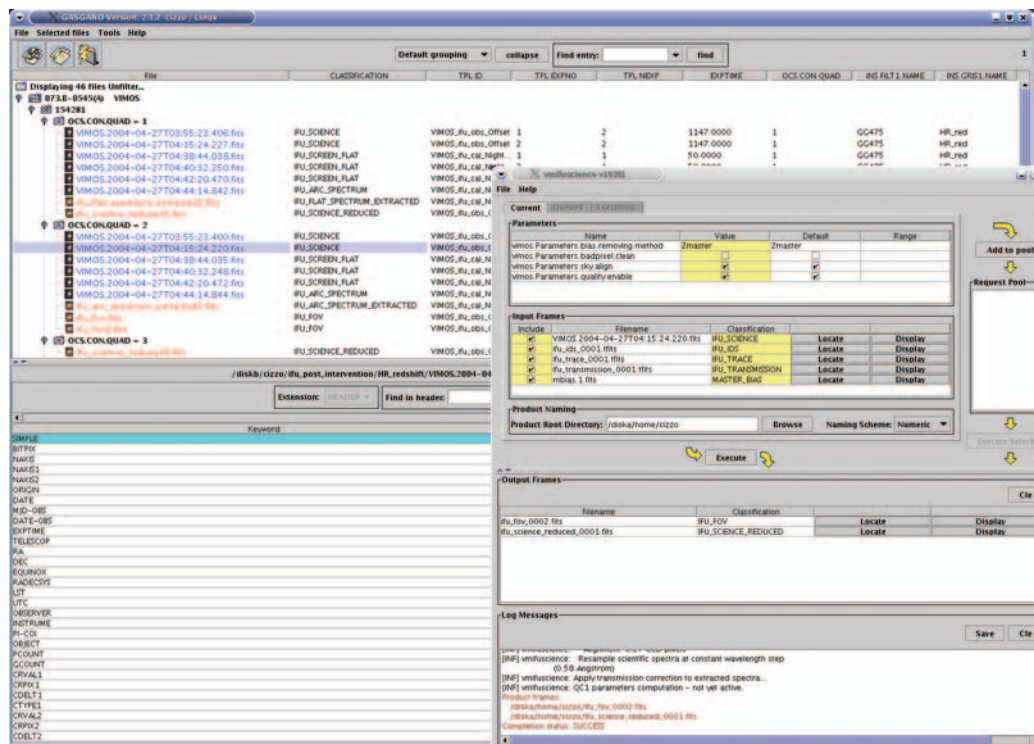
Gasgano is a data management tool that has been avail-able on Paranal and as a desktop application for several years. It simplifies the data organization process and allows file classification tasks such as: "What kind of data am I?", e.g. BIAS, "to which group do I belong?", e.g. to a particular Observation Block or template. Gasgano also makes the association of appropriate calibration files with science frames easier. The next logical step in the development of Gasgano was to extend its functionality to allow pipeline recipes to be executed directly on a set of user selected files. This upgrade has been completed by the DFS in the past year.

In addition to extending Gasgano, DFS has also started the development of a set of pipeline recipes for the IFU mode of VIMOS. The main requirements were to develop recipes which could be executed in a robust and automatic way, to support all existing grisms, to provide the operational teams with the information required to assess the quality of the observations and the health of the instrument and, last but not least, to be Gasgano compliant enabling astronomers to reduce their own data at their home institute. The first release of the IFU recipes has been operational on Paranal since May 2004.

In the middle of July 2004, the VIMOS pipeline recipes, including IFU support as well as imaging and MOS components based on the code delivered by the VIRMOS consortium, were released to the public together with Gasgano and are available for the community from the ESO web site as a bundled package.

The following sections summarise the technical capabilities of the Gasgano interface and provide an overview of the reduction strategy adopted by the pipeline recipes for the processing of VIMOS IFU data.

Figure 1: Gasgano main window and recipe panel. A set of IFU frames are loaded into the main panel. The recipe panel is opened with the recipe *vmifuscience* loaded. A science exposure is being processed using a number of calibration frames. The resulting log file is displayed at the bottom of the panel.
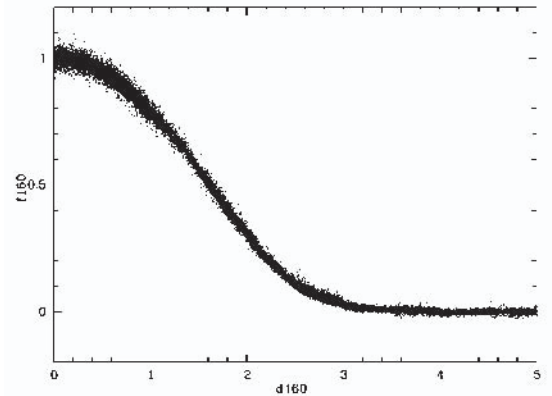
GASGANO

Gasgano provides a means to automatically identify and classify FITS files (e.g. BIAS, FLAT, SCIENCE). Classification rules for the VLT instruments are part of the distribution package. Gasgano also automatically groups files located on a specified set of directories in a tree structure based on the Run ID and Observation ID of the files as well as additional instrument specific keywords. Gasgano allows the user to view and search all the relevant information in a file and displays FITS files and keyword values from the headers, and it provides the user with an interface to pipeline recipes. The user selects the file(s) to be reduced and the appropriate recipe, launches the recipe panel and configures the execution of the data reduction procedure by entering parameters. The recipe can be executed directly from the panel, the log files reviewed and the generated products visualized. Figure 1 shows the main Gasgano window as well as the recipe panel after loading a VIMOS data set and selecting the *vmifuscience* recipe.

VIMOS IFU PIPELINE RECIPES

The VIMOS IFU pipeline consists of two main recipes, *vmifucalib* and *vmifuscience*, to process calibration and science data respectively. The recipe *vmifucalib* determines the spectral extraction mask, the dispersion solution and the fibre relative transmission correction. The results of this recipe are used by the recipe *vmifuscience* which in turn produces the extracted, wavelength calibrated and transmission corrected science

Figure 2: Data (about 24000 pixel values) from which the empirical fibre profile has been constructed for one fibre spectrum obtained with the HR_orange grism

spectra, plus an image of the field of view of a single VIMOS quadrant reconstructed from the extracted spectra by integrating over a predefined wavelength range.
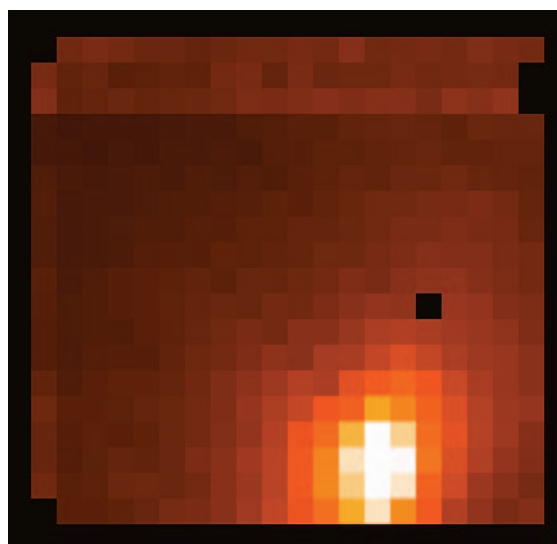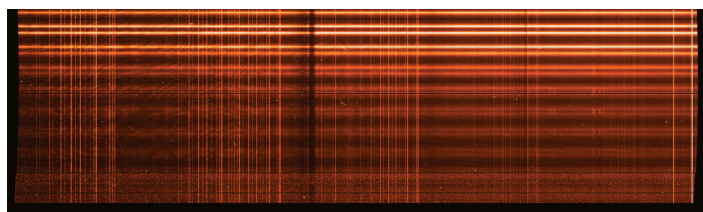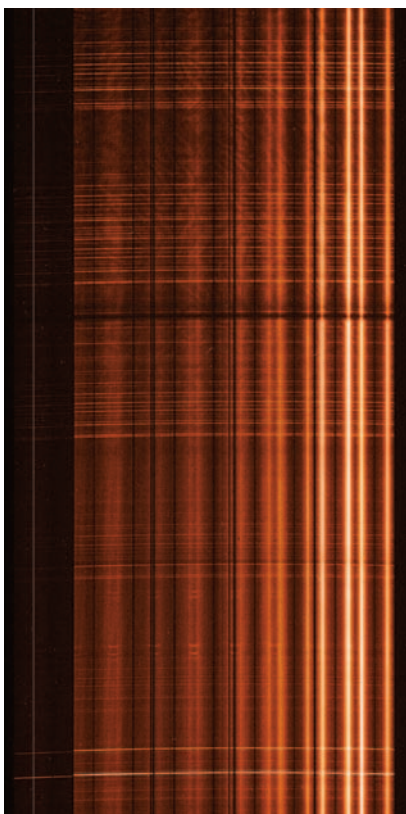
For a complete processing of a scientific IFU exposure, three types of data are required by the pipeline: one or more flat field lamp exposures, an arc lamp exposure, and a science exposure.

In addition the software assumes that flat-fields and arc-lamp exposures are obtained almost simultaneously, without moving the instrument between exposures. This is to ensure that the spectral extraction parameters obtained by processing the flat-field exposures are still valid for the arc-lamp exposure and can be applied directly.

The spectral extraction mask is created from the flat-field exposure by identifying the spectra, i.e. the association of a spectrum on the CCD with a particular fibre and the subsequent tracing of the spectra along the dispersion direction on the CCD. The fibres

are identified using a cross-correlation technique which requires a preexisting and certified fibre identification as reference. Tracing the spectra is also used to determine dead fibres (a fibre which cannot be traced is considered dead). The spectral trace is modeled by a low order polynomial. The accuracy of the tracing is typically 0.01 pixel.

The spectral extraction is based on an empirical spectral profile which has been constructed by examining the half-profiles of the first and last spectrum of each 80 fibres block of each pseudo-slit. The larger gap between the last fibre of a block and the first fibre of the next one allows the determination of the profile down to the background level. Because of the spectral curvature, a different sampling of the fibre profile is available at different positions along the dispersion direction. An example of such a empirical spectral profile is shown in Fig. 2. The obtained profile shows a negligible colour dependency (less than 2%); however,

Figure 3: Raw spectra (left) of an IFU observation (quadrant two) obtained using the high resolution grism HR_red. The dark area on the left is due to the lower transmission of those fibres. The extracted spectra (top right) has been wavelength calibrated and corrected for the relative fibre transmission effects. The noisy area at the bottom of the image corresponds to the dark area on the left of the corresponding raw image. The reconstructed image (bottom right) is also a product of the pipeline

profiles obtained from different fibres show differences, which may, in the future, be taken into account by a parameterised model of the profile. The currently implemented spectrum extraction algorithm uses only the values of the 3 pixels closest to the fibre centroid position, corrected for the profile shape and averaged, since up to 1.5 pixels from the centroid position, the cross-talk contamination by nearby fibres can be neglected.

The wavelength calibration is carried out on the extracted arc-lamp spectra. For high and medium resolution spectra an accuracy of 0.2 pixels is achieved, while for low resolution spectra the accuracy is approximately 0.5 pixels because of the multiplexing of spectra which leads to systematic errors due to the contamination of adjacent spectra along the dispersion direction.

When science observations are processed the spectral extraction mask is aligned to the science exposure using the brightest spectra in the science exposure as a reference. This compensates for changes in the positions of the science spectra on the CCD with respect to the positions of the flat-field spectra. Offsets along the dispersion direction are corrected by adjusting the dispersion solution computed by *vmifucalib* to the position of the selected sky lines. Using a single spectrum of the science exposure is sufficient to achieve a mask alignment accuracy of 0.1 pixel for all fibres. With a fibre-to-fibre distance of about 5 pixels in the direction perpendicular to the dispersion, there is a maximum displacement of about 2 pixels in that direction that can be corrected for. Should these displacements be larger (e.g. because of flexures due to a large rotation of the instrument or changes in the mechanical configuration), the fibres may not be correctly identified and the spectral extraction mask will not be correctly aligned.

Finally the extracted science spectra are corrected for the differences in the fibre transmission where the correction factor is computed from the flat-field spectra by integration over a fixed wavelength range (avoiding the 0th order contamination in the case of multiplexed spectra), normalised to the median of these integrated fluxes. The recipe *vmifuscience* does not currently apply a flat-field correction to the extracted science spectra. Instead, the extracted flat-field spectra are provided as an additional product, which can be used for an approximate flat-field correction, if desired. Figure 3 shows one quadrant of an IFU raw observation, the extracted spectra as well as the reconstructed image produced by the pipeline.

A description of how the IFU recipes are used by the Quality Control group in Garching can be found at http://www.eso.org/qc under the VIMOS section.

GETTING THE SOFTWARE

Gasgano & the VIMOS recipes can be downloaded together with user manuals from (www.eso.org/observing/gasgano/vimos-pipe-recipes.html). We look forward to the extensive use of these new data reduction tools among the community of investigators who have obtained VIMOS data. Your feedback is welcome at *usg-help@eso.org* and will help us to improve our tools.

Nico Housen/ESO

The Milky Way above La Silla. To the left is the decommisioned 15-metre dish of the Swedish-ESO Submillimetre Telescope (SEST), and on the right in the background is the dome of the ESO 3.6-metre telescope, at the highest point of the mountain. The southern Milky Way is seen along the right border of the SEST and above the 3.6 metre telescope. In the highly polished antenna dish of the SEST there is a upside-down reflection of the sky and the horizon behind the photographer. The yellow area of light to the right is the reflection of the city lights of La Serena, about 100 km away and too faint to disturb observations of celestial objects high above La Silla. Photo: *Nico Housen (ESO) – ESO PR Photo 27/04.*