Astronomical Data Analysis Software and Systems X
ASP Conference Series, Vol. 238, 2001
F. R. Harnden Jr., F. A. Primini, and H. E. Payne, eds.

Automated Spectral Extraction for High Multiplexing MOS and IFU Observations

Marco Scodeggio[1], Alessandra Zanichelli, Bianca Garilli

IFC–CNR, Milano, Italy

Olivier Le Fèvre

LAM–CNRS, Marseille, France

Giampaolo Vettolani

IRA–CNR, Bologna, Italy

Abstract. The distinguishing characteristic of VIMOS is its very high multiplex capability: in MOS mode up to 800 spectra can be acquired simultaneously, while the Integral Field Unit produces 6400 spectra to obtain integral field spectroscopy of an area approximately 1×1 arcmin in size. To successfully exploit the capabilities of such an instrument, it is necessary to expedite as much as possible the analysis of the very large volume of data that it will produce, automating almost completely the basic data reduction and the related bookkeeping process. The VIMOS Data Reduction Software (DRS) has been designed specifically to satisfy these two requirements. A complete automation is achieved using a series of auxiliary tables that store all the input information needed by the data reduction procedures, and all the output information that they produce. We expect to achieve a satisfactory data reduction for more than 90% of the input spectra, while some level of human intervention might be required for a small fraction of them to complete the data reduction. The DRS procedures can be used as a stand-alone package, but are also being incorporated within the VIMOS pipeline under development at the European Southern Observatory.

1. Introduction

VIMOS is the first of a pair of imaging spectrographs that are being built for the unit telescopes of the European Southern Observatory Very Large Telescope. The instrument field of view is split into four separate quadrants, each one covering approximately 7×8 arcmin. On one side of the instrument is anchored the head of the Integral Field Unit (IFU), consisting of a lenslet array of 6400 lenslets organized in an 80×80 array that covers a field of view of 54×54 arcsec.

[1]On behalf of the VIRMOS Consortium

The light collected by the IFU head is fed to the main spectrograph via optical fibers.

This instrument was designed specifically to carry out survey work, and to have a very high multiplexing capability. Because of this, it will also require a rather new approach to the process of data reduction: it will simply be impossible to reduce by hand the very large amount of data that VIMOS will produce, as the following example demonstrates. Working "by hand" using IRAF (or a similar package), even with a number of *ad hoc* scripts designed to carry out repetitive tasks, an astronomer could reduce one spectrum in 3 to 5 minutes. Since VIMOS in Multi Object Spectrograph (MOS) mode will produce between 150 and 200 spectra per quadrant for each exposure, and it has 4 quadrants, it would then take between 30 and 70 hours of work to reduce a single exposure. Therefore, reducing just one night of observations "by hand" would require between 300 and 700 hours of work, which is 40 to 150 working days (8 hours a day, doing nothing else)!! With IFU observations, each one producing 6400 spectra, things would obviously be even worse.

For this reason it was decided to implement a completely automatic data reduction pipeline for the processing of VIMOS data. As part of the agreement for the construction of the instrument, the VIRMOS consortium is developing the core components of this pipeline, which we call here the VIMOS Data Reduction Software (DRS). The European Southern Observatory is in charge of putting this core component into a completely automatic pipeline within the framework of their Data Flow System. Although the DRS has been designed specifically for VIMOS, its conceptual lay-out is general enough that it could be easily adapted to any kind of instrument with capabilities comparable to those of VIMOS.

2. Instrument and Individual Mask Calibrations

It is very difficult to design completely automated tasks to reduce complex datasets like those produced by VIMOS. It was decided that the DRS will *always and only* work from a "reasonable" first guess about all calibration parameters of the instrument. This will require the setup of an instrument calibration database, and the periodic execution of calibration procedures that will produce the necessary calibration data. When reduced using DRS procedures, these data will produce: (a) a mapping between positions on the slitlets mask and positions on the CCD frame where the slitlets images are recorded; (b) a mapping of the distortions that affect each individual spectrum; (c) a mapping of the wavelength dispersion solution that associates a wavelength to each pixel coordinate of a spectrum image; and (d) two mappings between celestial coordinates and coordinates in the plane of the slitlets mask and in the plane of the CCD frame. These mappings, generally in the form of second to fourth order spatial polynomials, are stored in calibration matrix coefficients inside FITS binary tables.

Starting from the general instrument calibrations, specific calibrations are obtained for each specific mask used for an observation (see Figure 1): (a) the Mask Preparation Software used by the astronomer to define the slitlets positions for MOS observations (see Bottini, Garilli, & Tresse 2001) produces an Aperture

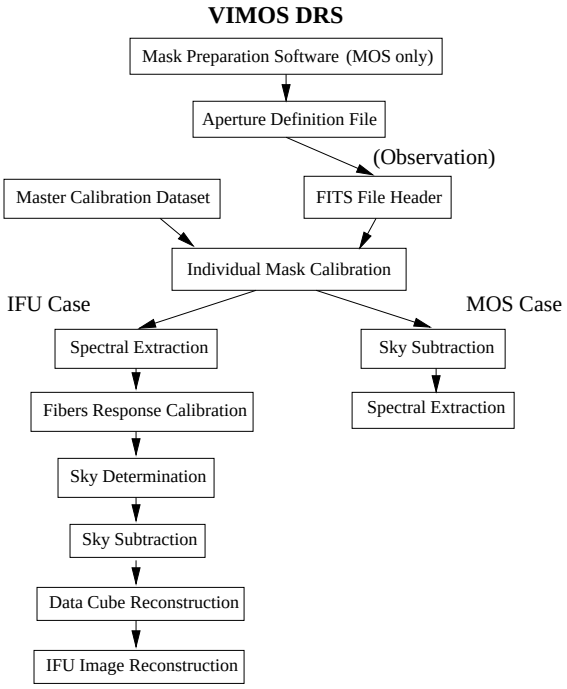

Figure 1. A block diagram scheme of the DRS spectral extraction process

Definition File (ADF), containing the positions of all slitlets in the mask plane; (b) the ADF is inserted into the FITS file header at the end of the observation (for IFU observations, where the ADF is always the same, this is stored in a separate table); (c) using the slit positions derived from the ADF, and the general calibration matrices, the approximate location of each 2-D spectrum on the CCD frame is computed; (d) a flat field exposure is used to measure the exact location of each 2-D spectrum on the CCD frame; and (e) a calibration lamp exposure is used to measure the position of a number of spectral lines and refine the approximate wavelength solution provided by the general calibration matrix.

3. Spectral Extraction

The final result of the calibration phase is the complete definition of a set of apertures to be used for the final spectral extraction. The extraction itself is carried out following two different procedures for MOS and IFU observations.

For observations carried out in MOS mode, it is assumed that slitlets always contain a region of "pure sky," where the contribution of the sky background to the composite spectrum of sky plus target astronomical object can be estimated. Each 2-D spectrum is collapsed along the wavelength dispersion axis, to produce a 1-D intensity profile along the entrance slit. Groups of at least three adjacent pixels, all with intensity above a certain threshold (derived from the rms noise in the profile itself) are considered as "object," while all other pixels are considered

as "sky." 1-D spectra for each object so identified are obtained using the Horne (1986) optimal extraction method.

For observations carried out in IFU mode, 1-D spectra for each lenslet are obtained by adding together the flux collected by the corresponding optical fiber. Each one of these spectra can belong to one of two categories: either it is the superposition of sky and astronomical object contributions, or it is a pure sky spectrum. It is therefore necessary to identify those spectra in this second category to build an estimate of the sky background intensity, before subtracting it from all the spectra. This identification is done on the basis of the distribution of total light intensities registered in the various spectra, considering as pure sky ones those that have an intensity below the mode of the distribution. For extremely crowded fields (or very deep exposures), the number of pure sky spectra is expected to be a very small fraction of the total number of spectra. In this case an interactive tool will be provided, to allow the astronomer to specify "by hand" the spectra to be used to build the sky background estimate.

After the pure sky spectra are identified, they are median-averaged together, to build an estimate of the sky spectrum, which is subtracted from all the 6400 1-D spectra. Since the optical fibers redistribute the light collected by the lenslet array over the four VIMOS quadrants following a rather complex pattern, the 1-D sky-subtracted spectra are then re-assembled in a data cube to provide a complete and spatially coherent reconstruction of the given data-set. Also, all spectra can be collapsed along the wavelength axis to provide a 2-D image of the area covered by the IFU field of view.

4. Final Remarks

The VIMOS DRS is written entirely using ANSI C code. Highly specialized tasks are carried out by external libraries, including the CFITSIO and WCS libraries, and the SExtractor object detection software. All input and output files are standard FITS files (image and binary table format). Heavy usage is made of ESO hierarchical keywords within headers (this means IRAF would have problems handling those headers).

The final DRS output will be: for MOS observations a 2-D FITS image, containing one extracted spectrum for each row of the image, plus a table containing the identification parameters for each one of those spectra; for IFU observations a 3-D FITS image containing the IFU data cube, plus a table containing the identification parameters for each spectrum.

References

Bottini, D., Garilli, B., & Tresse, L. 2001, this volume, 455

Horne, K. 1986, PASP, 98, 609