Clearly, ESO is pleased to see that their constant efforts and dedication are well received and appreciated, but would like to do more, and especially to hear from a larger audience. We are now in the process of evaluating all the extra comments we have received in the questionnaires and are investigating alternative solutions with the aim of making our user surveys more attractive and hopefully increasing their feedback. In the future, we plan to extend our targeted audience to include APEX PIs, and all ESO PIs for those phases common to both SM and VM runs (e.g. Phase 1 and data quality).

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ESO Reflex: A Graphical Workflow Engine for Astronomical Data Reduction

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ESO Reflex is a software tool that provides a novel approach to astronomical data reduction. The reduction sequence is rendered and controlled as a graphical workflow. Users can follow and interact with the processing in an intuitive manner, without the need for complex scripting. The graphical interface also allows the modification of existing workflows and the creation of new ones. ESO Reflex can invoke standard ESO data reduction recipes in a flexible way. Python scripts, IDL procedures and shell commands can also be easily brought into workflows and a variety of visualisation and display options, including custom product inspection and validation steps, are available. ESO Reflex was developed in the context of the Sampo project, a three-year effort led by ESO and conducted by a software development team from Finland as an in-kind contribution to joining ESO. It is planned that the software will be released to the community in late 2008.

The data reduction needs of ESO

ESO is currently operating a large suite of instruments covering the optical and the infrared, as well as the millimetre wavelength ranges. Although the responsibility for the quality of the scientific reduction of the data can only rest with the individual users, it is very difficult for users to be equally familiar with all the different observational techniques spanned by the ESO instruments at a level where general-purpose tools like IRAF and ESO-MIDAS can be effectively used. Instrument specific software, implementing carefully tuned algorithms, is therefore essential. Currently ESO aims to develop and export data reduction recipes for all VLT/VLTI instruments. These are based on the ESO Common Pipeline Library (CPL) and may be run offline using either the Gasgano graphical tool or the EsoRex command line tool. Recipes have the primary tasks of running as automatic pipelines within the dataflow system and being used to create products suitable for quality control (Silva and Péron 2004, Ballester et al. 2006).

The challenge is to allow the user greater flexibility to interact with the data reduction process and to study data products, both intermediate and final, in order to optimise the quality of the results. In addition it is desirable to reuse existing software as much as possible, both current pipelines and legacy software tools. The aim was to embed the ESO recipes within a flexible environment without the need to recreate a complete and expensive new software system. We believe that this approach has the potential to deliver a significant improvement to users whilst making optimal use of available resources.

Introducing ESO Reflex

The Sampo project, a three-year effort led by ESO and conducted by a software development team from Finland as an in-kind contribution to joining ESO, has concentrated on developing a graphical user interface to run ESO data reduction recipes. The high level goals of the project were described in an earlier article (Hook et al. 2005).

The primary outcome of the Sampo project is an application called ESO Reflex (ESO REcipe FLexible EXecution workbench), in which the sequence of reduction steps is rendered and controlled as a graphical workflow. This approach allows users to follow and interact with the data reduction flow in an intuitive manner without the need for complex scripting. Figure 1 illustrates the look and feel of an ESO Reflex workflow. In this particular example, it is a reduction sequence to produce master calibrations for the FORS2 MXU mode. The input files are at the top of the workflow (light blue boxes) and the data percolate through the workflow to produce the final outputs at the bottom. The boxes in between the inputs and outputs represent the actual processors acting on the data, while the arrows mark the data flowing from one processor to the next.

ESO Reflex is based on a graphical workflow engine called Taverna that was originally developed for the e-Science community in the context of the myGrid initiative in the United Kingdom (the project page is available at *http://taverna.sourceforge.net*). Once adopted after a survey of other available scientific workflow engines, Taverna was customised by the Sampo team to tailor it to the requirements, of astronomical workflows. These additions include a new interface for launching workflows, support for FITS files and interfaces to CPL, Python and IDL.

Workflows in ESO Reflex are easily edited and customised by simply adding or removing processors, the boxes in the middle of Figure 1, and connecting the appropriate input and output ports with arrows. The underlying workflow engine takes care of all the additional complexities linked to making the data flow through the reduction workflow, as defined graphically by the user. The users of such a system are left to focus on their core task: making scientific sense of their data and exploiting them to the maximum.

The interface of ESO Reflex is not instrument specific and users are presented with the same look and feel independently of the actual instrument from which the data originated.

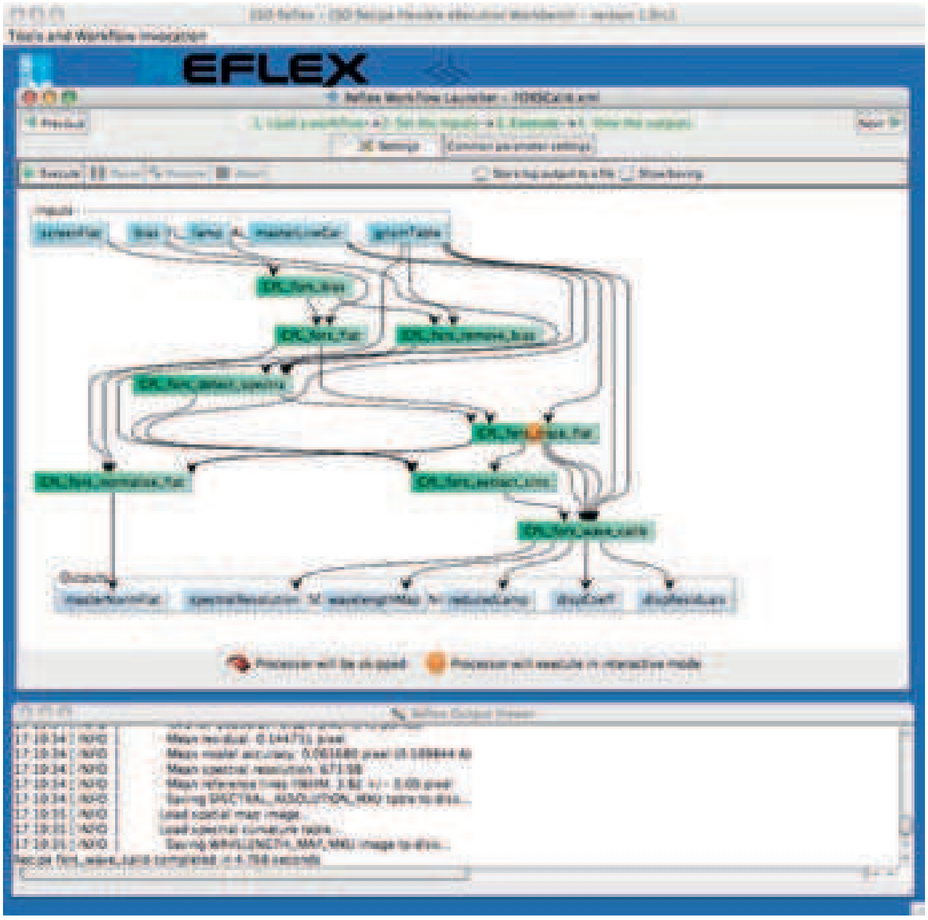

Figure 1: Example of a workflow with ESO Reflex: this case is based on FORS2 MXU calibration recipes. The input data are represented by the light blue boxes at the top. The data percolate through the processors in the middle section to produce the outputs at the bottom of the figure. The orange circular symbol indicates that one recipe will execute in interactive mode – this allows the user to inspect the input and output files of this stage of the processing and modify parameters if desired.

The key features of ESO Reflex

ESO Reflex aims to provide most of the key elements for a scientific data reduction:
- Convenient ways to select and organise data, based on code from the Gasgano application (*http://www.eso.org/gasgano*), to cope with the complexity of the headers of modern data.
- A CPL processor to include data reduction recipes for the vast majority of the data produced by ESO instruments into workflows. This dedicated processor is tailored to handling ESO data using CPL recipes and supports many extra features, including different processor modes (interactive, skipped, etc.), as well as control of recipe-specific parameter values.
- Processors through which Python scripts, IDL procedures and shell commands can be included within workflows.
- The possibility of basic flow control operators, such as conditional steps.
- Error handling: ESO Reflex catches errors returned by processors and offers options on how to proceed further, e.g. abort the workflow, reconfigure the offending processor and rerun it, proceed anyhow trying to execute the rest of the workflow.
- Skipping of processors and the possibility to allow optional steps.

- Automatic processing of lists of input files.
- Batch processing without the graphical user interface.
- The design of Taverna makes it very effective for building workflows that use web services such as those established within the Virtual Observatory. Experiments in this area have been successful and are described elsewhere (Järveläinen et al. 2008).
- A particularly important use of scripts is to analyse intermediate products within the reduction process. To illustrate this concept we have developed several interactive tools. A screenshot of such a tool, in this case to iteratively check and refine the wavelength solution of 2D spectra is shown in Figure 2.

It is perhaps inevitable that a graphical workflow system is, for some purposes, not as powerful as a well-crafted script. However, it is expected that the greater ease of use of a graphical workflow system will compensate for the loss of power, when compared to traditional scripting.

Current status and future plans

At the time of writing, ESO Reflex is in a beta state and is expected to be released to the community at large in the fourth quarter of 2008 along with appropriate workflows and tools. People interested in early access to ESO Reflex in conjunction with the instrument modes for which workflows have been developed, namely FORS spectroscopy and AMBER, should contact *reflex@eso.org*.

Work is also in progress to enhance the data reduction recipes. The current algorithms are focused on processing calibrations and extracting the parameters required to monitor the health status of the instruments. While in some cases the resultant products are of adequate quality for immediate scientific analysis, this is generally not yet the case. To this end, the data reduction recipes are being made available in modular form to allow interaction with the intermediate products at scientifically meaningful points and to work seamlessly with ESO Reflex. The data reduction algorithms themselves are also continuously being extended with the long-term aim of allowing the creation of high-quality science products on the user desktop.

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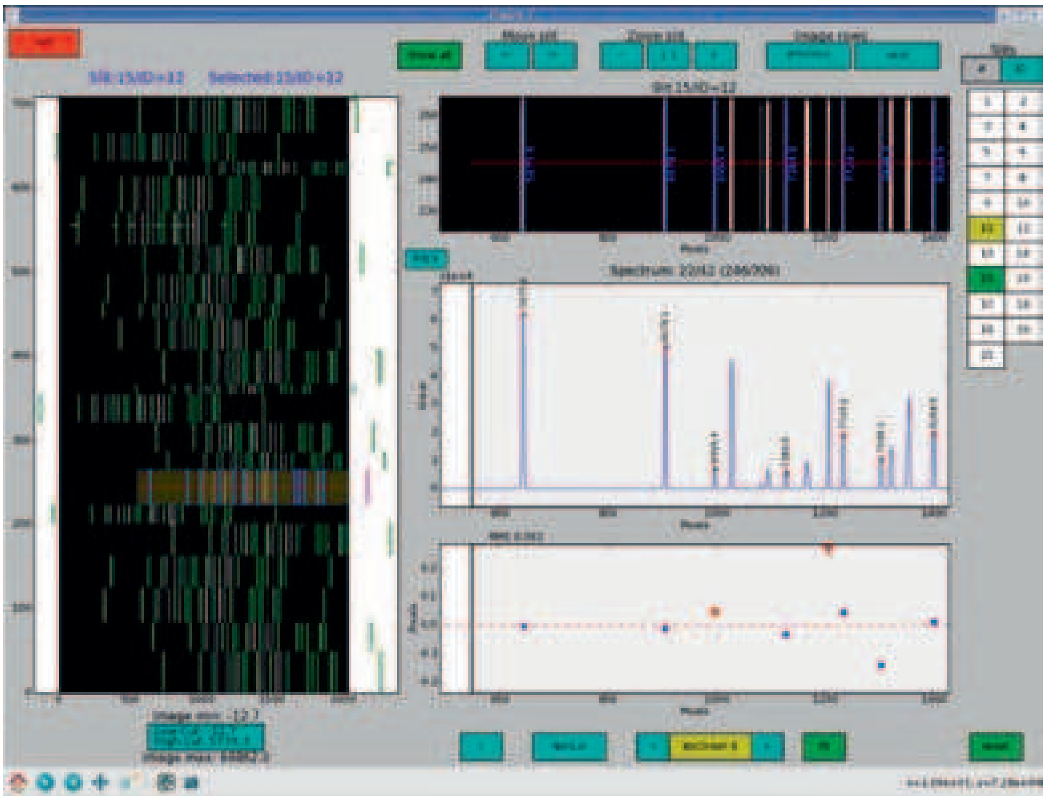

Figure 2: Screenshot of the Python tool to check and improve the wavelength solution of 2D spectra. Calibration spectral lines, either from an arc lamp or from the night sky, are displayed slit by slit and can be included or excluded when computing the wavelength solution with a polynomial fit, the order of which can also be set interactively. This example shows a FORS/MXU arc exposure.