IRAF Package for GNIRS Data Reduction — A Product of the Gemini/NOAO Collaboration

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Abstract. In August 2003 NOAO and Gemini began working together to improve the IRAF based data reduction packages used at the two telescopes. Here we report on the GNIRS (Gemini Near Infra-Red Spectrograph) Gemini/IRAF package - one of the first fruits of the collaboration.

The package helps the user generate high quality, calibrated spectra from the raw observations. It supports longslit, cross-dispersed and, experimentally, IFU (Integral Field Unit) observing modes - the processing of different data types is handled automatically, with the user following a similar reduction procedure in all cases. It can also be used as part of an automated pipeline and is generic enough to support other instruments with a similar data format.

This work is based on the earlier NIRI (Near Infra-Red Imager) spectroscopy routines, written by Joe Jensen (Gemini). All the tasks have been rewritten and, although they remain CL scripts, they now call new, compiled tasks to implement common functionality. This gives cleaner, more reliable code and an improved user response.

In this paper we illustrate the flow of data through the package, outlining how GNIRS observations are reduced.

This software was released as part of the Gemini IRAF Package, version 1.7, on October 27th 2004.

1. Introduction

Gemini and NOAO have been collaborating since August 2003 to improve the IRAF based software used for reducing data from the twin telescopes. The project is making progress along two related fronts – extending core IRAF support for commonly required functionality and improving the Gemini–specific packages with script refactoring and compiled tasks. On the NOAO side, Mike Fitzpatrick is technical lead, while Inger Jorgensen, from Gemini, is scientific lead.

Although many of the improvements are general, they are driven by deadlines for specific instruments. A set of tasks to support the Gemini Near Infra-Red Spectrograph (GNIRS), which is being commissioned during 2003-2004, was therefore chosen as the first development target. One of us (Bernadette Rodgers, the GNIRS Instrument Scientist) was responsible for the package design, the other (Andrew Cooke, Scientific Programmer) for the implementation.
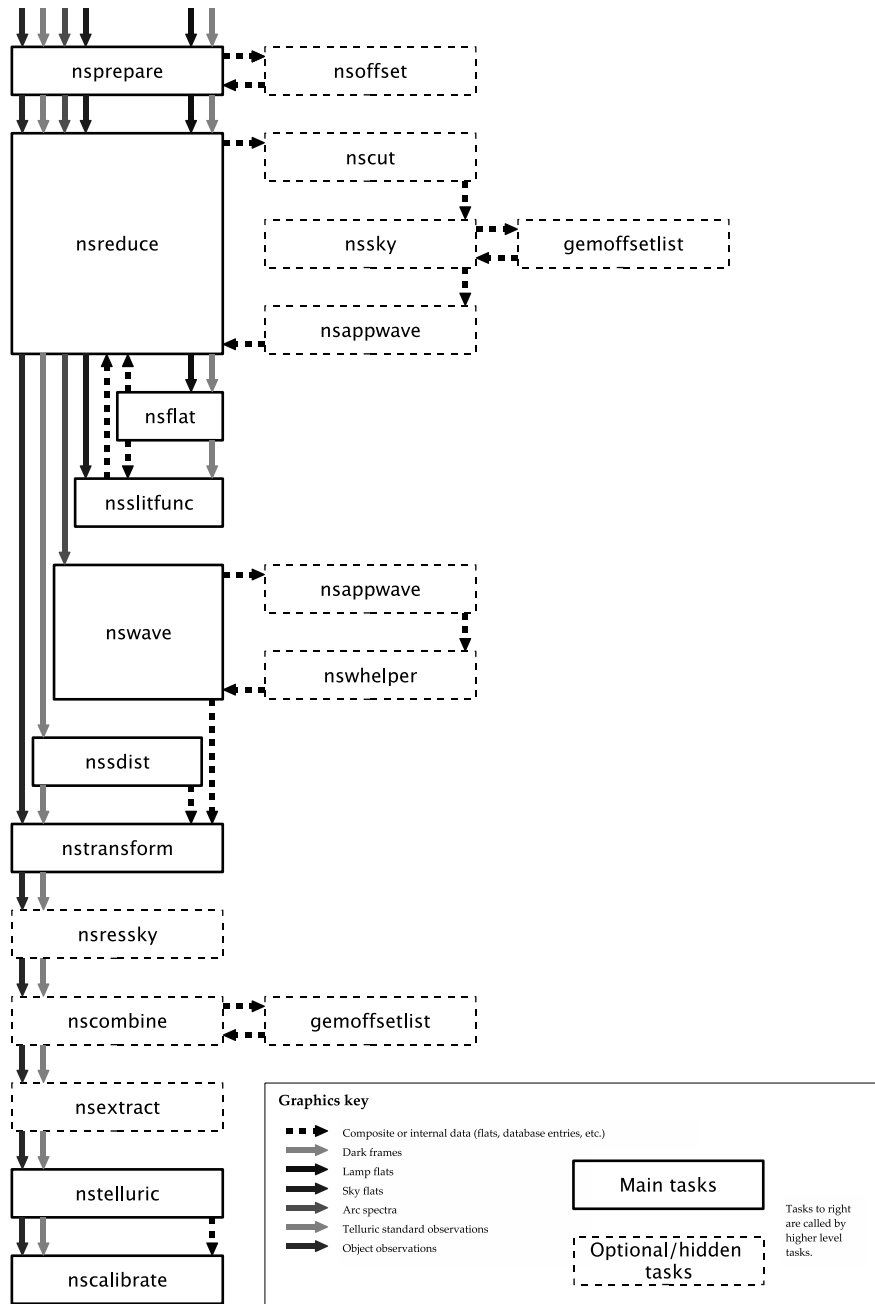
Figure 1.   Data flow through the main package tasks. The different types of data (distinct coloured arrows) are typically processed in order, from right to left.

GNIRS was designed to offer a wide variety of spectroscopic capabilities including long-slit (single order) spectroscopy within the 1-5.5 μm range at 2-pixel spectral resolutions of approx 1700, 5900 and 18000 with a choice of 2 pixel scales ($0.15''$/pix and $0.05''$/pix); cross-dispersed spectroscopy giving simultaneous coverage of 1-2.5 μm at R $\sim$ 1700 and 5900; integral field unit (IFU) spectroscopy from 1-5.5 μm over a 5 arcsec field with a pixel scale of $0.15''$/pix; and a Wollaston prism for spectral polarimetry with the Gemini polarization unit GPOL.

The first release of the GNIRS package, which is based on tasks written for the spectroscopy mode of the Near Infra-Red Imager (NIRI), will process long-slit and cross-dispersed spectroscopy, with limited support for IFU data. The same tasks work with all these different modes through the careful separation of instrument specific information and multi–extension FITS files.

Section 2. describes the main package tasks. Section 3. gives background implementation details.

2.   Data Flow

Figure 1 illustrates the data flow through the main package tasks. This section describes the flow from top to bottom.

nsprepare   Preparation corrects data for low noise reads, the detector offset, and non-linear response. It also modifies the noise model to compensate for digital averages and co-adding and, optionally, calculates variance and data quality frames.

The detector offset is a constant value that must be measured from a dark area of the data and then subtracted. This must be done before non-linearity corrections and noise estimates are made. It has a separate source from dark current, but any measurement (and consequent correction) will include both offset and dark levels. This is unfortunate, as dark current *does* contribute to the noise in the data. For most data we believe that the offset will be more significant than the dark, so by default **nsprepare** will subtract the offset, but it is possible to override this behaviour and remove the dark level within **nsreduce** (ie. after noise estimates have been calculated).

Header values in the observation determine the observation mode and so identify a particular Mask Definition File (MDF), which is associated with the data (see section 3.). The MDF describes the illumination pattern on the detector — information used later by **nscut**.

Once the data have been processed by **nsprepare** they are in a reasonably instrument–independent format. Similar preparation tasks can be written for other instruments, which will then be able to take advantage of the remaining tasks in the GNIRS package. Indeed, such tasks already exists for Michelle and the Thermal-Region Camera Spectrograph (T-ReCS).

nsreduce   Reduction removes the instrument signature (flat fielding and dark subtraction), identifies and subtracts sky frames, provides an approximate wavelength solution, and separates the observation into separate spectral regions.

All these steps are optional and the task is typically called several times to process the different observation types. For example, data that will be used to generate the flat field may be processed by **nsreduce** without applying the (still to be generated) flat field.

The **nscut** task isolates the useful sections of each frame. For cross-dispersed and IFU data each section is placed in a separate MEF extension.

nsflat, nsslitfunction   A flat can be constructed from lamp data alone (**nsflat**), or with sky flat observations to correct for variations in response along the slit (**nsslitfunction**). Flat field data are cut to size before processing and so pass through **nsreduce** first. The bad pixel map generated with the flat can be used to flag other data during preparation (**nsprepare**).

nswavelength   Wavelength calibration uses the core IRAF identify/reidentify tasks. These have been improved (Frank Valdes, NOAO), but still require careful selection of parameter values, so the help page includes step-by-step troubleshooting information. 3-5μm and mid-IR data can use skylines rather than arcs.

nssdist   The spatial alignment of spectra on the detector is measured with nssdist using standard star or pinhole observations.

nstransform   The measurements of dispersion and spatial variation (the output from nssdist and nswavelength) are used by **nstransform** to produce rectified data on a uniformly sampled wavelength scale.

nsressky   Optionally, residual sky emission can be subtracted by fitting to the data.

nscombine   This task will shift and combine 2D frames based on the the output from **gemoffsetlist**, which measures relative offsets using WCS header data.

nsextract   If desired, 1D spectra can be extracted using **nsextract**.

nstelluric   This removes the atmospheric signature by dividing by a 1D telluric standard spectrum. This can be applied to 1 or 2 dimensional data.

nscalibrate   Final flux calibration is calculated from a suitable standard with nscalibrate.

3.   Implementation

The Gemini packages make extensive use of the Multi-Extension FITS support (MEF) in IRAF. MEF allows a single FITS file to contain many different data sets, called extensions. These are typically identified by name and version. The most important extensions in Gemini data are called SCI (the data), VAR

(variance) and DQ (data quality). Versions correspond to different spectral orders (cross-dispersed data) or sub-apertures (IFU data).

Storing all the data for a single observation within one file simplifies the user interface. It is only necessary for the user to supply the file name to the tasks within the package; within each task each order or aperture is processed in turn, automatically.

Variance and data quality values are also carried forward through the tasks (as much as is possible, given the current IRAF core and simplifying assumptions about correlated statistics) to help the user assess the significance of features in the data.

Two other extensions are also important. The Primary Header Unit (PHU) contains header information applicable to all extensions (e.g., the initial World Coordinate System, or WCS, which reflects the telescope pointing and orientation). The Mask Definition File (MDF) describes how the SCI, VAR and DQ extensions are extracted from the original data.

To examine the extensions present in a MEF file, use the **gemextn** task (in the **gemtools** package). This is a new, compiled (SPP) task, developed to help simplify the task scripts and provide an easier interface to the MEF files.

4.   Conclusion

We hope that the GNIRS package will provide a useful, flexible and efficient tool for people working with data from this instrument. Revised help pages (wavelength calibration in particular, which now contains detailed step–by–step recipes for solving common problems) should make the tasks more useful; flexibility is already evident in the processing of Michelle and T-ReCS spectral data; efficiency should already be improved by the compiled **gemextn** task for file handling, with further advances expected in the next release as tasks dedicated

to calculations (**gemarith**, Craig Allen, Gemini), logging (**gemlog**, Kathleen Labrie, Gemini) and header handling (NOAO) are more tightly integrated into the package.