

NICMOSlook and Calnic C: Slitless Spectra Extraction Tools

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Abstract. A unique capability of NICMOS is its grism mode which permits slitless spectrometry at low resolution. Extracting spectra from a large number of NICMOS grism images requires a convenient interactive tool which allows a user to manipulate direct/grism image pairs. NICMOSlook and Calnic-C are IDL programs designed for that purpose at the Space Telescope – European Coordinating Facility¹. NICMOSlook is a graphical interface driven version of this extraction tool, while Calnic C is a program which performs the same functionality in a “pipeline” approach.

1. NICMOSlook and Calnic C

Typically, the NICMOS grism mode involves taking a pair of images which includes both a direct image and a grism image. The direct image is used to locate objects of interest, to find the position of the appropriate spectra in the grism image, to determine the optimal extraction technique to use, and to calibrate the wavelength range of the extracted spectra. NICMOSlook, which has an IDL user interface based on STISlook from Terry Beck, is designed to allow a user to interactively and efficiently extract spectra from a small batch of data. The user maintains full control over the extraction process. NICMOSlook was designed to be most useful to users who want to quickly examine data or fine tune the extraction process. The stand-alone version, Calnic C, is meant to be used on larger sets of data and requires only a minimum amount of user input. Both programs can be fully configured and extended through the use of a few configuration and calibration files.

2. Features Overview

2.1. Image Display

NICMOSlook allows a direct image and corresponding grism images to be read from FITS files and be displayed. A variety of display options are available to the user including a variety of color tables, selectable zoom factors, and the ability

¹<http://ecf.hq.eso.org>

to blink the images successively. Some basic image filtering and processing capabilities are also provided to allow the user to locate and identify objects in the direct image (or spectra in the grism image).

2.2. Object Identification

In NICMOSlook objects can be identified automatically using the DAOFIND algorithm or can be provided manually by the user (through the use of the cursor or of a text file containing the coordinates of the objects). The spatial extent of objects can also be determined either automatically or through additional user input. In Calnic C objects in the direct image are located without user input: the location, orientation, and size of each object are determined using SExtractor (Bertin 1996).

2.3. Determination of the Location of the Spectrum

Once the position, orientation, and shape of an object have been determined, they are used to infer the position, orientation, and extent of object's spectra in the grism image. This process is completely automatic but it can, nevertheless, be fully customized by the user.

2.4. Spectral Extraction

Extracting a spectrum can be done using either weighted or unweighted extractions and using either the Point Source mode (where the cross dispersion spectral profile is taken to be that of a point source), or the Extended Object mode (where the cross dispersion spectral profile is first determined from the shape of the object in the direct image). Once extracted, the spectrum is wavelength calibrated, and a response function is used to produce a calibrated spectrum in mJy or $\text{erg/s/cm}^2/\text{\AA}$ as a function of μm .

2.5. Deblending

An attempt can be made to automatically remove the spectral contamination caused by the presence of nearby objects. The method used uses only the assumption that the shape of the object is not wavelength dependent.

2.6. Spectral Lines Search

Emission and absorption lines are automatically identified in the resulting spectra. The continuum emission is automatically determined.

2.7. Result Output

In NICMOSlook the extracted spectrum is plotted on the screen. The user can interactively modify the continuum background fit and examine spectral features. The user can also export the spectrum as a binary FITS table and PostScript plots. Calnic C outputs a binary FITS table and PostScript plots of each of the extracted spectra.

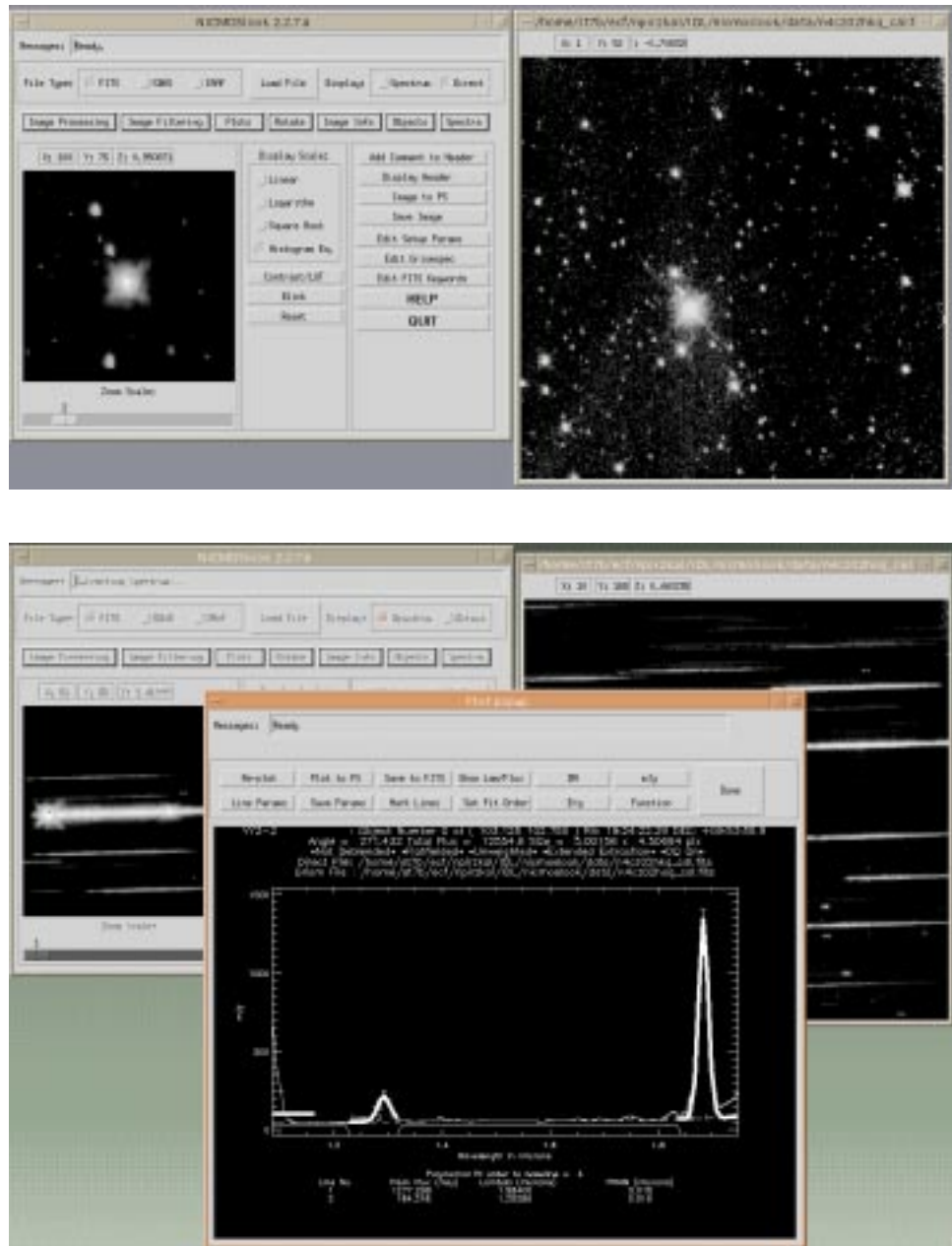


Figure 1. The NICMOSlook User Interface

3. How to Obtain NICMOSlook and Calnic C

NICMOSlook, Calnic C, and their respective User Manuals can be downloaded from <http://ecf.hq.eso.org/nicmos>

NICMOSlook and Calnic C require IDL 4.0 or 5.0.

N4CZ02HKQ : Object Number 0 at (101.875 102.375) RA: 19:24:22.27 DEC: +09:53:56.1
 Angle = 267.879 Total Flux = 13627.9 Size = 3.37731 x 2.75000 pix
 Not Deblended *Flatfielded* *Unweighted* *Extended Extraction* *DQ On*
 Direct File: /home/st7b/ecf/npirzkal/IDL/nicmoslook/data/n4cz02hkq_cal.fits
 Grism File : /home/st7b/ecf/npirzkal/IDL/nicmoslook/data/n4cz02hoq_cal.fits

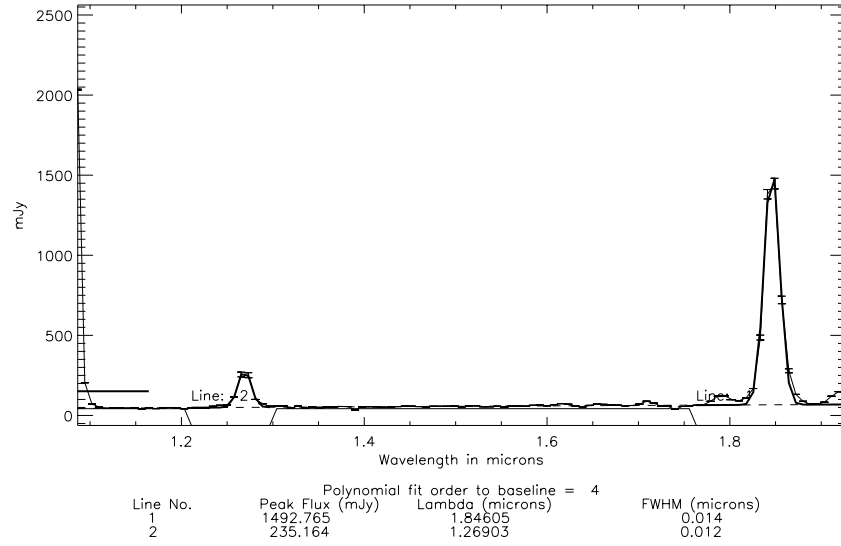


Figure 2. The paper output of NICMOSlook and Calnic C

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Analysis Tools for Nebular Emission Lines

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Abstract. The nebular analysis package in STSDAS has been substantially enhanced, and now includes several new ions and diagnostics, as well as updated atomic data for all supported ions. In addition, new tasks are being added to compute, from ratios of recombination lines, certain nebular physical parameters and the abundances of He^+ and He^{+2} relative to H^+ .

1. Introduction

The **nebular** analysis package is a set of applications within IRAF/STSDAS for computing physical parameters in emission line nebulae (such as electron density, N_e , and temperature, T_e), as well as ionic abundances of several elements relative to ionized hydrogen. **Nebular** also provides utilities for exploring the range of validity of the diagnostics themselves, and for employing them in the context of a very simple nebular model. Several enhancements to the package have been implemented since the original descriptive paper by Shaw & Dufour (1995) was published, and the major new features are described here.

2. New Ions and Atomic Data

Thirteen new ions of C, N, O, Ne, Na, Mg, Al, Si, S, Cl, K, and Ca have been added to the set of 21 previously supported in **nebular**. As a consequence, 15 new diagnostics for N_e and T_e are available, and they span a much greater range of density, temperature, and ionization than in the previous version. The full set of supported ions and diagnostics can be found from the **nebular** home page¹. Several new features have also been added, including the capability to compute collisional line emissivities from up to eight (rather than the five previously supported) atomic levels, depending upon the availability of the supporting atomic data. These low-lying levels arise from the same electron configurations as the ground level. The atomic data for the various lines have been updated to the best, most recent available as of mid-1996. These data have been appearing in the literature at a rapid rate, owing to the success of the IRON project (Hummer et al. 1993), a concerted international effort to compute precise atomic data for iron-group ions of astrophysical interest. The collision strengths in particular

¹<http://ra.stsci.edu/nebular/>

have been computed for most ions over a much wider range of T_e , and are more accurate by factors of 3 to 10. This improvement in the data quality permits the calculation of reliable diagnostics over a much greater range of T_e and N_e . The references to the atomic data are too numerous to include here (though they are given in the **nebular** help documentation), but in general are at least as recent as those given in the compilation by Pradhan and Peng (1995).

The T_e and N_e diagnostics of collisionally excited lines that are typically used in the literature derive from ratios of specific line intensities (or ratios of sums of intensities) which have a reasonably high emissivity, consistent with being very sensitive to the diagnostic in question. These line intensity ratios are generally the same for ions with a given ground state electron configuration. Table 1 lists the line ratios that are traditional in this sense, where the notation $I_{i \rightarrow j}$ refers to the intensity of the transition from level i to j . The correspondence of wavelength and transitions between energy levels for a given ion can be found by running the *ionic* task.

Table 1. Traditional Diagnostic Ratios

| Ground Configuration | Diagnostic | Traditional Ratio |
|----------------------|------------|---|
| s^2 | N_e | $I_{4 \rightarrow 1} / I_{3 \rightarrow 1}$ |
| | T_e | $(I_{4 \rightarrow 1} + I_{3 \rightarrow 1}) / I_{5 \rightarrow 1}$ |
| p^1 | N_e | $I_{5 \rightarrow 2} / I_{4 \rightarrow 2}$ |
| p^2 | T_e | $(I_{4 \rightarrow 2} + I_{4 \rightarrow 3}) / I_{5 \rightarrow 4}$ |
| p^3 | N_e | $I_{3 \rightarrow 1} / I_{2 \rightarrow 1}$ |
| | T_e | $(I_{2 \rightarrow 1} + I_{3 \rightarrow 1}) / (I_{4 \rightarrow 1} + I_{5 \rightarrow 1})$ |
| | T_e^a | $(I_{2 \rightarrow 1} + I_{3 \rightarrow 1}) / (I_{5 \rightarrow 3} + I_{5 \rightarrow 2} + I_{4 \rightarrow 3} + I_{4 \rightarrow 2})$ |
| p^4 | T_e | $(I_{4 \rightarrow 1} + I_{4 \rightarrow 2}) / I_{5 \rightarrow 4}$ |

^aFor N^0 and O^+ .

Note that these traditional diagnostic ratios are not the only viable ratios to use: some ratios, though perhaps not as sensitive to the diagnostic in question, are useful if the spectral coverage or resolution is limited; others are simply better for some purposes, such as the T_e -sensitive [O III] ratio $I(1660 + 1666)/I(4363)$. Some **nebular** tasks, such as *temden* and *ntcontour*, now allow the user to specify a transition other than the traditional (default) one.

3. Recombination Lines

The **nebular** package will soon include new tasks to accommodate the analysis of recombination lines. Atomic data for H^+ , He^+ , and He^{+2} have been incorporated from Storey & Hummer (1995). Specifically, we adopt their tabulations of emissivities, ϵ , separately for Case A and Case B recombination. (The code

interpolates in $\log-T_e$, $\log-\epsilon$ for intermediate values within their grid.) The *recomb* task will solve for the interstellar reddening and/or T_e , given a list of recombination line intensities for a single ion. The *rec_abund* task will compute the abundance of these ions with respect to H^+ from a list of recombination lines. The *abund* task, which computes abundances from collisional lines in the context of a simple model, is being enhanced to include the ionic abundance calculations from recombination lines as well.

4. Exploration of the Diagnostics

The *ntcontour* task has been substantially enhanced, and is now more useful for exploring new or traditional diagnostics from collisionally excited lines. This task computes and plots curves that show the range of T_e , N_e , and/or intensity ratios that are consistent with a specified diagnostic. A family of secondary curves may optionally be plotted, where each curve may be specified explicitly or as a set of successive, small differences from the reference ratio, giving the appearance of contours. Though for all ions there are default diagnostics for N_e and/or T_e , it is possible to customize the diagnostic to the ratio of any of the supported transitions. In addition, the diagnostics may be plotted as N_e vs. T_e , N_e vs. I_{line} , and T_e vs. I_{line} . This task may be run interactively, so that it is possible to investigate many diagnostics quickly. *Ntcontour* is particularly useful for determining the range of N_e and T_e where a particular diagnostic is sensitive, for investigating non-traditional diagnostics, and for estimating the consequences of a given level of uncertainty in an observed line ratio. Figure 1 shows an example plot of the default density-sensitive ratio for Al II.

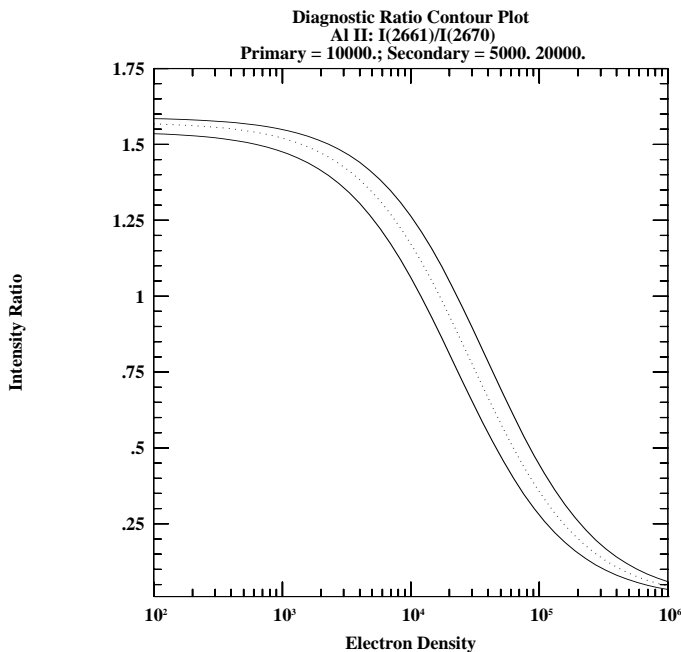


Figure 1. Ratio of [Al II] $I(2661)/I(2670)$ vs. N_e using *ntcontour*.

5. Software Features

The **nebular** package has been substantially re-designed, and is largely table-driven. For example, the atomic reference data are encapsulated in FITS binary tables, and the data pedigree (including literature references) are documented in header keywords. Fits to the collision strengths as a function of T_e are evaluated at run-time, so that the reference tables contain data in a form much as it appears in the literature. These features provide great flexibility for anyone to substitute improved atomic data, and allow for easy extensibility of the package to accommodate high-quality data for more ions as they become available.

The data and associated functional fits for one or more atoms/ions of interest are collected into persistent in-memory objects during the course of program execution. The diagnostics for N_e and T_e are stored internally as strings containing algebraic relations (in a form not unlike those given in Table 1), and are evaluated at run-time. These features allow much greater flexibility in the applications to make use of relations between ions, such as the comparison of physical diagnostics from similar ions, or the computation of relative abundances.

6. Software Availability

In their sum, the applications in the **nebular** package are a valuable set of tools for nebular analysis: the derived quantities can be used directly or as input to full photo-ionization models. Most of the enhancements described here have already been incorporated into V2.0 of the **nebular** package; the new tasks for analysis of recombination lines will be available in the next release. **Nebular** is publically available, and is included in the STSDAS external package; the new version will be found under the **analysis** package in STSDAS V2.0 and later. Users who do not have STSDAS may obtain the new version for personal installation from the **nebular** ftp² area. Note that **nebular** V2.0 requires that IRAF V2.10.4 (or later) and TABLES V2.0 (or later) be installed. Some of the tasks may alternatively be run via the Web from an HTML forms interface: view the **nebular** home page for details.

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References

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²ftp://ra.stsci.edu/pub/nebular/