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A Spectroscopy Exposure Time Calculator for IRAF

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Abstract. This paper describes a new IRAF spectroscopy exposure time calculator. It is intended to provide reasonable estimates of exposure times for observations. A simple component model is used for the optical elements Each component is described by simple text files. This makes the task very general and easily configurable by different sites and instruments. The input spectrum can be chosen from several models as well as a user spectrum. The output consists of text information and graphs over various quantities over the wavelength of observation. The task can be used with various user interfaces such as the IRAF CL, IRAF scripts, a web form, or a GUI. The tool is in use at NOAO through a web interface to assist in proposal preparation.

1. Overview

The IRAF task SPTIME estimates exposure times for a desired signal-to-noise ratio (SNR) or SNR for a specified exposure time for general spectrographic systems. It models a spectroscopic system as a flow of photons from a source to the detector through various components. Table 1. shows the various components. The spectroscopic system components are defined at a moderate level of detail. It is not so detailed that every optical element has to be described and modeled and not so coarse that a single throughput function is used (though one is free to put all the throughput information into one component). Not all components modeled by the task occur in all spectroscopic systems. Therefore many of the components can be left out of the calculation.

SPTIME takes an input source spectrum, either a reference blackbody, power law, or a user spectrum, a background "sky", observing parameters such as exposure time, central wavelength, seeing, airmass, and moon phase, instrument parameters such as aperture sizes and detector binning, a description of the spectrograph, and desired output. The output consists of a description of the observation, SNR statistics, and optional graphs and tables of various quantities as a function of wavelength over the spectrograph wavelength coverage. The SNR is computed from the detected photons of the source and background, and from the instrumental noise characteristics.

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Each of the components specify a transmission or related function giving the fraction of incident light transmitted as a function of some parameter or parameters. Except for the aperture, which is a function of the incident source profile (typically the seeing profile) relative to the aperture size, the transmissions of the components are a function of wavelength.

To make SPTIME easily configurable by observatories and users, all the component transmission functions are given in text files, called tables since they often contain an interpolation table. The data files may also include parameters, pointers to other tables, or defaults for the task parameters. The files are searched first in the users working directory and then using a list of directories. Thus, users may place files in their work area to override system supplied files and observatories can organize the data files in a database directory tree.

Many spectrographs provide a wide variety of wavelength regions and dispersions. For gratings (and to some extent for grisms) this means use of different gratings, orders, tilts, and possibly camera angles in the spectrograph. The transmission as a function of wavelength (the grating efficiency) changes with these different setups. If the transmission function is given as an interpolation table this would require data files for each setup of each disperser. The structure of SPTIME allows for this.

However, it is also possible to specify the grating and spectrograph parameters and have the task predict the grating efficiency in any particular setup. In many cases it may be easier to use the calculated efficiencies rather than measure them. Depending on the level of accuracy desired this may be adequate or deviations from the analytic blaze function can be accounted for in another component.

Table 1. List of Components

Components
source (spectrum table)
background (spectrum table)
the atmosphere (extinction table)
the telescope (transmission table)
atmospheric dispersion compensator (transmission table)
aperture (throughput table)
fiber feed (transmission table)
filters (transmission table)
spectrograph (transmission table)
a collimator (transmission table)
a disperser (efficiency table)
a cross disperser (efficiency table)
a corrector (transmission table)
a camera (transmission table, vignetting table)
a detector (DQE table)

2. User Interfaces

SPTIME may be called directly as an IRAF task. Because of it's generality there are many parameters. Also there will usually be many tables for different gratings and filters. Therefore it is desirable to provide a user interface which limits the parameters and selections for specific instruments. The can be done with IRAF scripts, IRAF GUIs, or a web interface. At NOAO such a web interface has been developed for specific instruments. The purpose of this interface is to support users' in preparing proposals. The web form can currently be found at `http://www.noao.edu/scope/spectime/`.

3. Output

The output of SPTIME consists of text and graphs. The text output verifies the requested inputs along with some additional detail and the results of the observation at some requested wavelength. The results include throughput information, the signal-to-noise and exposure time. Figure 3. shows an example of the text output.

There is a selection of graphs which may be produced showing various quantities as a function of wavelength. These include the expected observation data numbers, signal-to-noise, and throughput, as well as the individual transmission functions. Figure 1 shows an example of some of the graphical output.

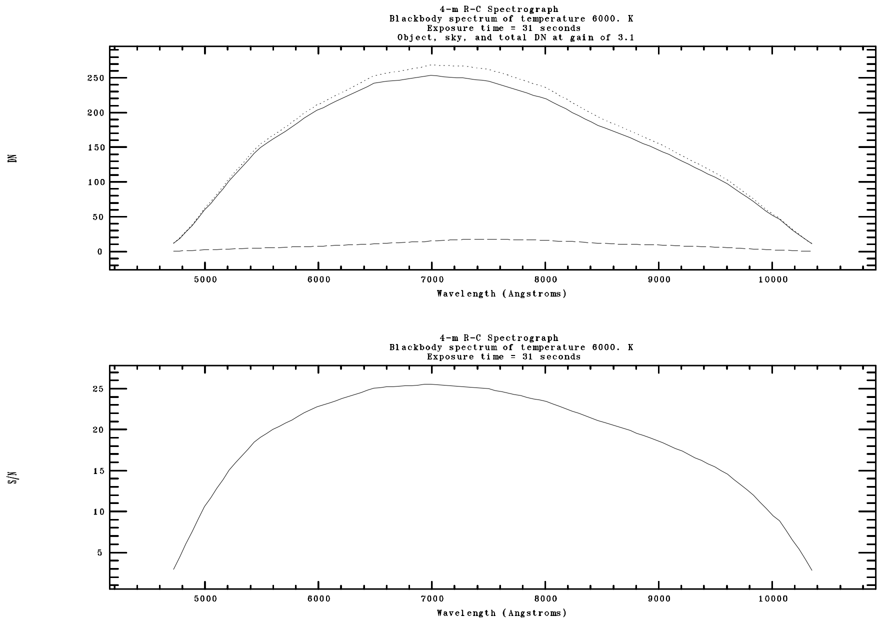

Figure 1. Sample Graphical Output for the KPNO RC Spectrograph The upper graph shows the predicted data numbers as a function of wavelength for the source (solid), sky (dashed), and total (dotted). The lower graph shows the SNR where the target was 25.

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Object spectrum: Blackbody spectrum of temperature 6000. K
Reference wavelength: 7500. A
Reference flux: AB = 15. (1.95E-15 ergs/s/cm^2/A)
Sky spectrum: KPNO sky brightness as a function of moon phase
Moon phase: 7
Airmass: 1.2
Seeing: 1.1" (FWHM)

Telescope: KPNO Mayall 4-m Telescope
Spectrograph: 4-m R-C Spectrograph
Collimator: R-C Spectrograph Collimator
Apertures: Slit with Gaussian profile
Size: 2.0" x 300.0", 0.302 x 45.3 mm, 2.6 x 430.7 pixels
Filter: Filter OG-530 3mm used by RCSpec and CryoCam
Disperser: BL 181: 316 l/mm
Central order = 1
Central wavelength = 7499.57 Angstroms
Central dispersion = 115. Angstroms/mm, 2.76 Angstroms/pixel
Grating tilt = 7.4 degrees
Grating magnification = 0.90
Using predicted efficiencies
Camera: UV Fast Camera
Detector: T2KB - SITe 2048x2048 CCD
Pixel size: 24 microns
Binning: 1x1 (XxY)
Number of pixels = 2048
Read noise = 4.0 e-, Gain = 3.1 e-/DN, Dark = 0. e-/s

Source pixels: 7 pixels (3xFWHM seeing disk)
Sky pixels: 426 pixels

---- Results for 37.7s exposure at 7500. Angstroms ----

Source flux: 7.36E-4 photons/s/cm^2/A (AB=15.)
Sky flux: 3.54E-5 photons/s/cm^2/A (over source)

Transmission/Efficiencies:              individual cumulative
    Atmosphere (0.062 mag/airmass)         93.4%      93.4%
    Telescope                              77.3%      72.2%
    Aperture (seeing=1.1")                 88.3%      63.7%
    Filter                                 96.2%      61.3%
    Spectrograph                           53.0%      32.5%
    Collimator                             88.0%      28.6%
    Disperser                              68.5%      19.6%
    Camera                                 66.0%      12.9%
    Detector DQE                           73.2%       9.5%

Statistics per exposure per pixel:            e-      sigma
    Source                                   749       27.4
    Sky                                       38        6.2
    Dark                                       0        0.0
    Readout                                            10.6
    Net                                      749       30.0

Signal-to-Noise Statistics:
   24 per exposure per pixel
   35 per exposure per 6.66 A (2 pixel) resolution element

Exposure time: 37.7s
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Figure 2. Sample Output for the KPNO RC Spectrograph