The Slitless Spectroscopy package aXe

Martin Kümmel, H. Kuntschner, J.R. Walsh
Space Telescope - European Coordinating Facility,
Karl-Schwarzschild-Str. 2, D-85748 Garching b. München, Germany

Abstract

Slitless spectroscopy is a rather unusual way to obtain spectral information of celestial objects. The method unfolds its main advantage of delivering many spectra in a single image particularly in the low background environment in space, and many satellites, e.g. **HST**, **GALEX** and **GAIA**, deliver slitless spectroscopic data. The software package **aXe** was built specifically for slitless spectroscopy. Its main extraction package **aXe**, originally designed for the grism and prism data of the **A**dvanced **C**amera for **S**urvey (**ACS**) on board of Hubble, is supplemented by the visualization module **aXe2html** and the simulation software **aXeSIM**. In this contribution we present the **aXe** package and show how **aXe** contributes to observation planning, data reduction and data distribution. Contamination, which is the mutual overlap of object spectra, is an ubiquitous phenomenon in slitless spectroscopy that originates in the degeneracy of one spatial coordinate and the spectral coordinate. Rather than solving this degeneracy with inverse techniques, **aXe** uses the information from direct images to model the spectral contribution from contamination, thus providing an important tool for quality control.

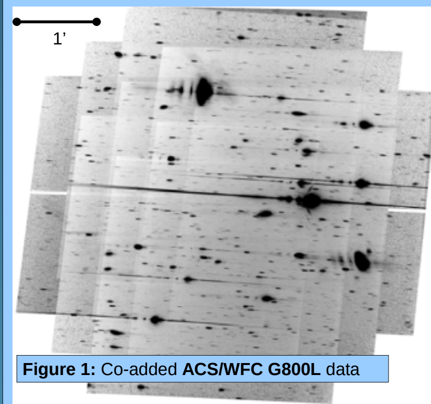

Figure 1: Co-added **ACS/WFC G800L** data

1.The aXe spectral extraction software

Slitless spectroscopy data can easily contain hundreds of object spectra, as can be seen in the combined Hubble **ACS/WFC G800L** data in **Figure 1**. However special software is needed to exploit the data to the full. The slitless spectroscopic data extraction software **aXe** ([1], distributed also as part of the **IRAF/STSDAS** software package [2]) was designed to handle large format spectroscopic slitless images such as from the **ACS**. As data input, **aXe** needs a grism/prism image, a corresponding direct image and a catalogue which lists the objects detected on the direct image. Driven by the object catalogue, the various **aXe** tasks extract wavelength and flux calibrated 1D spectra for each object from the grism image. In data sets consisting of several images with small position shifts (dithers) between them deep, dispersed images are co-added before doing the 1D extraction on the 2D combined spectra. This technique called **aXedrizzle** was presented at **ADA III** [3]. The **aXe** software is successfully being applied to all **ACS** grism and prism data and within the reduction of slitless spectroscopic **NIMCOS** data in the **H**ubble **L**egacy **A**rchive project [4].

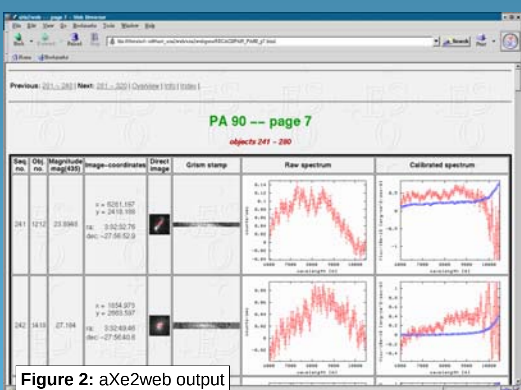

Figure 2: aXe2web output

2. With aXe2web to the World Wide Web

Since a deep slitless image (e.g. from **ACS/WFC**) can contain detectable spectra of hundreds to over a thousand objects, visual checking of each spectrum is very tedious. For this reason we developed **aXe2web** [5,6], a tool which produces browsable web pages for fast and discerning examination of many hundreds of spectra.This additional task to the aXe package takes the **aXe** output files and produces an html summary containing a number of results for each spectrum. Each object produces a line in an html file which lists the reference number, magnitude in the magnitude system of the direct object, the X and Y position of the direct object, its Right Ascension and Declination, a cut-out image showing the direct object, the spectrum stamp image showing the 2D spectrum, a 1D extracted spectrum in counts and the same in flux units. **Figure 2** shows two objects presented by **aXe2web**. An overview page listing only basic object information and an index page, both linked to the corresponding object pages, facilitate the fast navigation within the data set. **aXe2web** accepts custom made style sheets and offers to create and link to the spectral data in tabular form.

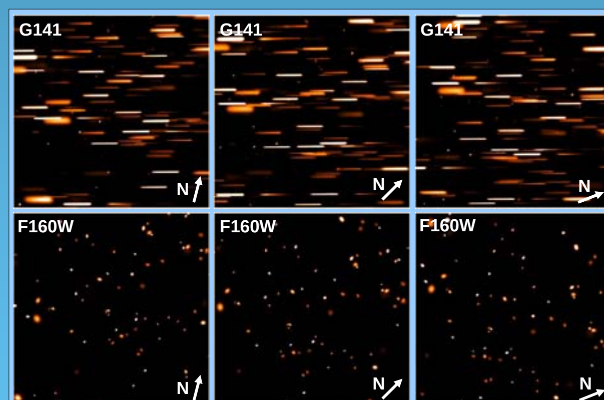

Figure 3: The HUDF simulated at different roll angles with **aXeSIM**

3. Simulating slitless data with aXeSIM

To help users during proposal preparation and observation planning we have developed the simulation tool **aXeSIM** [7]. For simulating slitless spectroscopic images, **aXeSIM** needs a complete characterization of the instrument and a description of the objects to be simulated. Concerning the instrumental characterization, **aXeSIM** uses configuration and calibration files that are also used by the extraction package **aXe**. This closes the loop between the simulation and a subsequent extraction of the simulated spectra, since identical files are used in both. Concerning the description of the simulation objects, there are several possibilities. In the most basic form an object has a Gaussian shape and a flat spectrum in f_λ. For simulating more realistic objects, the user can:

- provide 2D image templates for 'real' object shapes;
- build more complex spectral energy distributions by specifying several magnitude values at different wavelengths;
- give a high resolution spectrum, which is shifted in redshift and scaled in flux to user-provided values .

The basic input for every object is collected in a SExtractror-like text table. As a typical application of **aXeSIM**, **Figure 3** shows some noise-free simulations of the **NICMOS Hubble Ultra Deep Field** (**HUDF**) [10] for the **Hubble Wi**de **F**ield **C**amera **3 (WFC3,** to be installed during Sercive Mission 4**) G141** grism and **F160W** filter. The 144"x144" size of this field is a perfect match to the 123"x137" Field of View of the WFC3 IR channel. The right and left column display simulations with roll angles plus and minus 20deg relative to the central column, respectively. Such simulations can be used to select the roll angle with minimal contamination for the prime target objects, for example. **aXeSIM** is distributed as a **PyRAF** package [8] and as a web application [9].

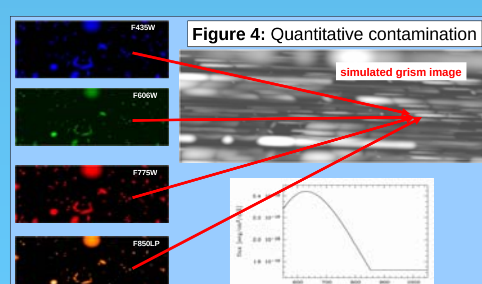

Figure 4: Quantitative contamination

4. Quantitative contamination

To handle the overlap of spectra, the aXe quantitative contamination scheme [11] estimates for each object spectrum the contributing flux from its neighbouring objects. As **Figure 4** illustrates, information from associated direct images (shape, brightness) is used to generate a modelled grism image. Based on this model image the contamination from outside sources to each object is determined and processed through the 1D extraction. As a result, we derive two spectra for every object: one extracted from the real grism image (red lines in **Fig. 2**), and a second one extracted from the modelled grism image (blue lines in **Fig. 2**). Since the model contribution of the object itself was excluded in the extraction of the latter spectrum, this spectrum is a quantitative estimate of the contamination from all other sources to the object spectrum in question. Quantitative contamination aims not to provide decontaminated spectra, but a reliable estimate of how a flux value can be trusted (effectively a systematic error).

References

1. The **aXe** software: **www.stecf.org/software/slitless_software/axe**
2. **IRAF/STSDAS** package: **www.stsci.edu/resources/software_hardware/stsdas**
3. Kümmel, M., Walsh, J.R., Larsen, S.S. & Hook, R. 2004, **ADA III**
4. Freudling, W., Haase, J., Hook, R. et al. 2007, ST-ECF Newsletter 43, p.4
5. Walsh, J.R. & Kümmel, M. 2004, ST-ECF Newsletter 35, p. 9
6. **aXe2web** software: **www.stecf.org/software/slitless_software/axe/#axe2html**
7. Kümmel, M., Kuntschner, H., Walsh, J.R. 2007, ST-ECF Newsletter 43, p. 8
8. The **aXeSIM** softgware: **www.stecf.org/software/slitless_software/axesim**
9. **aXeSIM** web application: **www.stecf.org/instruments/aXeSIMweb**
10. Thompson, R.I., Illingworth, G.I., Bouwens, R., et. al. 2005, AJ, 130, 1
11. Kümmel, M., Larsen, S.S. & Walsh, J.R. 2005, ST-ECF Newsletter 38, p. 8