Improved Cosmic Ray Rejection for Slitless Spectroscopic Data

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Abstract

Data from space based instruments such as the Advanced Camera for Surveys (**ACS**) and the Wide Field Camera 3 (**WFC3**) on the Hubble Space Telescope (**HST**) suffer from a high rate of cosmic ray hits. In **WFC3 IR** data, cosmic ray hits are detected and rejected during the "up-the-ramp" fitting of the individual detector reads. For direct imaging, the **MultiDrizzle** software can detect deviant pixel values such as from cosmics when combining dithered data. We have implemented a similar technique in the **aXe** software package to be able to detect and flag deviant pixels in slitless spectroscopy data. We introduce the method and demonstrate its application to **WFC3/IR** and **ACS/WFC** slitless data. Details on the number of previously undetected cosmics are given and examples of improved extracted spectra shown.

1. aXedrizzle with pixel rejection

A typical slitless spectroscopic data set taken with **HST**, using e.g. the **WFC3/IR** channel with the **G102** or **G141** grisms, consists of several images with only small shifts or dithers between them. The aXedrizzle method in the aXe software package [5] uses drizzle [1] to co-add deep 2D slitless spectra and then extracts the 1D spectra from the deep images. **aXe** version 2.1 (available in **STSDAS 3.12**) contains a new, extended **aXedrizzle** that detects and excludes deviant pixel values caused by e.g. cosmics or pixels with an unstable response that previously had not been noticed. The primary target of this new method is **WFC3/IR G102** and **G141** grism data.

In direct imaging, **MultiDrizzle** [2] detects deviant pixel values when combining dithered data, and the extended **aXedrizzle** follows the **MultiDrizzle** approach. The new **aXedrizzle** performs the following processing steps on its set of individual 2D grism stamp images:

1. drizzle each 2D stamp image individually;
2. median-combine the rectified stamps;
3. blot the median image back to the geometry of each individual image;
4. compare the original with the blotted back stamps, identify and mask out deviating pixel values;
5. drizzle the improved 2D stamps to a co-added, deep 2D grism stamp image;
6. extract 1D spectra from the co-added stamp.

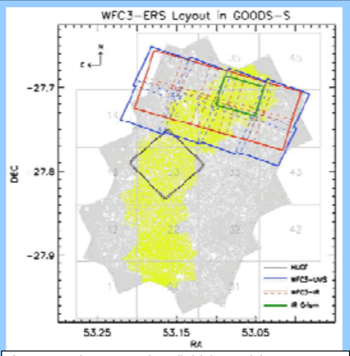

Figure 1: The ERS grism field (green) in GOODS-S

2. aXedrizzle applied to WFC3/IR data

We compare **WFC3/G102** and **G141** data from the Early Release Science (ERS) grism field (green footprint in **Figure 1**), reduced with the basic and the new **aXedrizzle** including pixel rejection. The combined exposure times are 4.2 ksec for each grism and 0.8 ksec for each filter with four images per grism/filter. Spectra of 550 sources are extracted from the **G102** and **G141** slitless images [4, 6]. To measure the effect of the extended **aXedrizzle** on the extracted spectra, we compute the difference spectrum:

$spec_{i,diff}(\lambda) = spec_{i,extended}(\lambda) - spec_{i,basic}(\lambda)$

For spectral bins with $spec_{i,diff}(\lambda) > 0.01$e/s we compute the significance, defined as:

$sig_{i,diff}(\lambda) = |spec_{i,diff}(\lambda)/error_i(\lambda)|$

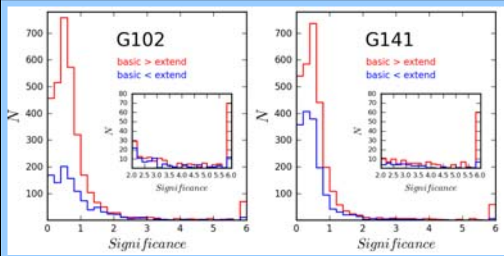

Figure 3: Histograms of all differences in the **G102** (left) and **G141**(right) data. The insets zoom on *sig>2.0.*

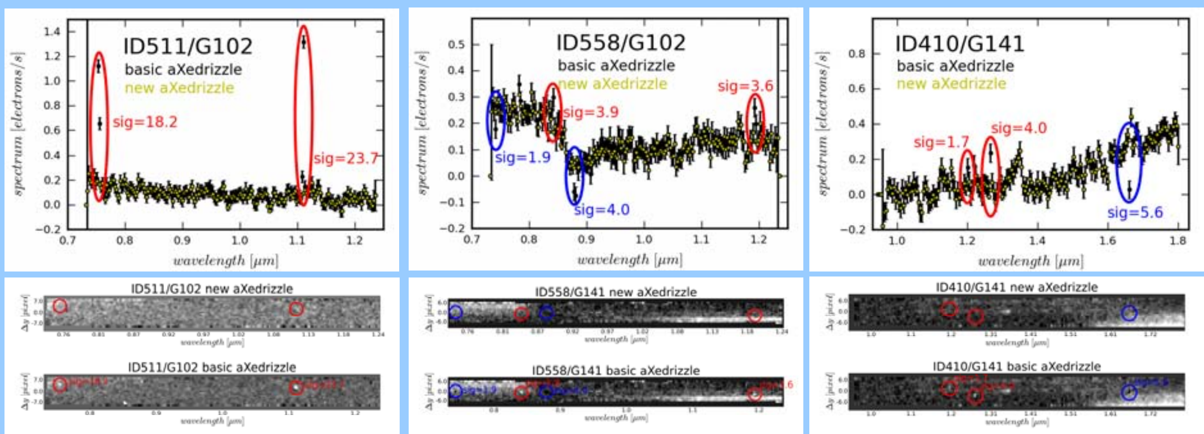

Figure 2: Comparison of extractions with the basic and the new **aXedrizzle** using the 2D grism stamp images (lower panels) and the final 1D spectra (upper panels). Differences and their significance are marked. Blue and red mean lower and higher values in the basic extraction, respectively.

Results

Figure 2 compares the basic and extended **aXedrizzle** extraction for three objects (ID511, ID550, ID410) in the ERS **G102** and **G141** data. The upper panels show basic **aXedrizzle** spectra (black dots plus error bars) and the new **aXedrizzle** spectra (yellow dots). The lower panels show the corresponding deep 2D grism stamp images from which the spectra were extracted. Differences and their significance are marked with ellipses, with red and blue colours indicating enhancements and depressions in the data reduced with basic **aXedrizzle**, respectively. It is evident that blue depressions in the basic **aXedrizzle** reduction originate from individual, unstable pixels. The red enhancements show the typical signatures of cosmic ray hits that had not been detected in the standard calibration pipeline. **Figure 3** shows the histograms of the significance of all differences in the **G102** and **G14**1 datasets in the left and right panels, respectively. Differences where the spectrum from the basic extraction is enhanced are marked red, the ones with depressions in the basic **aXedrizzle** are blue. We now focus on all differences with *sig>2.0* as have a clear impact (see Fig. 2) when corrected with the new **aXedrizzle**. There are 102 and 185 differences with *sig >2.0* for the negative (blue) and positive (red) deviations for **G102** and 34 and 154 for **G141,** respectively . Almost every second spectrum from the 550 in the entire data set is significantly improved with the new **aXedrizzle**. The average fraction of rejected pixels is 0.3% in an exposure of 1ksec.

A similar analysis based on **ACS/WFC G800L** data leads to the histogram of differences in Figure 4. Here we compare the pixel rejection from running **MultiDrizzle** on the slitless images [3] (named "basic" in Fig. 4) with the extended **aXedrizzle** (using the optimized parameters `combine_nhigh=1`, `driz_cr_snr='3.5 3.0'`). In contrast to WFC3/IR, the number of differences with a high significance is rather small. Even on the deep 2D grism stamps it is very difficult to identify an undetected image artifact in one reduction. Identifying cosmic ray hits in **ACS** grism data with the new aXedrizzle is thus equivalent to the previously recommended method of using **MultiDrizzle** before the **aXe** extraction.

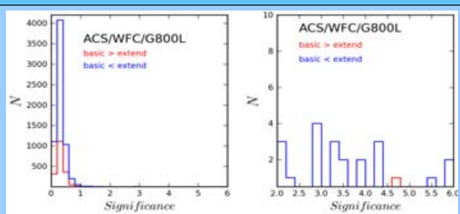

Figure 4: Histograms of all differences in the **ACS/WFC G800L** data set (left) and the zoom on *sig>2.0* (right).

References

1. Fruchter, A.S. & Hook, R.N. 2002, PASP, 114, 144
2. Koekemoer, A.M. et al. 2005, The 2005 Calibration Workshop, p.423
3. Kümmel, M., Walsh, J.R. & Kuntschner, H. 2010, The aXe Manual
4. Kümmel, M., Kuntschner, H., Walsh, J.R. & Bushouse, H. 2010, The 2010 Calibration Workshop
5. Kümmel, M., et al., 2009a, PASP, 121, p.59
6. Straughn, A. N. et al. 2010, AJ, accepted, arXiv:1005.3071