Instrument Science Report WFC3 2017-??

Throughput Updates to the WFC3/IR Grism Configuration Files

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Abstract

We reduce 7 years of WFC3/IR calibration data on the two standard stars GD-71 and GD-153 with the grism reduction software `grizli`*. We compare the extracted spectra to preexisting spectroscopy data from the X-Shooter Spectral Library (Chen et al, 2014) with ratios of flux profiles with wavelength and sensitivity curves. We estimate required throughput changes to the IR Grism configuration files. We find required changes on the order of ...*

Introduction

WFC3 (Wide Field Camera 3) has three grisms (spectral elements combining a grating and prism to conduct slitless spectroscopy) for the UVIS and IR channels. For the IR grisms, filters G102 and G141, much work has gone into precisely calibrating their wavelength trace and throughput (Pirzkal et. al 2016). Recently `grizli` – an open source reduction software (Brammer?) was created to extract grism observations and provide high quality WFC3/IR and JWST data.

For this project we extract WFC3/IR grism observations of GD-71 and GD-153 and compare the WFC3 slitless spectroscopy to the exisiting spectroscopy both from STIS (the Space Telescope Imaging Spectrograph) and the XShooter Spectral Library. We take care to not only examine the first order fringes of the grism used for the bulk of science data, but to also extract second and negative first order grism fringes. (The distinction is shown in Figure 1.)

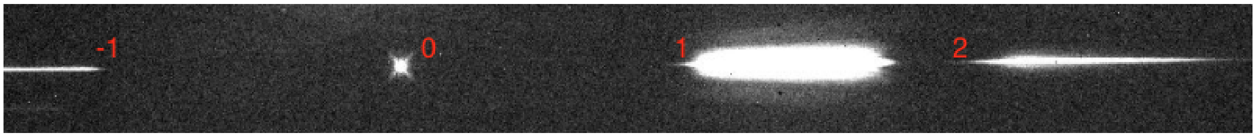

Fig. 1.—*An example of a grism observation and the fringe orders. This image is of GSC* 02581 − 02323 *in the G14 filter. As numbered, the zeroeth order is what's left in the image of the original source. The first order is the brightest projection and the one used predominately for science. The second and negative first order are much fainter (often only visual for bright stars).*

Data

We began with two WFC3/IR grism data sets on standard calibrator stars GD-71 and GD-153 from the Barbara Mikulski Archive for Space Telescopes (MAST); both queries are linked. Each set of data includes grism exposures (G102 and G141) and corresponding direct exposures (F105, F098, and F140, F160), dithered across the field of view. The data spans 7 years of WFC3/IR grism calibration proposals and consists of 591 individual exposures (303 for GD-71 and 282 for GD-153). Tables 1 and 2 list the proposals and visits used for GD-71 and GD-153 respectively.

Root	Proposal	Visit	PA °	Exposures	Filters	Obs. Date
ibbt	11936	01	90.08	30	F098M, F105W, G102	2009-10-03
		02	89.22	30	F160W, F140W, G141	2009-09-21
		03	274.53	30	F098M, F105W, G102	2010-04-24
		04	275.16	30	F160W, F140W, G141	2010-04-24
ibcf	11926	04	91.08	5	F140W, G141, +*	2009-10-05
		05	90.56	5	F140W, G141, +	2010-02-16
		06	264.73	5	F140W, G141, +	2010-02-16
		29	95.73	5	F140W, G141, +	2009-11-01
		30	104.62	5	F140W, G141, +	2009-11-25
iblf	12357	01	235.00	30	F098M, F105W, G102	2011-01-14
		02	209.57	30	F160W, F140W, G141	2010-12-24
ibll	12333	14	105.00	14	F098M, G102, F140W, G141	2010-11-17
ibwq	12702	02	235.00	12	F098M, F105W, G102, F160, F140, G141	2011-12-31
icqw	14024	01	265.74	36	F098M, F105W, G102	2015-01-02
		02	265.74	36	F160W, F140M, G141	2015-02-08

Table 1:*The above data (303 exposures) make up the body of data used for the GD-71 analysis. These exposures consist of grism observations (in G102 and G141) and the accompanying direct exposures in F105W or F098M for G102 and F140W and F160W for G141. The + indicates exposures with more filters were taken in the visit, but are not relevant to grism analysis. Note these visits and proposals consist of WFC3 grism calibration proposals.*

The data on each calibrator was also dithered across the detector (and in some cases

Root	Proposal	Visit	PA °	Exposures	Filters	Obs. Date
iab9	11552	01	277.04	9	F098M, F105W, G102	2009-09-09
		04	276.20	9	F160W, F140W, G141	2009-09-09
		A1	291.37	3	F098M, F105W, G102	2009-09-09
		A4	291.36	3	F160W, F140W, G141	2009-09-09
ibwq	12702	1A	291.37	48	F098M, F105W, G102	2012-06-23
		1B	291.37	42	F160W, F140W, G141	2012-05-18
		AA	292.14	9	F098M, F105W, G102, F160, F140, G141	2012-06-24
		AB	292.15	3	F160W, F140W, G141	2012-05-18
ic46	13092	1A	292.14	28	F098M, F105W, G102, F160, F140, G141	2013-06-01
ich4	13579	01	292.00	28	F098M, F105W, G102, F160, F140, G141	2014-06-24
		02	292.00	28	F098M, F105W, G102, F160, F140, G141	2014-07-05
id2q	14386	01	326.00	36	F098M, G102, F140W, G141	2016-05-02
		02	346.24	36	F160W, F140W, G141	2016-04-13

Table 2:*The above data (282 exposures) make up the body of data used for the GD-153 analysis.*

beyond) to provide a track on how (if at all) the extraction varied with detector position. Figure 2 shows the detector position (as calculated by `astropy.wcs`) for the data on both calibrator stars.

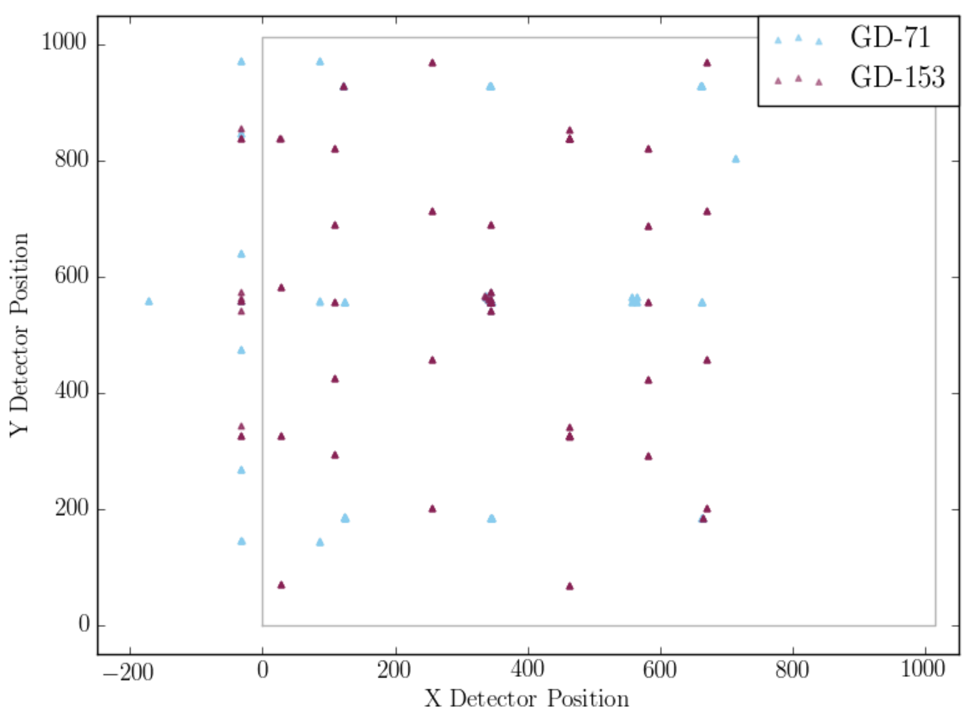

Fig. 2.—*The detector position of the target source (GD-71 or GD-153 in blue and maroon respectively) varies to test for extraction across the detector field.*

Grism Extraction with `grizli`

The data were reduced using the grism reduction software **`grizli`**. Thus far, grizli has been predominately used for more compact (and generally single-epoch) datasets. The details of the extraction are beyond the scope of this ISR, but documented in detail in a `grizli` cookbook.

In summary, the grism extraction and analysis required :

- Matching visits by WCS orient and creating direct/grism filter pairs. →
- Preprocessing and drizzling the calibrated FLT files. →
- Creating a drizzled mosaic and a segmentation map of all of the data on each source. →
- Correcting the segmentation map for proper motion of the main source (as the data spans multiple epochs). →
- Resetting Data Quality flags that flag out grism traces. →
- Extracting beams and making model comparisons. →

Products of Grism Extraction

`grizli` utilizes `Astrodrizzle` to align grim data. For every direct filter we created drizzled mosaics of each dithered field, shown in Figure 3. These mosaics allow for the creation of segmentation maps with `SExtractor` as well as make any proper motion of the sources evident.

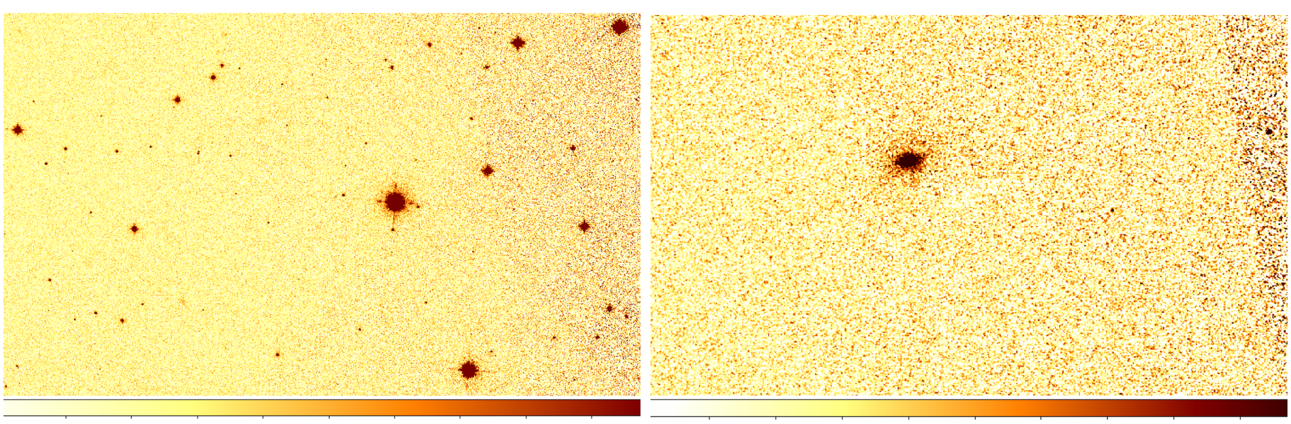

Fig. 3.—*Left: An example of a drizzled mosaic image for the dithered field around GD-71 through the F105W. Right: A close up of a source artificially extended by proper motion from the field around GD-153 through F105W. (Scale is consistent between the two images.)*

We used grizli to create beam cutouts around each spectral order trace for the calibrator source. The beam cutouts allow for closer inspection of the match between the extraction and model and track if Data Quality flags have been artifically excluding grism data, as shown in Figure 4

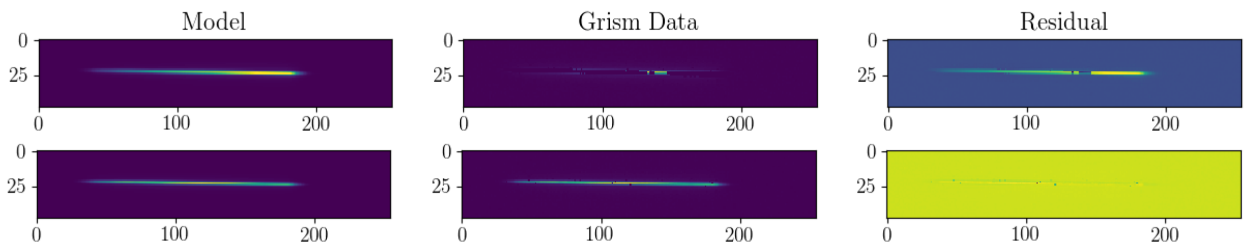

Fig. 4.—*Top: Model, grism data, and residual subtraction of a first order grism trace before Data Quality flagging has been reset to exclude grisms. Bottom: Model, grism data, and residual subtraction after the Data Quality flags have been fixed. For both images, the model is a* pysynphot *normalized model from the X-Shooter spectral library, as described in the next section.*

Data from STIS and the X-Shooter Spectral Library

For comparison to existing spectroscopy, we compared the grism extraction to both STIS (Space Telescope Imaging Spectrograph) archival calibration data and against data from the X-Shooter Spectral Library. We found better agreement with the X-Shooter Spectral Library (which is the newer data release?) and used that for our model comparisons moving forward. We renormalized the spectral data from X-Shooter to WFC3/IR bandpasses with the Python package pysynphot, as described in the modeling section of the cookbook.

Analysis

Flux Ratios for Throughput Profiles

Once the traces have been corrected and passed a brief (due to high data volume) visual inspection, we extracted the flux vs wavelength profile for each grism order within the images. We display the throughput profiles both in comparison to the model, as well as ratio them to the model spectra, to give a numerical comparison of where the grizli extraction is less accurate. Figure 5 shows an example of one of these figures, and the remaining (which were created for G102 and G141 on each observable grism order for both calibrator stars) are in Appendix A.

Sensitivity Curves?

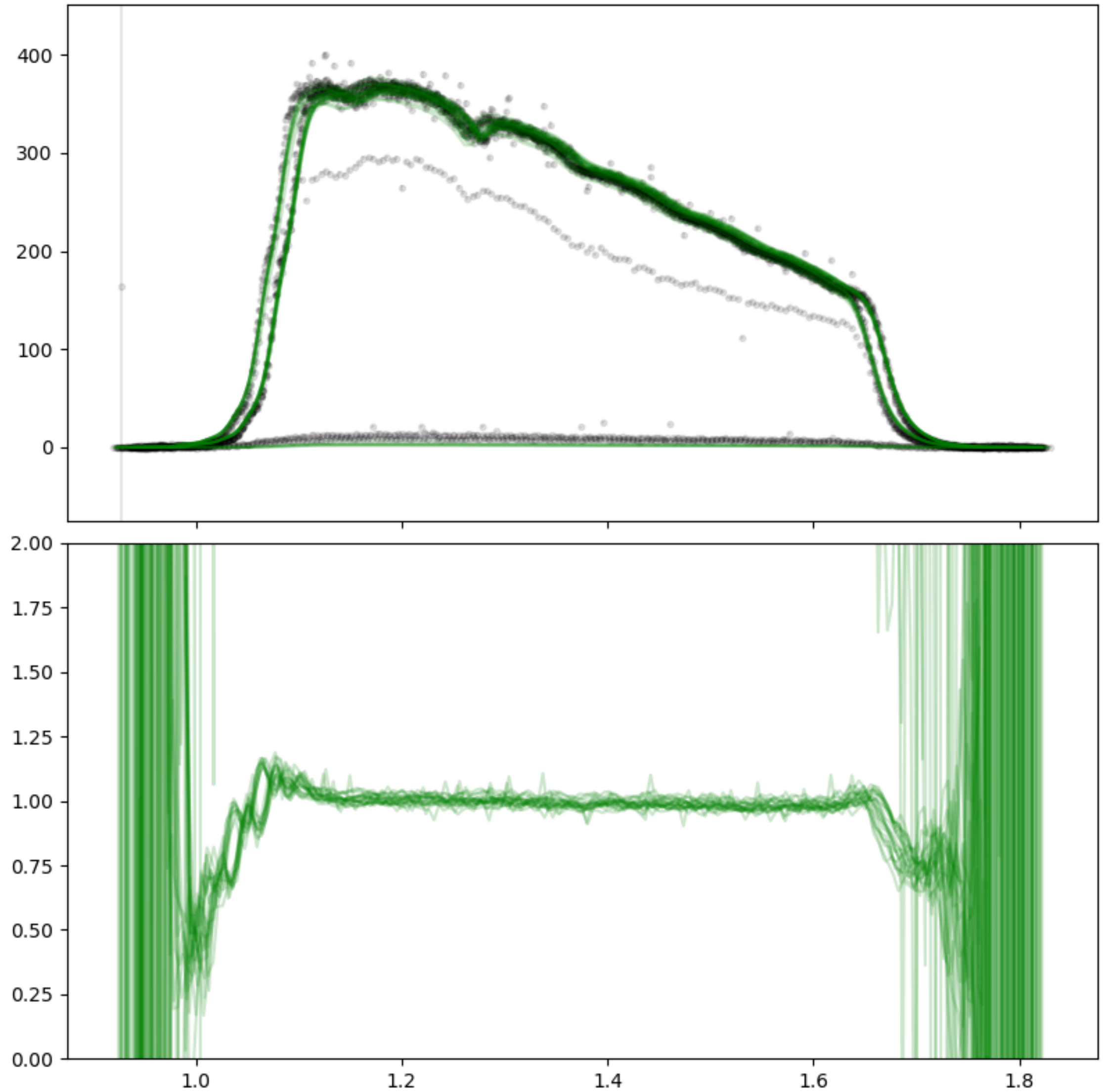

Fig. 5.—*Top: For the first order beam extracted from each exposure, the black are the extracted data and green is the accompanying X-Shooter model. Bottom: This ratio of the model and data shows a close agreement except around the edges, where some issue with filter bandpass is to be expected.*

Throughput Updates to Configuration Files

Acknowledgements

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TIR 2017-01: Aladin Overlay of a Zone of Avoidance for Dragon’s Breath, P. R. McCullough 2017 (in prep)

Appendix A

Following, we show the model vs data extraction for each filter, source, and grism order combination.