
BHTOM-SPEC

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This provides the spectroscopic data reduction for BHTOM. At the time of writing, it is planned for implementing the longslit spectral reduction of Gemini/GMOS, LT/SPRAT and LCO/Floyds.

CHAPTER 1

Usage

To perform a spectral extraction from SPRAT data, user only needs to type:

```
python sprat_extraction.py extraction_config.yaml
```

While for GMOS, the images have to be flattened first, before performing the spectral extraction:

```
python gmos_reduction.py reduction_config.yaml  
python gmos_extraction.py extraction_config.yaml
```

Some the Configuration Files section for more information.

2.1 Installation Guide

2.1.1 Dependencies

Python \geq 3.6

These packages can be installed with pip

- numpy \geq 1.16
- scipy \geq 1.5
- spectres \geq 2.1.1
- reportlab
- svglib
- pyyaml

These have to be installed from the respective development branches at

- <https://github.com/cylammarco/aspired#dev>
- <https://github.com/jveitchmichaelis/rascal#dev>

This is required if you wish to build the document locally

- <https://github.com/SuperKogito/sphinxcontrib-pdfembed>

2.1.2 BHTOM Spec

Clone the repository

```
git clone https://github.com/cylammarco/bhtomspec
git clone https://github.com/cylammarco/bhtomspec-example
```

To test the bhtomspec, all the examples should run, e.g.

```
python3 [some_path_a]/bhtomspec/SPRAT/sprat_extraction.py [some_path_b]/
↳bhtomspec-example/SPRAT/example/ExtractionCase1/20180810_lhs6328_case1.yaml
python3 [some_path_a]/bhtomspec/GMOS/gmos_reduction.py [some_path_b]/
↳bhtomspec-example/GMOS/example/ReductionCase1/flattening_config.yaml
python3 [some_path_a]/bhtomspec/GMOS/gmos_extraction.py [some_path_b]/
↳bhtomspec-example/GMOS/example/ExtractionCase1/extraction_config_1.yaml
```

There are 3 shell scripts that run all the examples, however, the path has to be configured before they work. For example, in [some_path_b]/bhtomspec-example/SPRAT/run_all_examples.sh

```
python3 sprat_extraction.py example/ExtractionCase1/20180810_lhs6328_case1.
↳yaml
python3 sprat_extraction.py example/ExtractionCase2/20180810_lhs6328_case2.
↳yaml
python3 sprat_extraction.py example/ExtractionCase3/20180810_lhs6328_case3.
↳yaml
python3 sprat_extraction.py example/ExtractionCase4/20180810_lhs6328_case4.
↳yaml
python3 sprat_extraction.py example/ExtractionCase5/20180810_lhs6328_case5.
↳yaml
```

has to be modified to

```
python3 [some_path_a]/bhtomspec/SPRAT/ssprat_extraction.py example/
↳ExtractionCase1/20180810_lhs6328_case1.yaml
python3 [some_path_a]/bhtomspec/SPRAT/ssprat_extraction.py example/
↳ExtractionCase2/20180810_lhs6328_case2.yaml
python3 [some_path_a]/bhtomspec/SPRAT/ssprat_extraction.py example/
↳ExtractionCase3/20180810_lhs6328_case3.yaml
python3 [some_path_a]/bhtomspec/SPRAT/ssprat_extraction.py example/
↳ExtractionCase4/20180810_lhs6328_case4.yaml
python3 [some_path_a]/bhtomspec/SPRAT/ssprat_extraction.py example/
↳ExtractionCase5/20180810_lhs6328_case5.yaml
```

before it can run.

2.1.3 Other repositories for BHTOM Spec

It is currently not a package, just scripts, so it is not registered on any package index service. It may happen if this project continues onto a full integration with BHTOM.

2.2 Reduction Configuration

This only applies to GMOS reduction where a full reduction is performed. SPRAT reductions begin with flattened spectral image data.

2.2.1 GMOS field-flattening configuration (YAML)

```
1 folder_path: "."
2 output_folder_path: "output"
```

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```

3 light_folder: ~
4 flat_folder: ~
5 arc_folder: ~
6 bias_folder: ~
7 arc_flat_folder: ~
8 arc_bias_folder: ~
9 light_extension: ["fits", "fit", "bz2", "gz"]
10 flat_extension: ["fits", "fit", "bz2", "gz"]
11 arc_extension: ["fits", "fit", "bz2", "gz"]
12 bias_extension: ["fits", "fit", "bz2", "gz"]
13 arc_flat_extension: ["fits", "fit", "bz2", "gz"]
14 arc_bias_extension: ["fits", "fit", "bz2", "gz"]
15 bias_master_filename: bias_master
16 arc_bias_master_filename: arc_bias_master
17 flat_row_size: 10
18 flat_edge_size: 10
19 flat_strip_size: 20
20 force_recreate_bias: false
21 save_bias: true
22 save_bias_format: ["fits", "numpy"]
23 overwrite_bias_image: true
24 save_flattened_image: true
25 save_flattened_image_format: ["fits", "numpy"]
26 overwrite_flattened_image: true
27 create_fig: true
28 show_fig: false
29 diagnostic_pdf: true

```

The *light_folder*, *flat_folder*, *arc_folder*, *bias_folder*, *arc_flat_folder* and *arc_bias_folder* are relative to the *folder_path*. If they are empty, the folders are assumed to be called *light*, *flat*, *arc*, *bias*, *arc_flat*, *arc_bias* folders located at *folder_path*.

All the files with the extension listed in the respective extension arguments (*light_extension...*) will be processed.

flat_row_size is the number of rows on either size from the central row of the spectral image that are to be summed to compute the sensitivity function. *flat_edge_size* is the number of edge pixels that are removed in the computation. *flat_strip_size* is the number of pixels from the *flat_edge_size*-th pixel to be fitted a straight line over.

2.3 Extraction Configuration

This applies to both GMOS and SPRAT.

2.3.1 Extraction configuration (YAML)

Once the flattening is performed, the longslit spectral extraction is like any extractions from a generic spectrograph. The format of the parameter files for GMOS and SPRAT are the same. Most of the parameters can be kept constant, respective to the instrument. The file paths, which are the first few lines of the file, have to be updated for each extraction. The output data can be exported as FITS/CSV, static png/jpg/pdf image, an interactive plotly iframe, or just the JSON file for the plotly graph. The following shows the example YAML of the GMOS extraction.

```

1 folder_path: "."
2 output_folder_path: "20181115_gaia18cnz/output"
3

```

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```

4  # Input
5  science_file:
6      # - they have to be in a list
7      - "20181115_gaia18cnz/output/N20181115S0097_flattened.fits"
8      - "20181115_gaia18cnz/output/N20181115S0098_flattened.fits"
9      - "20181115_gaia18cnz/output/N20181115S0101_flattened.fits"
10     - "20181115_gaia18cnz/output/N20181115S0102_flattened.fits"
11  science_arc_file: "20181115_gaia18cnz/output/N20181115S0215_flattened.fits"
12
13  standard_file: "20180811_g191b2b/output/N20180811S0148_flattened.fits"
14  standard_arc_file: "20180811_g191b2b/output/N20180813S0115_flattened.fits"
15
16  # If sensitivity curve is provided, standard star extraction will be skipped
17  sensitivity_file: "20180811_g191b2b/output/sensitivity_itp.npy"
18
19  # Output - they have to be lists
20  science_output_file:
21      # - they have to be in a list
22      - "20181115_gaia18cnz/output/N20181115S0097"
23      - "20181115_gaia18cnz/output/N20181115S0098"
24      - "20181115_gaia18cnz/output/N20181115S0101"
25      - "20181115_gaia18cnz/output/N20181115S0102"
26  standard_output_file: "20180811_g191b2b/output/N20180811S0148"
27
28  science_output_type:
29      - "fits"
30      - "csv"
31      - "png"
32      - "iframe"
33  standard_output_type:
34      - "fits"
35      - "csv"
36      - "png"
37      - "iframe"
38
39  # Output
40  savefits: True
41  fits_output: 'flux_resampled+wavecal+flux+adu+adu_resampled'
42  fits_filename: 'reduced'
43  fits_stype: 'science'
44  fits_individual: False
45  fits_overwrite: False
46  savecsv: True
47  csv_output: 'flux_resampled+wavecal+flux+adu+adu_resampled'
48  csv_filename: 'reduced'
49  csv_stype: 'science'
50  csv_individual: False
51  csv_overwrite: False
52
53  # Only needed if images/iframe are being exported
54  width: 1920
55  height: 1080

```

It is then followed by all the extraction parameters. At the time of writing, the readnoise, gain, seeing and exptime are not read automatically from the header. In order to have a correct absolute flux calibration, the exposure time has to be filled in manually. The gain is constant for the instrument over time, so it does not need adjusting unless the observatory has changed the instrument setting. While the seeing varies with time, it does not affect the extraction quality, it can

slightly slow down the speed in aperture tracing, which is hardly a bottleneck process of the data extraction to begin with, so it can be left as it is. The same applies to the parameters for the standard.

```

1 # Science target
2
3 # TwoDSpec parameters
4 science_axis: 1
5 science_spatial_mask: ''
6 science_spec_mask: ''
7 science_flip: True
8 science_cosmicray: True
9 science_cosmicray_sigma: 5.
10 science_readnoise: 0.
11 science_gain: 1.64
12 science_seeing: 1.2
13 science_exptime: 300
14 science_silence: False

```

Below is the rest of the configuration file.

```

1 # Aperture Tracing
2 science_aptrace_nspec: 1
3 science_aptrace_nwindow: 25
4 science_aptrace_spec_sep: 5
5 science_aptrace_resample_factor: 10
6 science_aptrace_rescale: False
7 science_aptrace_scaling_min: 0.995
8 science_aptrace_scaling_max: 1.005
9 science_aptrace_scaling_step: 0.001
10 science_aptrace_percentile: 5
11 science_aptrace_tol: 3
12 science_aptrace_polydeg: 3
13 science_aptrace_ap_faint: 10
14 science_aptrace_display: False
15 science_aptrace_renderer: "default"
16 science_aptrace_jsonstring: False
17 science_aptrace_iframe: False
18 science_aptrace_open_iframe: False
19 # Aperture Extraction
20 science_apextract_apwidth: 10
21 science_apextract_skysep: 5
22 science_apextract_skywidth: 5
23 science_apextract_skydeg: 1
24 science_apextract_optimal: True
25 science_apextract_display: False
26 science_apextract_renderer: "default"
27 science_apextract_jsonstring: False
28 science_apextract_iframe: False
29 science_apextract_open_iframe: False
30 # WavelengthCalibration
31 science_silence: False
32 science_pixel_list: ~
33 # Provide polyfit coefficients
34 science_polyfit: False
35 science_polyfit_coeff: [0., 0., 0., 0., 0.]
36 science_polyfit_type: ['poly']
37 # Extract Arc spectrum
38 science_arc_spec_display: False

```

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```

39 science_arc_spec_jsonstring: False
40 science_arc_spec_renderer: 'default'
41 science_arc_spec_iframe: False
42 science_arc_spec_open_iframe: False
43 # Find arc lines
44 science_findarc_background: 1000.
45 science_findarc_percentile: ~
46 science_findarc_prominence: 0.
47 science_findarc_distance: 5.
48 science_findarc_refine: True
49 science_findarc_refine_window_width: 5
50 science_findarc_display: False
51 science_findarc_jsonstring: False
52 science_findarc_renderer: 'default'
53 science_findarc_iframe: False
54 science_findarc_open_iframe: False
55 # Calibrator parameters
56 science_wavecal_min_wavelength: 5000
57 science_wavecal_max_wavelength: 9500
58 science_wavecal_plotting_library: 'plotly'
59 science_wavecal_log_level: 'info'
60 # Calibrator Fit constraints
61 science_constraints_num_slopes: 10000
62 science_constraints_range_tolerance: 500
63 science_constraints_fit_tolerance: 10.
64 science_constraints_polydeg: 4
65 science_constraints_candidate_thresh: 15.
66 science_constraints_linearity_thresh: 1.5
67 science_constraints_ransac_thresh: 3
68 science_constraints_num_candidates: 25
69 science_constraints_xbins: 200
70 science_constraints_ybins: 200
71 science_constraints_brute_force: False
72 science_constraints_polyfit_type: 'poly'
73 science_constraints_spec_id: ~
74 # Atlas
75 science_atlas_elements: ['Cu', 'Ar']
76 science_atlas_min_atlas_wavelength: 0
77 science_atlas_max_atlas_wavelength: 15000
78 science_atlas_min_intensity: 0
79 science_atlas_min_distance: 0
80 science_atlas_vacuum: False
81 science_atlas_pressure: ~
82 science_atlas_temperature: ~
83 science_atlas_relative_humidity: ~
84 science_atlas_constrain_poly: False
85 science_atlas_spec_id: ~
86 # User-supplied Atlas, the following OVERRIDES the Atlas config set above
87 science_atlas_user_supplied: True
88 science_atlas_user_wavelengths: [
89     4703.632, 4728.19041, 4766.19677, 4807.36348, 4849.16386, 4881.22627,
90     ↪4890.40721, 4906.12088, 4934.58593, 4966.46490,
91     5018.56194, 5063.44827, 5163.723, 5189.191, 5497.401,
92     5560.246, 5608.290, 5913.723,
93     6754.698, 6873.185, 6967.352,
94     7032.190, 7069.167, 7149.012, 7274.940, 7386.014,
95     7505.935, 7516.721, 7637.208, 7725.887, 7893.246, 7950.362,

```

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```

95         8105.921, 8117.542, 8266.794, 8410.521, 8426.963,
96         8523.783, 8670.325,
97         9125.471, 9197.161, 9227.03, 9356.787,
98         9660.435, 9787.186
99     ]
100 science_atlas_user_elements: ['CuAr']
101 science_atlas_user_vacuum: True
102 science_atlas_user_pressure: ~
103 science_atlas_user_temperature: ~
104 science_atlas_user_relative_humidity: ~
105 science_atlas_user_constrain_poly: False
106 science_atlas_user_spec_id: ~
107
108 # Fit
109 science_fit_sample_size: 5
110 science_fit_top_n: 10
111 science_fit_max_tries: 20000
112 science_fit_progress: True
113 science_fit_coeff: ~
114 science_fit_linear: True
115 science_fit_weighted: True
116 science_fit_filter_close: False
117 science_fit_display: False
118 science_fit_savefig: False
119 science_fit_filename: ~
120 science_fit_spec_id: ~
121 # Refine Fit 1st pass
122 science_refinefit1: False
123 science_refinefit1_polyfit_coeff: ~
124 science_refinefit1_n_delta: 2
125 science_refinefit1_refine: True
126 science_refinefit1_tolerance: 10.
127 science_refinefit1_method: 'Nelder-Mead'
128 science_refinefit1_convergence: 1.0e-6
129 science_refinefit1_robust_refit: True
130 science_refinefit1_polydeg: ~
131 science_refinefit1_display: False
132 science_refinefit1_savefig: False
133 science_refinefit1_filename: ~
134 science_refinefit1_spec_id: ~
135 # Refine Fit 2nd pass
136 science_refinefit2: False
137 science_refinefit2_polyfit_coeff: ~
138 science_refinefit2_n_delta: ~
139 science_refinefit2_refine: True
140 science_refinefit2_tolerance: 5.
141 science_refinefit2_method: 'Nelder-Mead'
142 science_refinefit2_convergence: 1.0e-6
143 science_refinefit2_robust_refit: True
144 science_refinefit2_polydeg: ~
145 science_refinefit2_display: False
146 science_refinefit2_savefig: False
147 science_refinefit2_filename: ~
148 science_refinefit2_spec_id: ~
149
150 # Standard target
151

```

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```

152 # TwoDSpec parameters
153 standard_saxis: 1
154 standard_spatial_mask: ''
155 standard_spec_mask: ''
156 standard_flip: True
157 standard_cosmicray: True
158 standard_cosmicray_sigma: 5.
159 standard_readnoise: ~
160 standard_gain: ~
161 standard_seeing: ~
162 standard_exptime: ~
163 standard_silence: False
164 # TwoDSpec header keywords (NOT used if the values are provided above)
165 standard_readnoise_keyword: ~
166 standard_gain_keyword: ~
167 standard_seeing_keyword: ~
168 standard_exptime_keyword: ~
169 # Aperture Tracing
170 standard_aptrace_nspec: 1
171 standard_aptrace_nwindow: 25
172 standard_aptrace_spec_sep: 5
173 standard_aptrace_resample_factor: 10
174 standard_aptrace_rescale: False
175 standard_aptrace_scaling_min: 0.995
176 standard_aptrace_scaling_max: 1.005
177 standard_aptrace_scaling_step: 0.001
178 standard_aptrace_percentile: 5
179 standard_aptrace_tol: 3
180 standard_aptrace_polydeg: 3
181 standard_aptrace_ap_faint: 10
182 standard_aptrace_display: False
183 standard_aptrace_renderer: "default"
184 standard_aptrace_jsonstring: False
185 standard_aptrace_iframe: False
186 standard_aptrace_open_iframe: False
187 # Aperture Extraction
188 standard_apextract_apwidth: 15
189 standard_apextract_skysep: 5
190 standard_apextract_skywidth: 5
191 standard_apextract_skydeg: 1
192 standard_apextract_optimal: True
193 standard_apextract_display: False
194 standard_apextract_renderer: "default"
195 standard_apextract_jsonstring: False
196 standard_apextract_iframe: False
197 standard_apextract_open_iframe: False
198 # WavelengthCalibration
199 standard_silence: False
200 standard_pixel_list: ~
201 # Provide polyfit coefficients
202 standard_polyfit: False
203 standard_polyfit_coeff: [0., 0., 0., 0., 0.]
204 standard_polyfit_type: ['poly']
205 # Extract Arc spectrum
206 standard_arc_spec_display: False
207 standard_arc_spec_jsonstring: False
208 standard_arc_spec_renderer: 'default'

```

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```

209 standard_arc_spec_iframe: False
210 standard_arc_spec_open_iframe: False
211 # Find arc lines
212 standard_findarc_background: 1000.
213 standard_findarc_percentile: ~
214 standard_findarc_prominence: 0.
215 standard_findarc_distance: 5.
216 standard_findarc_refine: True
217 standard_findarc_refine_window_width: 5
218 standard_findarc_display: False
219 standard_findarc_jsonstring: False
220 standard_findarc_renderer: 'default'
221 standard_findarc_iframe: False
222 standard_findarc_open_iframe: False
223 # Calibrator parameters
224 standard_wavecal_min_wavelength: 5000
225 standard_wavecal_max_wavelength: 9500
226 standard_wavecal_plotting_library: 'plotly'
227 standard_wavecal_log_level: 'info'
228 # Calibrator Fit constraints
229 standard_constraints_num_slopes: 10000
230 standard_constraints_range_tolerance: 500
231 standard_constraints_fit_tolerance: 10.
232 standard_constraints_polydeg: 4
233 standard_constraints_candidate_thresh: 15.
234 standard_constraints_linearity_thresh: 1.5
235 standard_constraints_ransac_thresh: 3
236 standard_constraints_num_candidates: 25
237 standard_constraints_xbins: 200
238 standard_constraints_ybins: 200
239 standard_constraints_brute_force: False
240 standard_constraints_polyfit_type: 'poly'
241 standard_constraints_spec_id: ~
242 # Atlas
243 standard_atlas_elements: ['Cu', 'Ar']
244 standard_atlas_min_atlas_wavelength: 0
245 standard_atlas_max_atlas_wavelength: 15000
246 standard_atlas_min_intensity: 0
247 standard_atlas_min_distance: 0
248 standard_atlas_vacuum: False
249 standard_atlas_pressure: ~
250 standard_atlas_temperature: ~
251 standard_atlas_relative_humidity: ~
252 standard_atlas_constrain_poly: False
253 standard_atlas_spec_id: ~
254 # User-supplied Atlas, the following OVERRIDES the Atlas config set above
255 standard_atlas_user_supplied: True
256 standard_atlas_user_wavelengths: [
257     4703.632, 4728.19041, 4766.19677, 4807.36348, 4849.16386, 4881.22627,
↪ 4890.40721, 4906.12088, 4934.58593, 4966.46490,
258     5018.56194, 5063.44827, 5163.723, 5189.191, 5497.401,
259     5560.246, 5608.290, 5913.723,
260     6754.698, 6873.185, 6967.352,
261     7032.190, 7069.167, 7149.012, 7274.940, 7386.014,
262     7505.935, 7516.721, 7637.208, 7725.887, 7893.246, 7950.362,
263     8105.921, 8117.542, 8266.794, 8410.521, 8426.963,
264     8523.783, 8670.325,

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```

265         9125.471, 9197.161, 9227.03, 9356.787,
266         9660.435, 9787.186
267     ]
268     standard_atlas_user_elements: ['CuAr']
269     standard_atlas_user_vacuum: True
270     standard_atlas_user_pressure: ~
271     standard_atlas_user_temperature: ~
272     standard_atlas_user_relative_humidity: ~
273     standard_atlas_user_constrain_poly: False
274     standard_atlas_user_spec_id: ~
275     # Fit
276     standard_fit_sample_size: 5
277     standard_fit_top_n: 20
278     standard_fit_max_tries: 20000
279     standard_fit_progress: True
280     standard_fit_coeff: ~
281     standard_fit_linear: True
282     standard_fit_weighted: True
283     standard_fit_filter_close: False
284     standard_fit_display: False
285     standard_fit_savefig: False
286     standard_fit_filename: ~
287     standard_fit_spec_id: ~
288     # Refine Fit 1st pass
289     standard_refinefit1: True
290     standard_refinefit1_polyfit_coeff: ~
291     standard_refinefit1_n_delta: 2
292     standard_refinefit1_refine: True
293     standard_refinefit1_tolerance: 10.
294     standard_refinefit1_method: 'Nelder-Mead'
295     standard_refinefit1_convergence: 1.0e-6
296     standard_refinefit1_robust_refit: True
297     standard_refinefit1_polydeg: ~
298     standard_refinefit1_display: False
299     standard_refinefit1_savefig: False
300     standard_refinefit1_filename: ~
301     standard_refinefit1_spec_id: ~
302     # Refine Fit 2nd pass
303     standard_refinefit2: True
304     standard_refinefit2_polyfit_coeff: ~
305     standard_refinefit2_n_delta: ~
306     standard_refinefit2_refine: True
307     standard_refinefit2_tolerance: 5.
308     standard_refinefit2_method: 'Nelder-Mead'
309     standard_refinefit2_convergence: 1.0e-6
310     standard_refinefit2_robust_refit: True
311     standard_refinefit2_polydeg: ~
312     standard_refinefit2_display: False
313     standard_refinefit2_savefig: False
314     standard_refinefit2_filename: ~
315     standard_refinefit2_spec_id: ~
316
317     # Choose Flux Calibration
318     fluxcal_target: 'LTT7987'
319     fluxcal_library: 'esoxshooter'
320     fluxcal_ftype: 'flux'
321     fluxcal_cutoff: 0.4

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```

322 fluxcal_display: True
323 fluxcal_renderer: 'default'
324 fluxcal_jsonstring: False
325 fluxcal_iframe: True
326 fluxcal_open_iframe: True
327 # Compute sensitivity curve
328 sensecurve_kind: 3
329 sensecurve_smooth: False
330 sensecurve_slength: 5
331 sensecurve_sorder: 3
332 sensecurve_mask_range:
333     - [6860, 6960]
334     - [7150, 7410]
335     - [7580, 7720]
336 sensecurve_display: False
337 sensecurve_renderer: 'default'
338 sensecurve_jsonstring: False
339 sensecurve_iframe: False
340 sensecurve_open_iframe: False

```

2.4 LT SPRAT

The Liverpool Telescope distributes the [SPRAT Level 2 \(L2\) data](#) in multi-extension FITS files containing a primary image array for the Level 1 (L1) reduced CCD frame and up to five FITS extensions of derived products. The executive summary of the data product is listed in the following table, full description can be referred to the same link above.

Table 1: Multi-extension FITS data format

Index	EXTNAME	Description
0	L1_IMAGE	Fieldflattened long-slit image.
1	LSS_NONSS	Wavelength calibrated and trimmed long-slit image.
2	SPEC_NONSS	Tophat extracted 1D spectrum.
3	SPEC_SS	Tophat extracted and sky subtracted 1D spectrum. Always exists if SPEC_NONSS exists, but it may not be picking the right regions for sky subtraction (e.g. nebulosity from the resolved host galaxy).
4	NORMFLUX	Detector response corrected SPEC_SS spectrum. Flux is normalised to unity over the region 5000-6000 Å. Always exists if SPEC_SS exists.
5	FLUX	Absolute flux calibrated spectrum in unit of $\text{erg} / \text{s} / \text{cm}^2 / \text{Å}$.

The provided reduced data only guarantee to contain index 0 and 1. The native pipeline may fail to produce SPEC_NONSS in crowded field; the flux may not be calibrated if the photometry from the acquisition image is not reliable ([see more here](#)).

2.4.1 With only the Science FITS file

If the data comes with 6 HDUs, the spectrum can be re-extracted directly from the LSS_NONSS image, and then re-apply the absolute flux calibration by extracting the sensitivity function by dividing [SPEC_SS] by [FLUX]. The sensitivity function the native pipeline applied is $(\text{ADU} / \text{s}) / (\text{erg} / \text{s} / \text{cm}^2 / \text{Å})$. This can improve the signal-to-noise ratio (SNR) by up to ~30% coming purely from the difference between optimal extraction and tophat extraction.

If the data comes with 5 HDUs, the same procedure applies except the absolute calibration will be done by using a pre-saved sensitivity function adjusted to the unit of $(\text{erg} / \text{s} / \text{cm}^2 / \text{Å}) / \text{s}$. This will only give the estimate of the

absolute flux. The spectral shape will be the same as the NORMFLUX data from their native pipeline.

If the data comes with less than 5 HDUs, the sensitivity function will be taken from the pre-saved data, which can be out of date but should give a good general shape of the spectrum.

2.4.2 With only the Science and Standard FITS file

It is not common for the LT programmes to include standard frames. However, if one is provided, it can be used to compute a more representative response function. The procedures are the same as above in terms of spectral extraction. The sensitivity will be computed by providing the name of the standard star in the configuration file.

2.4.3 With arc files

The arc file is taken every time after an observing group/block. It is extremely rare that the automated LT pipeline fail to the perform wavelength calibration. Using a different way to compute the wavelength solution with more lines with RASCAL, a recalibration may give a marginal improvement in the calibration (less than the resolution in any case). We recommend providing an arc file if you wish to use the native pixel scale such that the resampling done from L1_IMAGE to LSS_NONSS will not lead to any loss of information, regardless of how small they can be.

2.4.4 Data Processing

The above processes will be assigned as one of the following five scenarios when handled by this pipeline:

1. science frame only (Science L1 Image)
 - i. Improving the S/N ratio by using optimal extraction (Science)
 2. science + science arc frames only (Science LSS_NONSS)
 - i. Improving the S/N ratio by using optimal extraction (Science)
 - ii. Recomputing the wavelength solution (Science)
 3. science + standard frames only (Science L1 Image + Standard L1 Image)
 - i. Improving the S/N ratio by using optimal extraction (Science + Standard)
 - ii. Recompute the sensitivity response function
 4. science + science arc + standard frames (Science L1 Image + Standard LSS_NONSS)
 - i. Improving the S/N ratio by using optimal extraction (Science + Standard)
 - ii. Recomputing the wavelength solution (Science)
 - iii. Recompute the sensitivity response function
 5. science + science arc + standard + standard arc frames (Science L1 Image + Standard L1 Image)
 - i. Improving the S/N ratio by using optimal extraction (Science + Standard)
 - ii. Recomputing the wavelength solution (Science + Standard)
 - iii. Recompute the sensitivity response function
- science + standard + standard arc will be treated as (3)
 - science + standard arc will be treated as (1)
 - If sensitivity file is provided, they will be used and the reprocessing will ignore the standard and standard arc files, i.e. (3) will reduced to (1), (4) & (5) will reduced to (2).

2.5 GMOS Longslit

The GMOS Longslit spectrograph is available with both Gemini North and Gemini South. The characteristics of the instruments are very similar, with only some minute differences, at the detector plane. This comment is at least true for the purpose of this quicklook pipeline. The non-negligible differences are taken care of, for example, different sizes of the chip gaps. [See the detailed description of the instruments here.](#)

This quicklook pipeline divides the reduction in two parts - (1) fieldflattening and (2) spectral extraction. The first part takes care of the different binnings, Region Of Interest (ROI), chip gap sizes (North/South are different), bias subtraction, overscan subtraction and response function within chip & across the focal plane. The second part is the spectral extraction.

2.5.1 1. Fieldflattening

The procedure follows that described on the [US National Gemini Office GMOS cookbook page](#). The *gmosspectral_extraction.py* keeps the functions for performing image reconstruction, generating master bias and global sensitivity function. The only procedure that is not directly obvious from the page is the construction of the response function across the detector array, the steps are as follow:

1. Generate the master flat by dividing the stacked flat by the mean (with sigma clipping and NAN handled).
2. Sum the ADU counts over the few pixels covered by the 2D spectrum in the spatial direction to generate the relative response across the spectral direction.
3. Fit straight lines through the back-to-back end pixels (ignore the last few pixels) of the relative response between the adjacent chips in order to normalise the inter-chip response. See the *linear_fit()* function.
4. Apply the global response function to absolutely normalise the 3-chip image.

In order to reduce the images, the *gmoss_reduction.py* should be executed, which makes use of the *gmoss_extraction.py* and the parameter YAML file.

The different combinations of available frames will be assigned as one of the following eight scenarios, we require at least one light and one flat frame:

1. Light + Flat
2. Light + Flat + Bias
3. Light + Flat + Arc
4. Light + Flat + Arc + Arc Flat
5. Light + Flat + Arc + Arc Bias
6. Light + Flat + Bias + Arc + Arc Flat
7. Light + Flat + Bias + Arc + Arc Bias
8. Light + Flat + Bias + Arc + Arc Flat + Arc Bias

An example diagnostic pdf:

2.5.2 2. Spectral Extraction

After the images are flattened and reconstructed, the '*gmosspectral_extraction.py*' can be executed with another YAML parameter file for the spectral extraction configuration. For the purposes of quicklook, most of the parameters can be kept untouched. The paths have to be changed accordingly in order to extract the spectra properly. Mismatched binnings could be handled by automatically up/downsampling the flat/bias frames. However, even when mismatched

instruments (North/South) and mismatched gratings can allow the output of a reduced spectrum, the pipeline is not checking all the cases whether the input combination makes sense.

With only Science FITS file

Extraction will be performed and only the ADU as a function of pixel can be produced.

With only Science and Arc FITS files

Extraction will be performed and only the ADU as a function of wavelength can be produced.

With only Science, Standard and one of Science or Standard Arc FITS files

Extraction will be performed on both the science and standard spectra. The arc will be used for wavelength calibration for both frames. Wavelength and flux will be calibrated.

With Science, Science Arc, Standard and Standard Arc FITS file

Extraction will be performed on both the science and standard spectra. The respective arc will be used for wavelength calibration for the respective frames. Wavelength and flux will be calibrated.

The different combinations of available frames from the fieldflattening will give different sets of final products, they will be one of the following five scenarios:

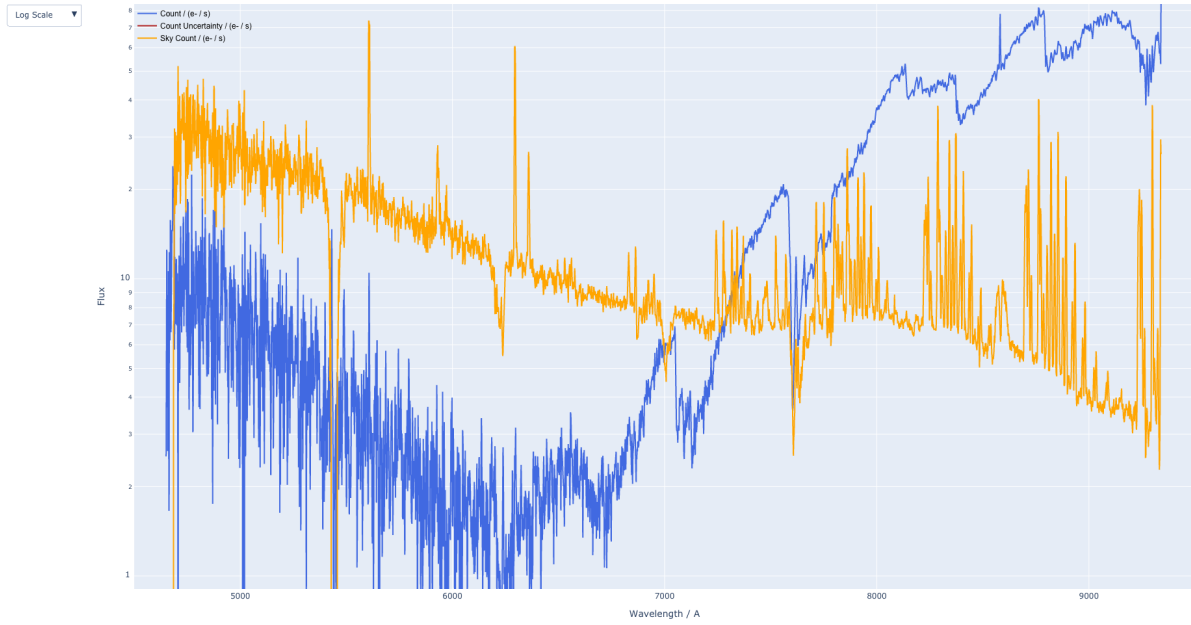
Table 2: Data Product

Case	Input	Output
1	Science	ADU(pixel)
2	Science + Arc	ADU(wavelength)
3	Science + Arc + Sensitivity Curve	Flux(wavelength) from pre-saved sensitivity curve, though it may not provide a good SED, it should be good enough for quick inspection. Need to be careful to select the right combination of grating and central wavelength.
4	Science + Arc + Standard	Flux(wavelength) with the potential in getting better absolute flux calibration, if a bad standard is used, the quality will be lower than (3)
5	Science + Arc + Standard + Standard Arc	Flux(wavelength) with the potential in getting better absolute flux calibration, if a bad standard is used, the quality will be lower than (3)

- If sensitivity file is provided, (4) & (5) will reduced to (3).
- Without Arc, sensitivity file cannot be used, it will remain as case (1).

An example output html of the extracted spectrum (click for the interactive display in a new tab):

Log scale



CHAPTER 3

Indices and tables

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