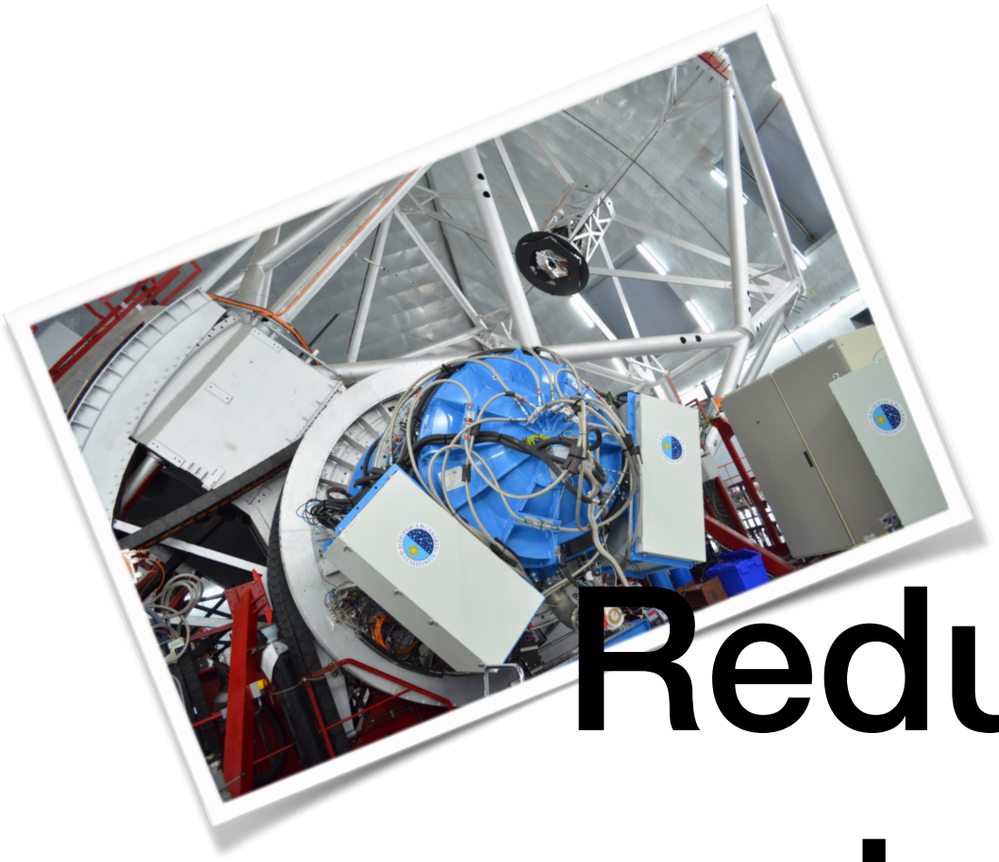
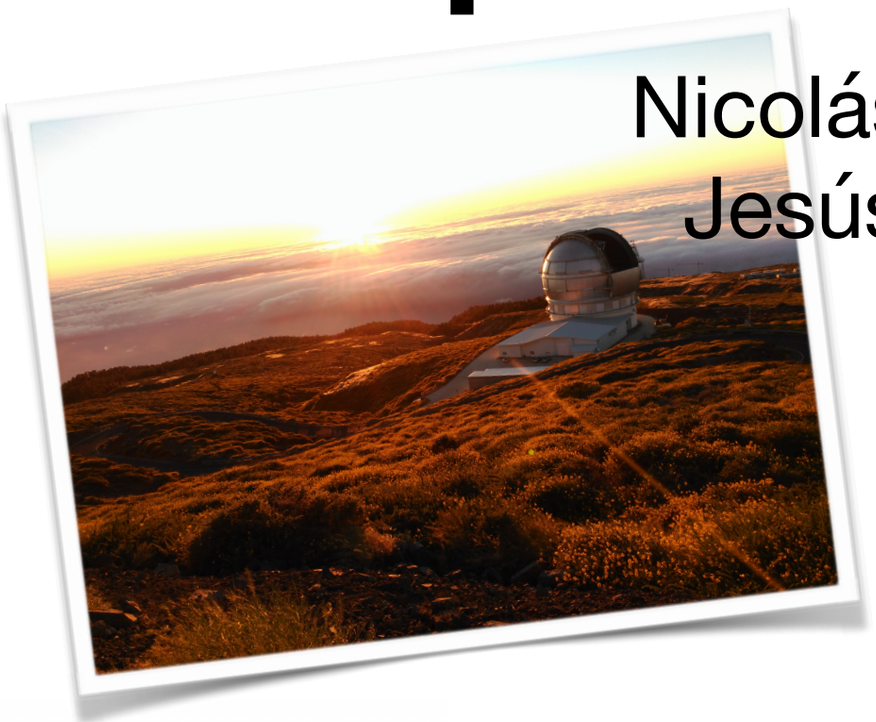




Reducing EMIR spectroscopic data

Nicolás Cardiel, Sergio Pascual
Jesús Gallego, Pablo Picazo
UCM





RED DE INFRAESTRUCTURAS DE ASTRONOMIA

EMIR@GTC: aprendiendo a usarlo

Reducing EMIR spectroscopic data with pyemir

RAW DATA

pyemir →

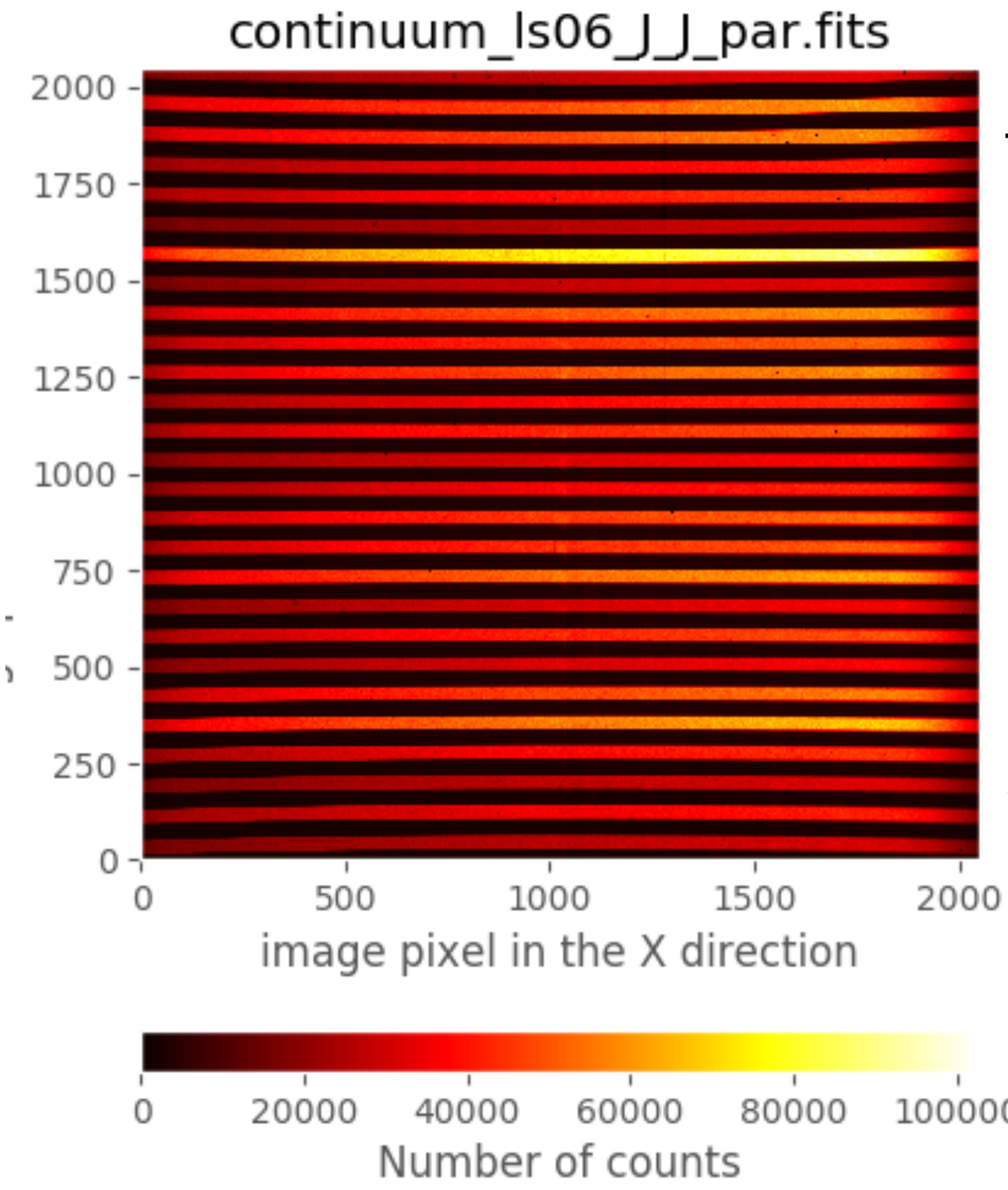
- Subtraction of consecutive images
- Flatfielding
- Application of bad-pixel mask
- Rectification and wavelength calibration

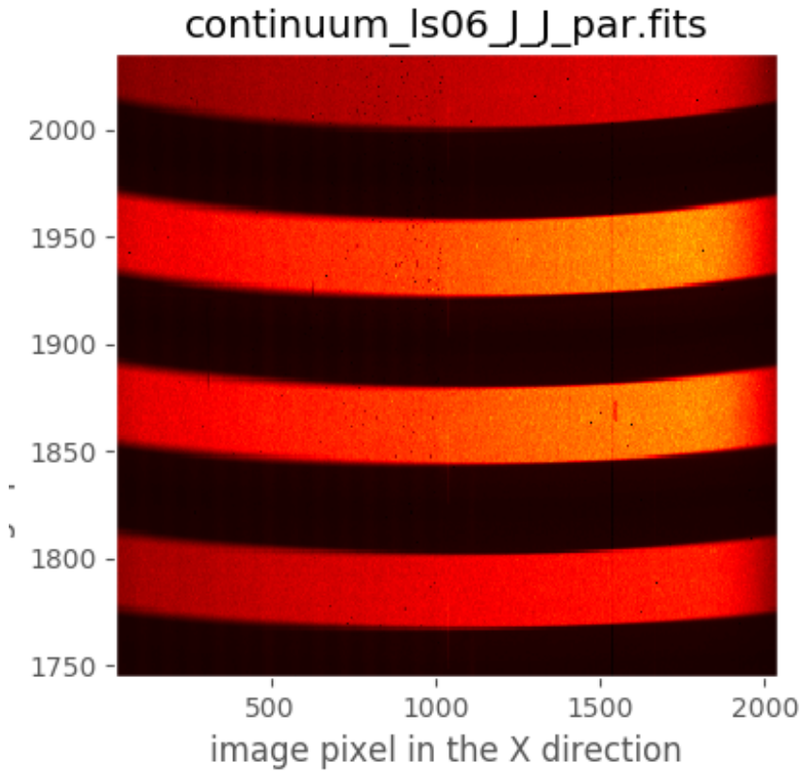
RECTIFIED AND WAVELENGTH CALIBRATED 2D IMAGE

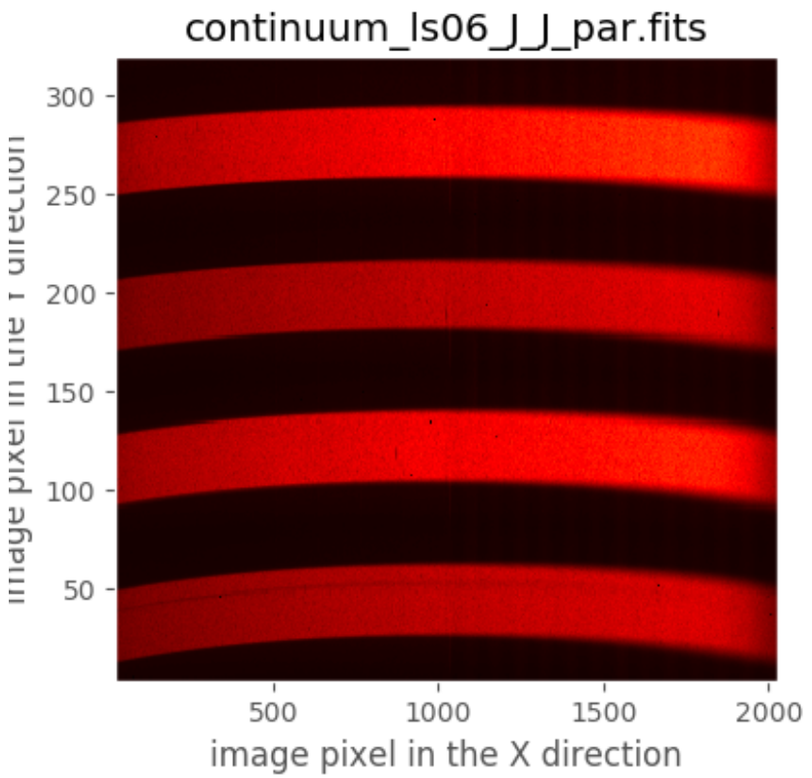
auxiliary scripts, python, iraf, idl, midas, …

SCIENTIFIC PAPER

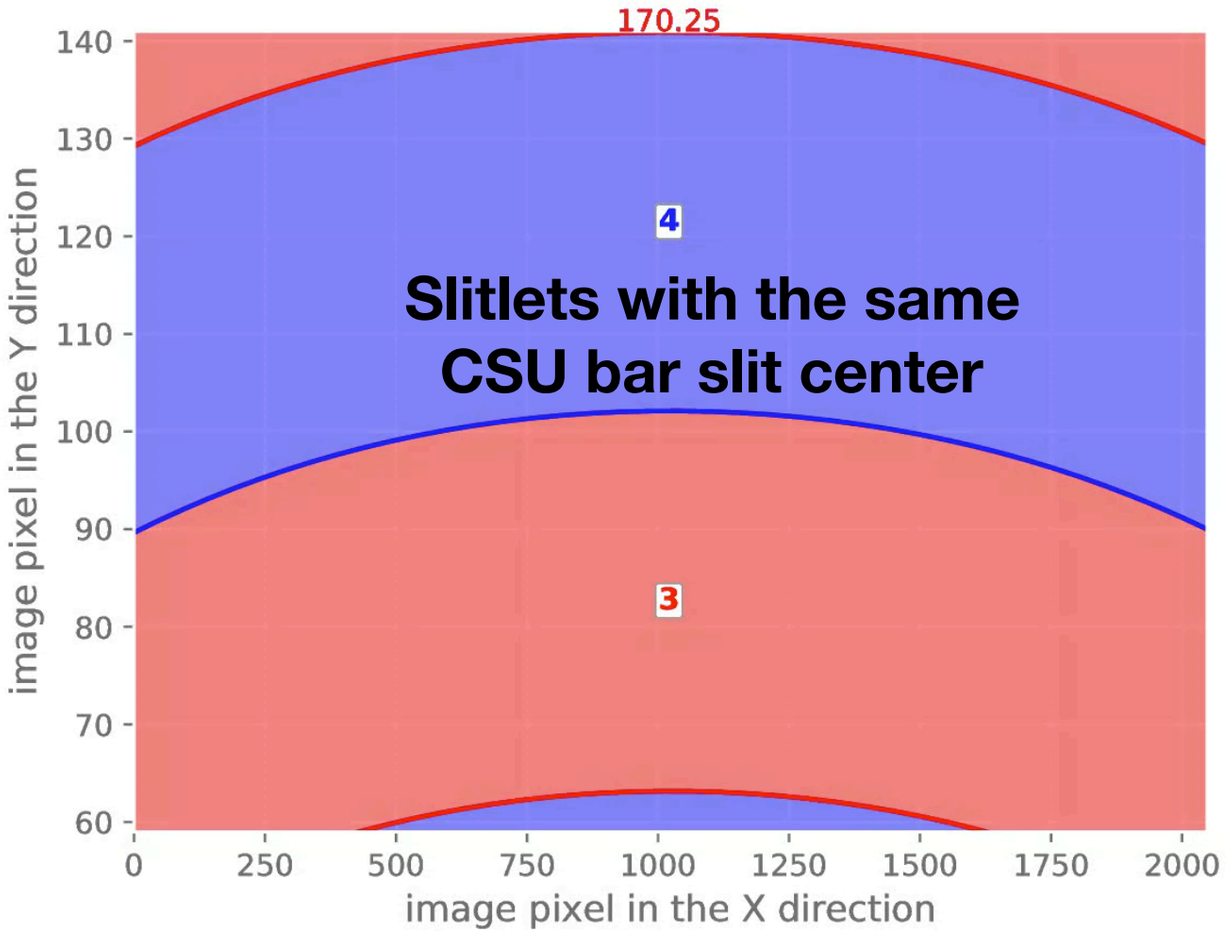
Understanding the data: image distortions

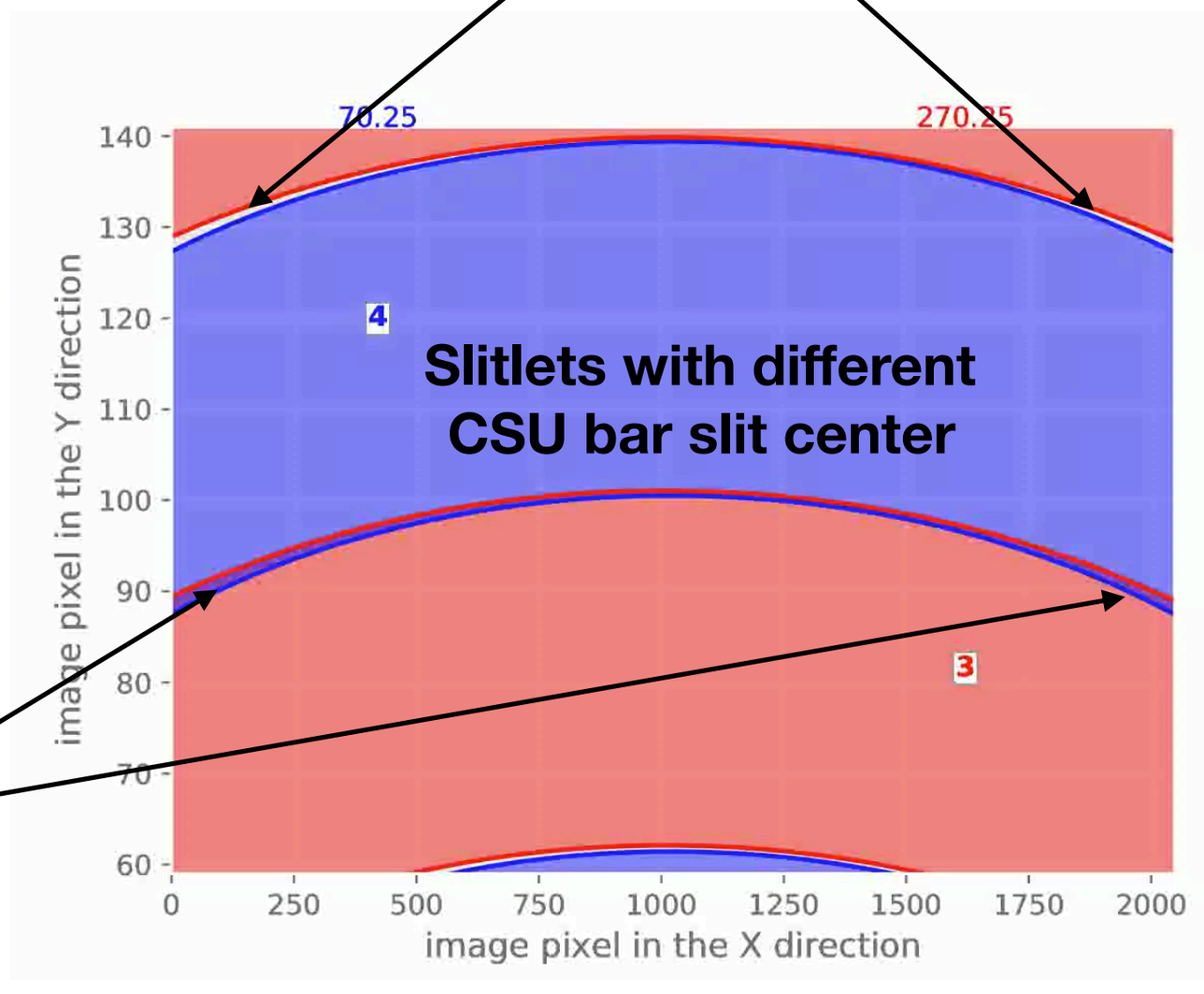




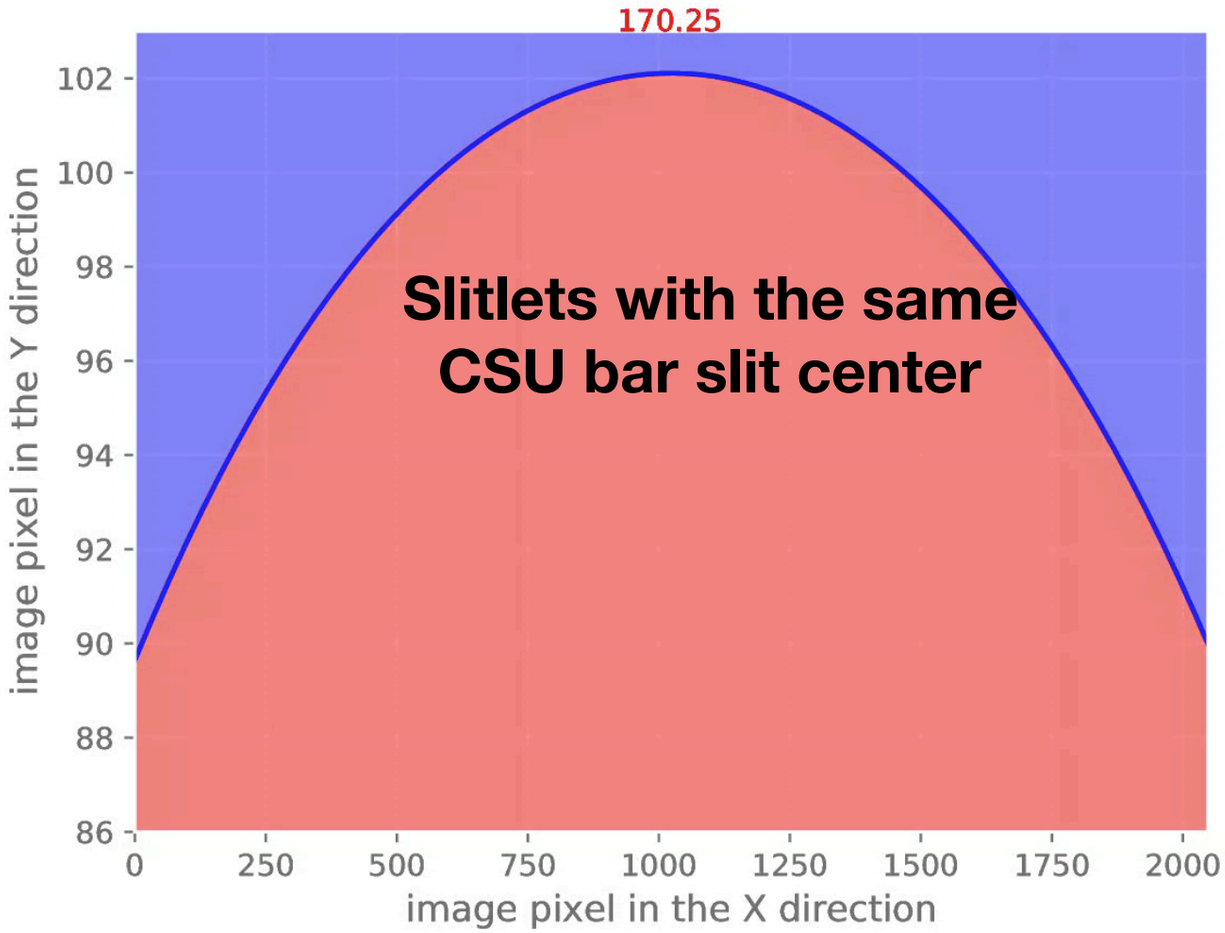


Understanding the data: image distortions

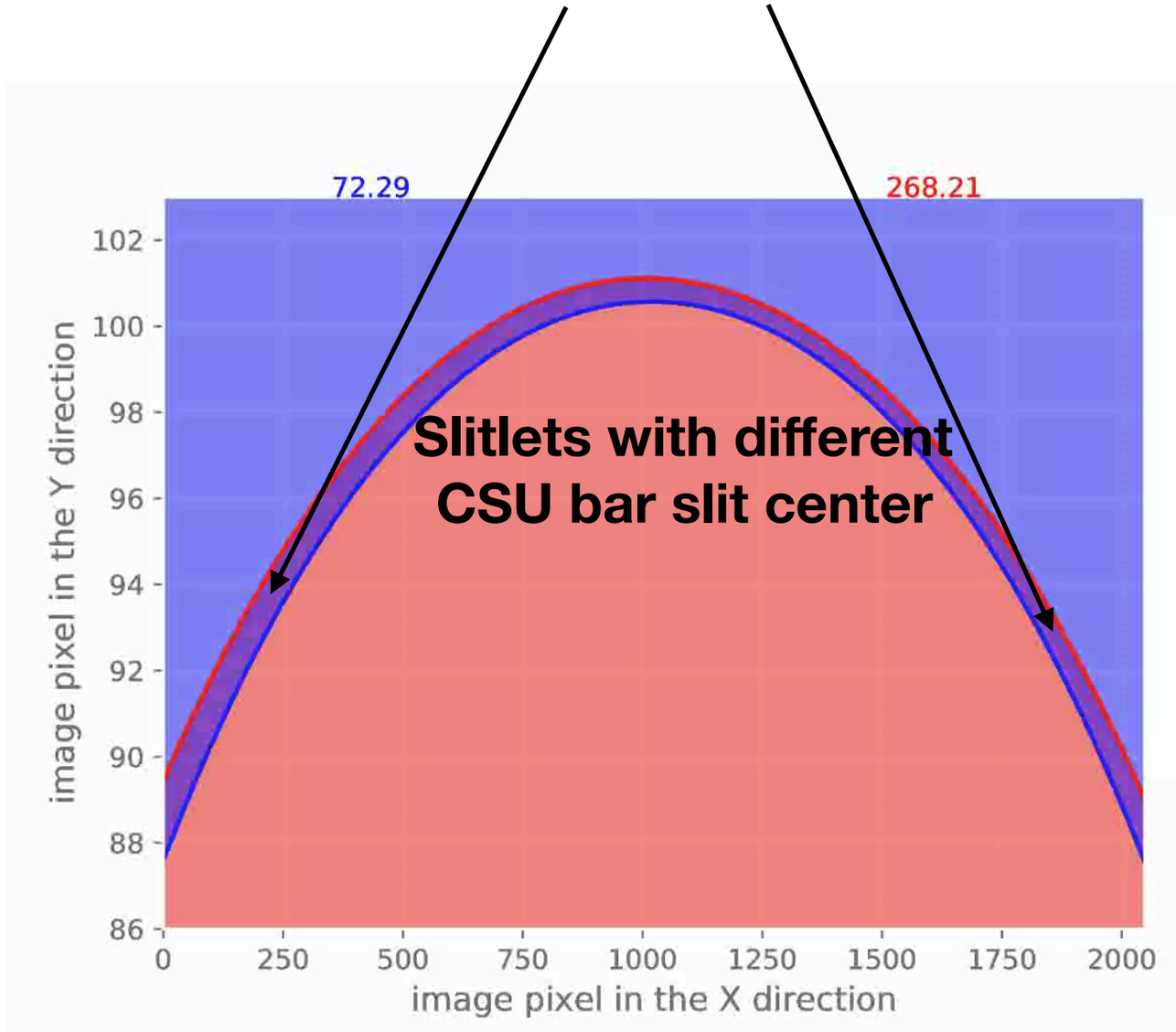




Understanding the data: image distortions



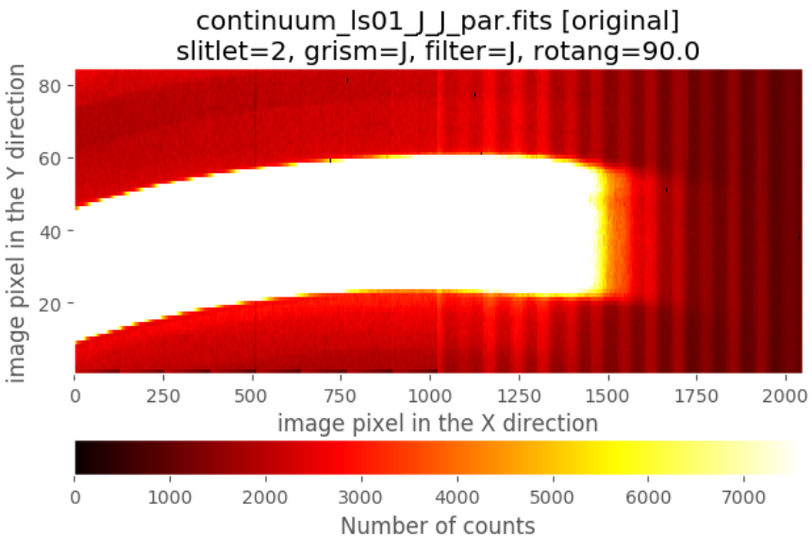
boundary overlapping region enlarged

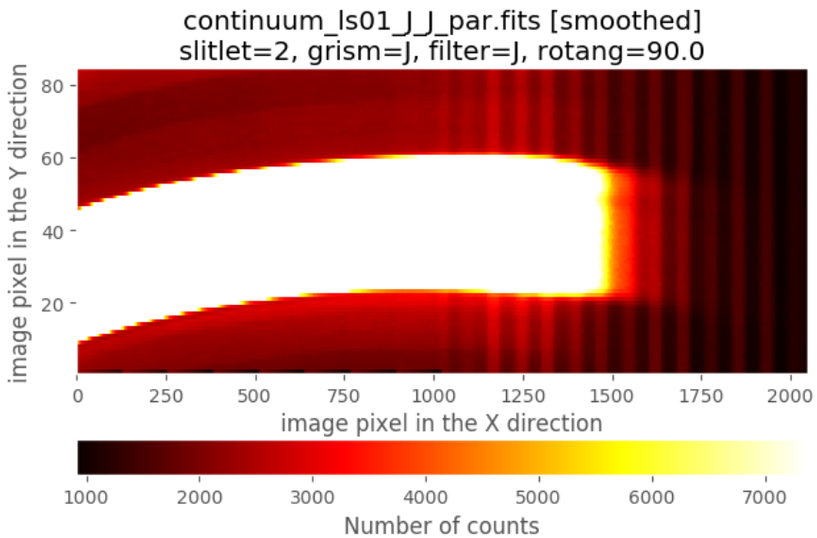


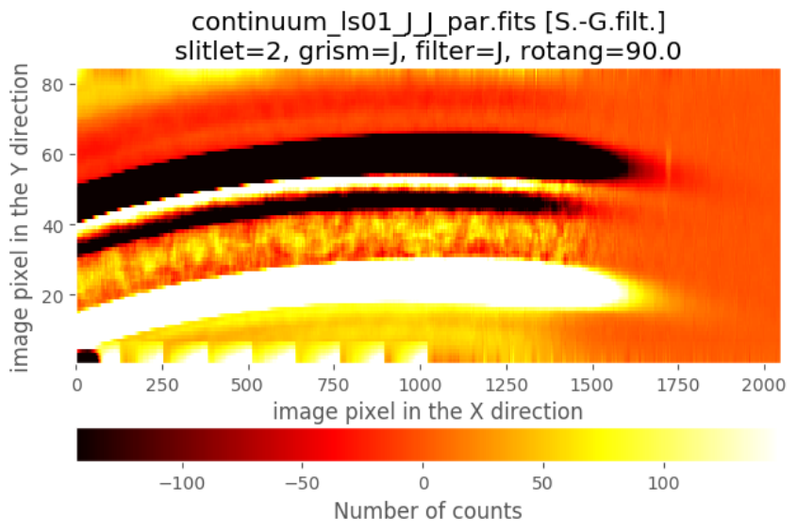
Computing the slitlet boundaries

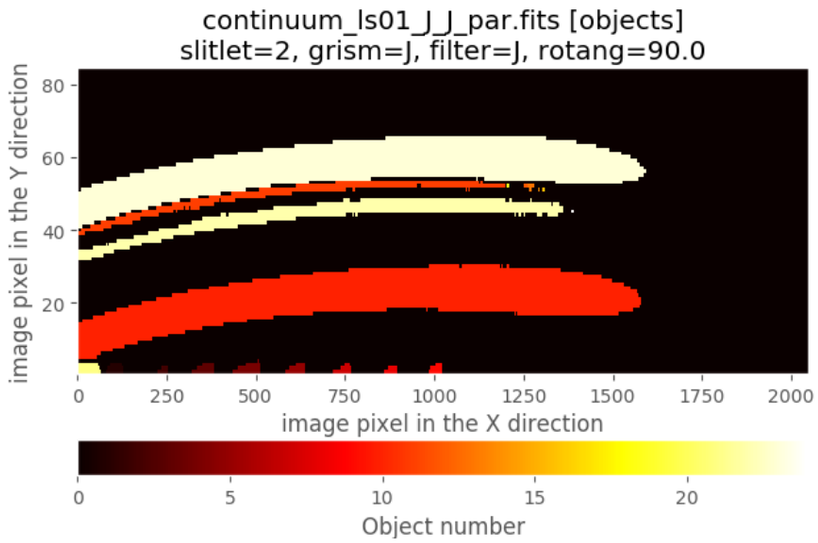
```
% pyemir-slitlet_boundaries_from_continuum -parmodel longslit
```

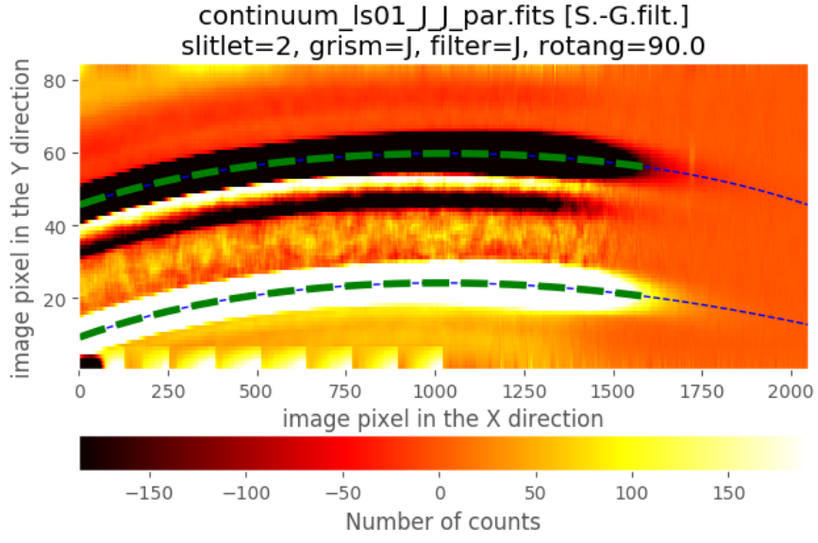
```
output: bounddict_grism_J_filter_J_ls01.json
```












```
% pyemir-fit_boundaries
```

```
output: fitted_bound_param_grism_J_filter_J_ls01.json
        ds9_bounddict_ls01.reg
        ds9_fittedpar_ls01.reg
```

Computing the slitlet boundaries

```
% 02_plot_param_vs_slitcenter.ipynb
```


Image distortion parameters as a function of csu_bar_slit_center (fitting **independently** the 10 free parameters using 11 longslits configurations)

```
output: multislit_param_grism_J_filter_J.json
```

Computing the slitlet boundaries

```
% pyemir-merge_boundict_files
% pyemir-slitlet_boundaries_from_continuum –parmodel multislit
```

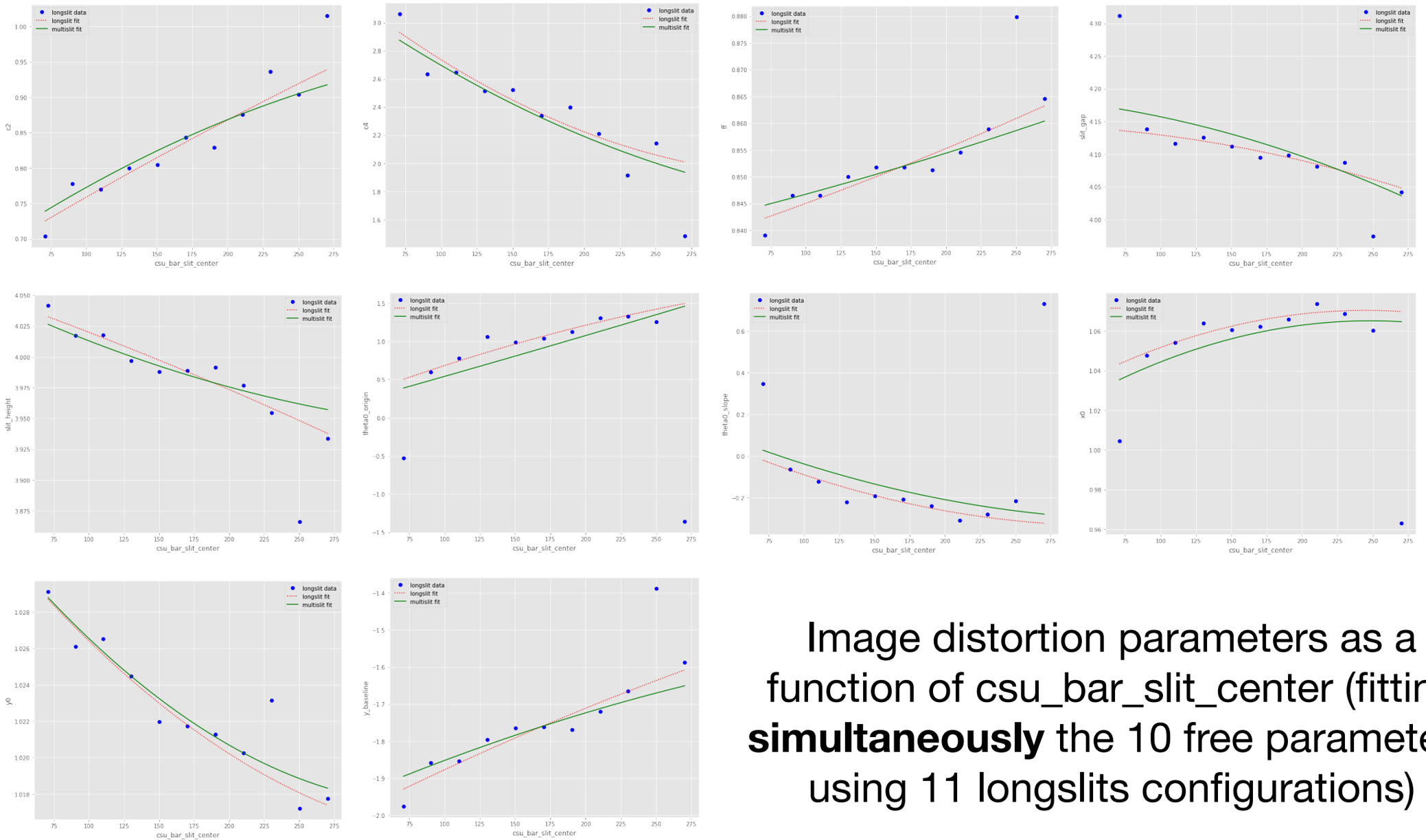


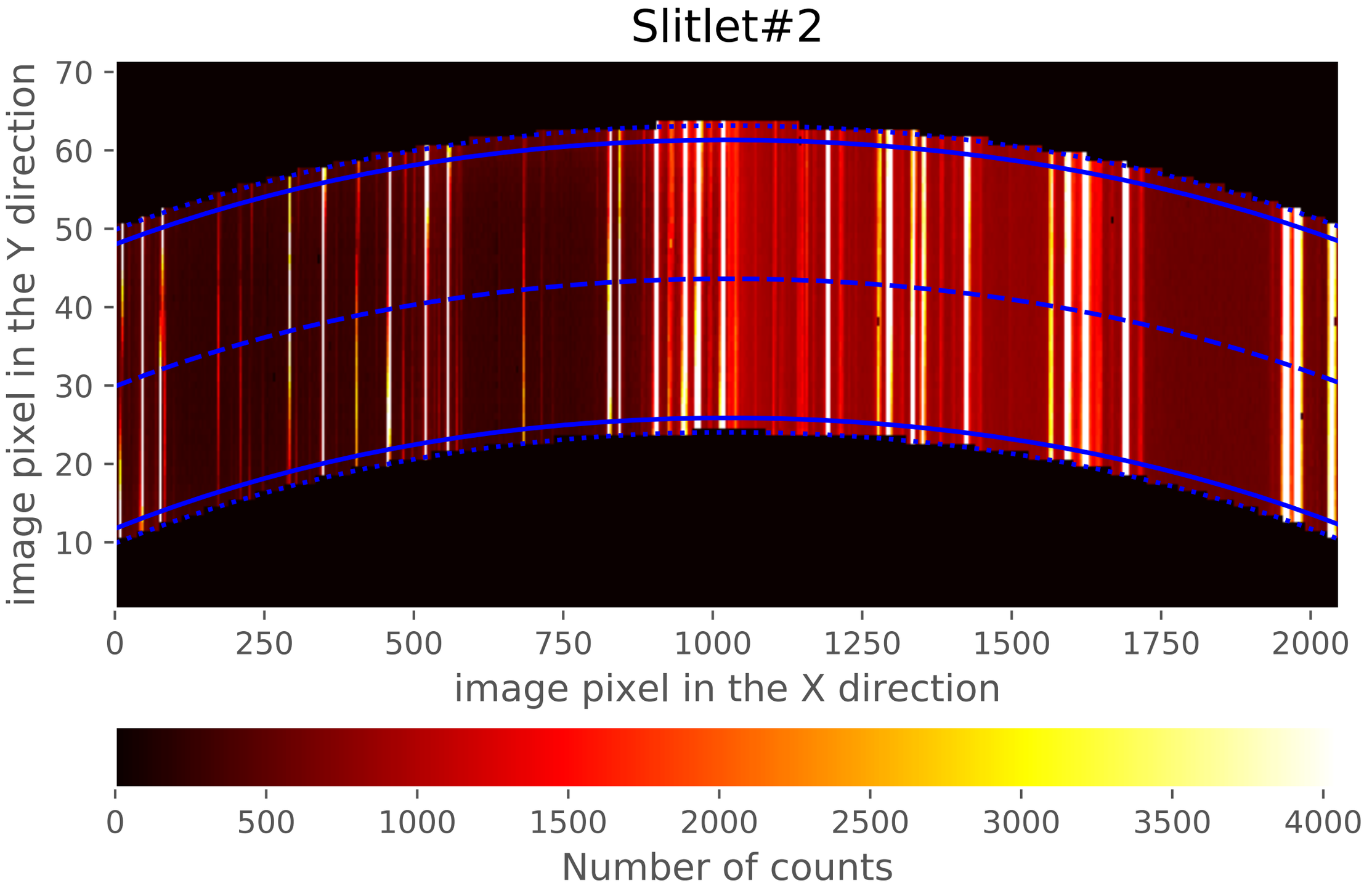
Image distortion parameters as a function of csu_bar_slit_center (fitting **simultaneously** the 10 free parameters using 11 longslits configurations)

```
output: refined_multislit_param_grism_J_filter_J.json
```

Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```

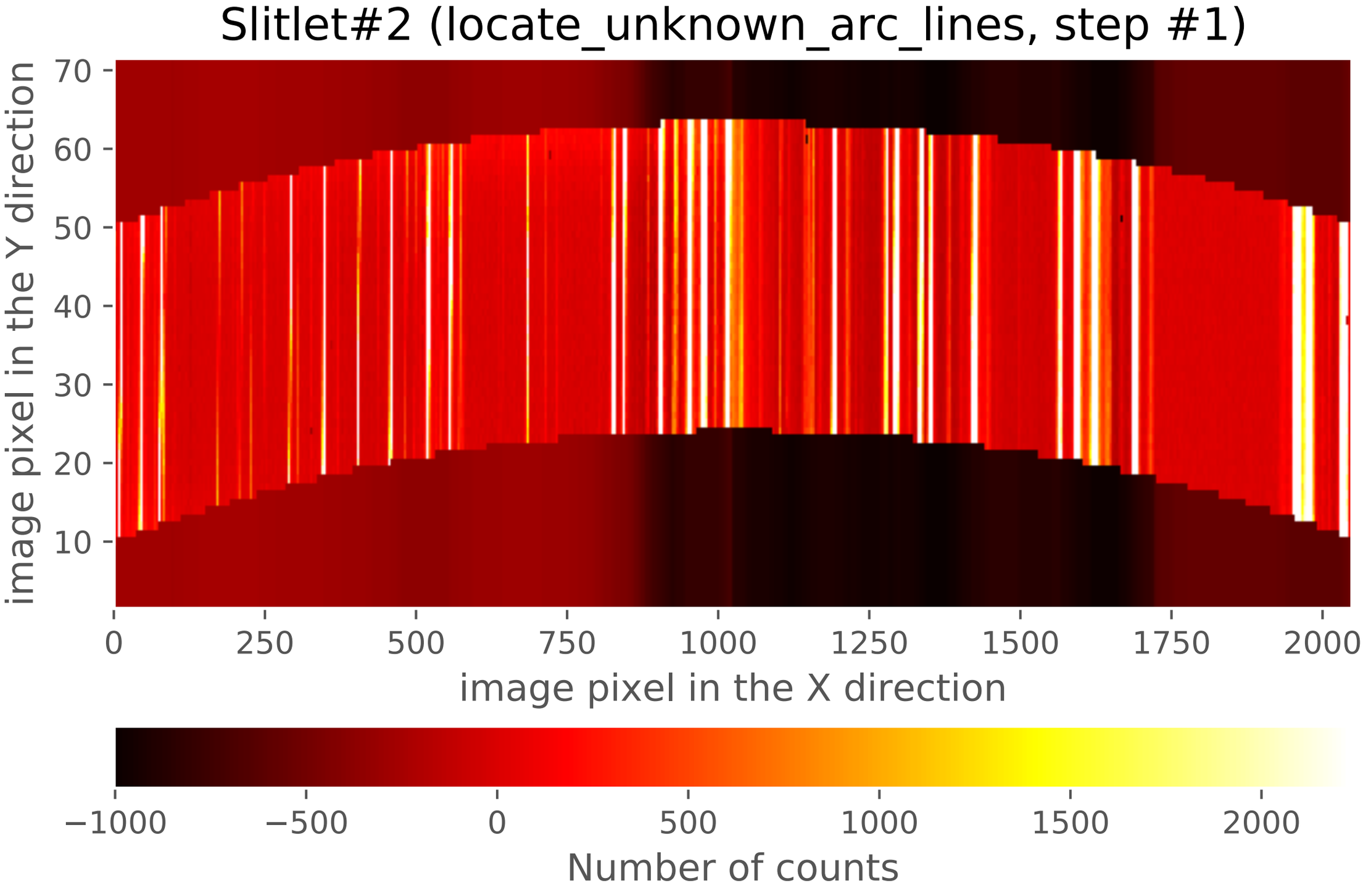
slitlet selection



Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```

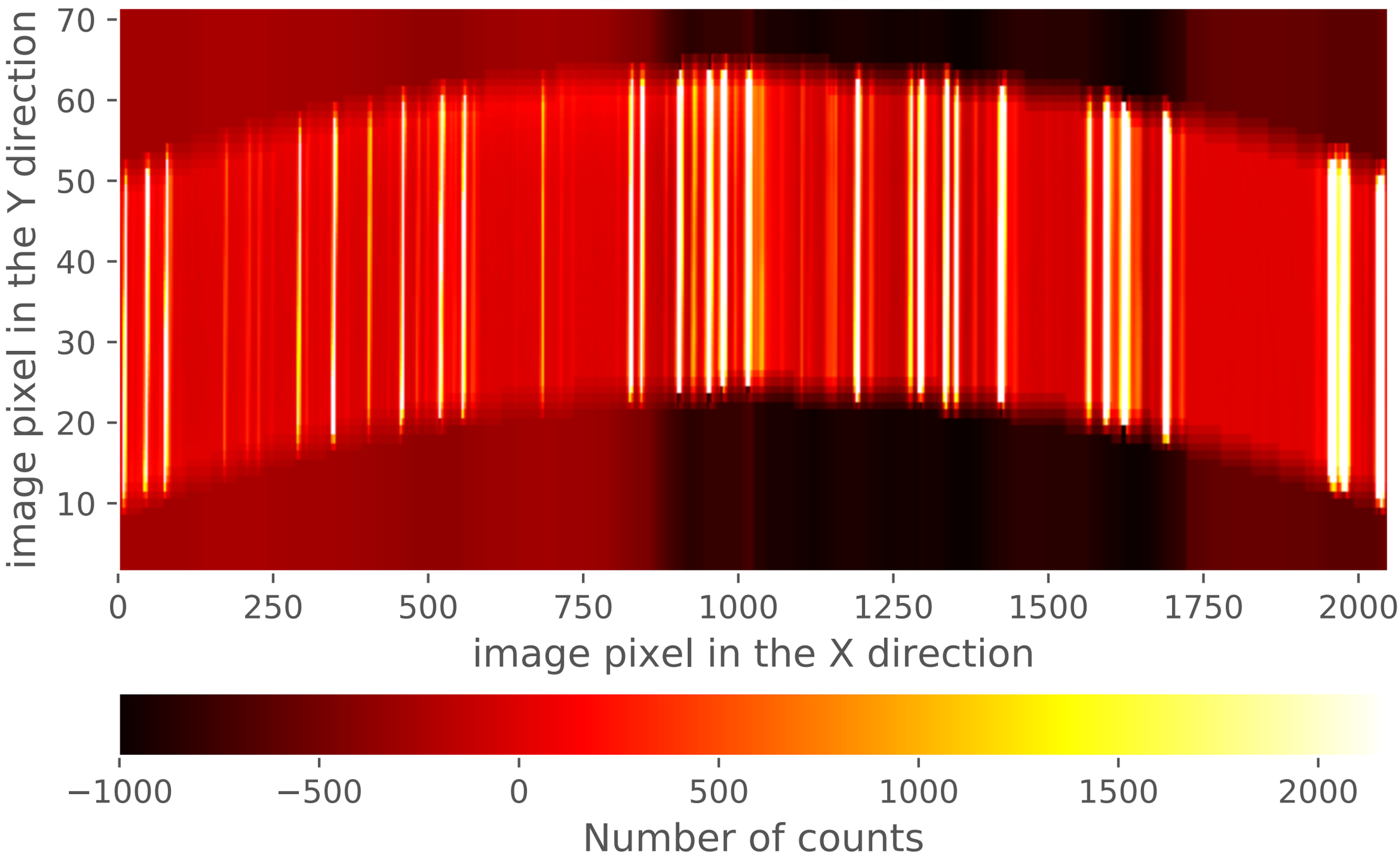
background removal



Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```

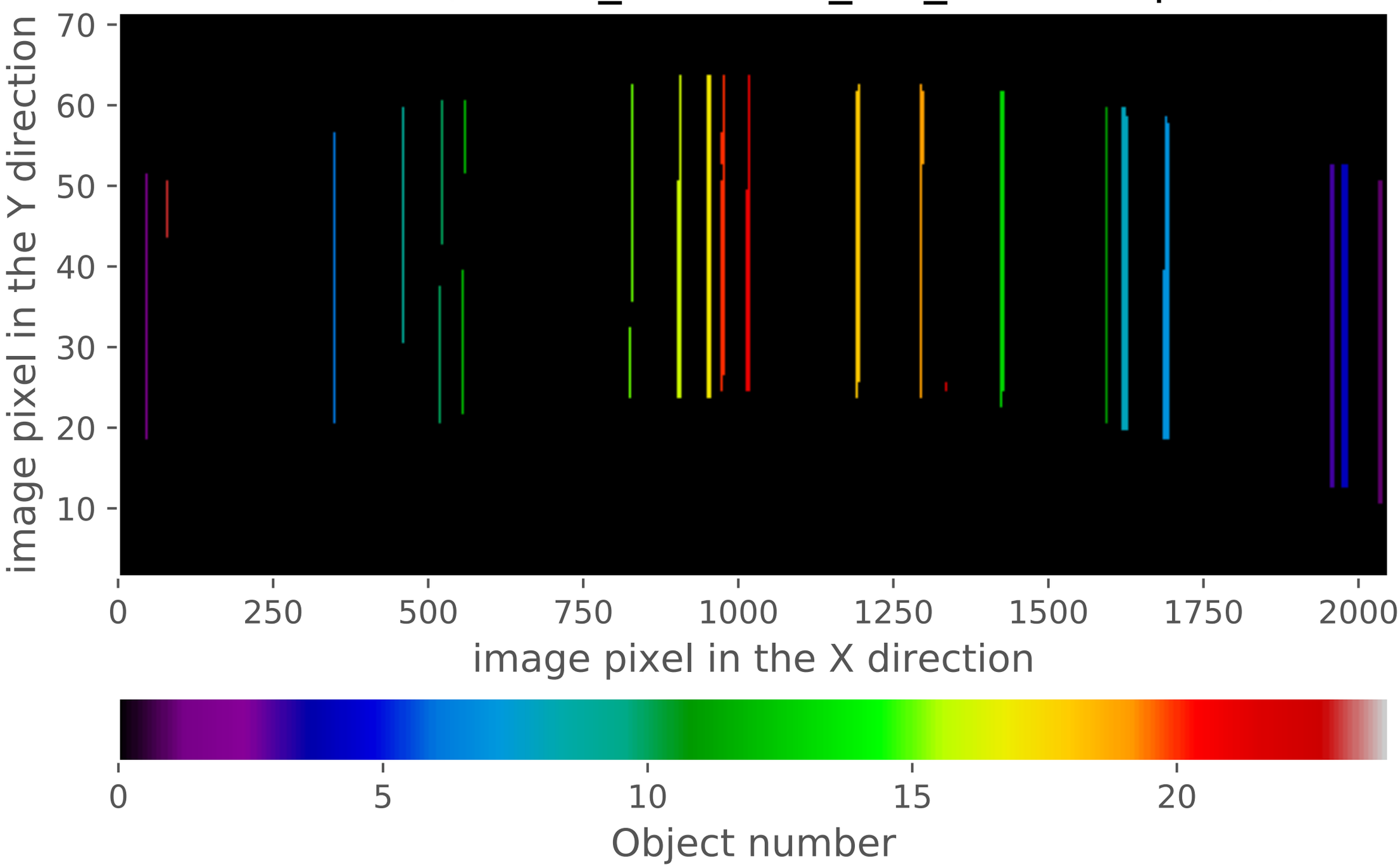
image smoothing



Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```

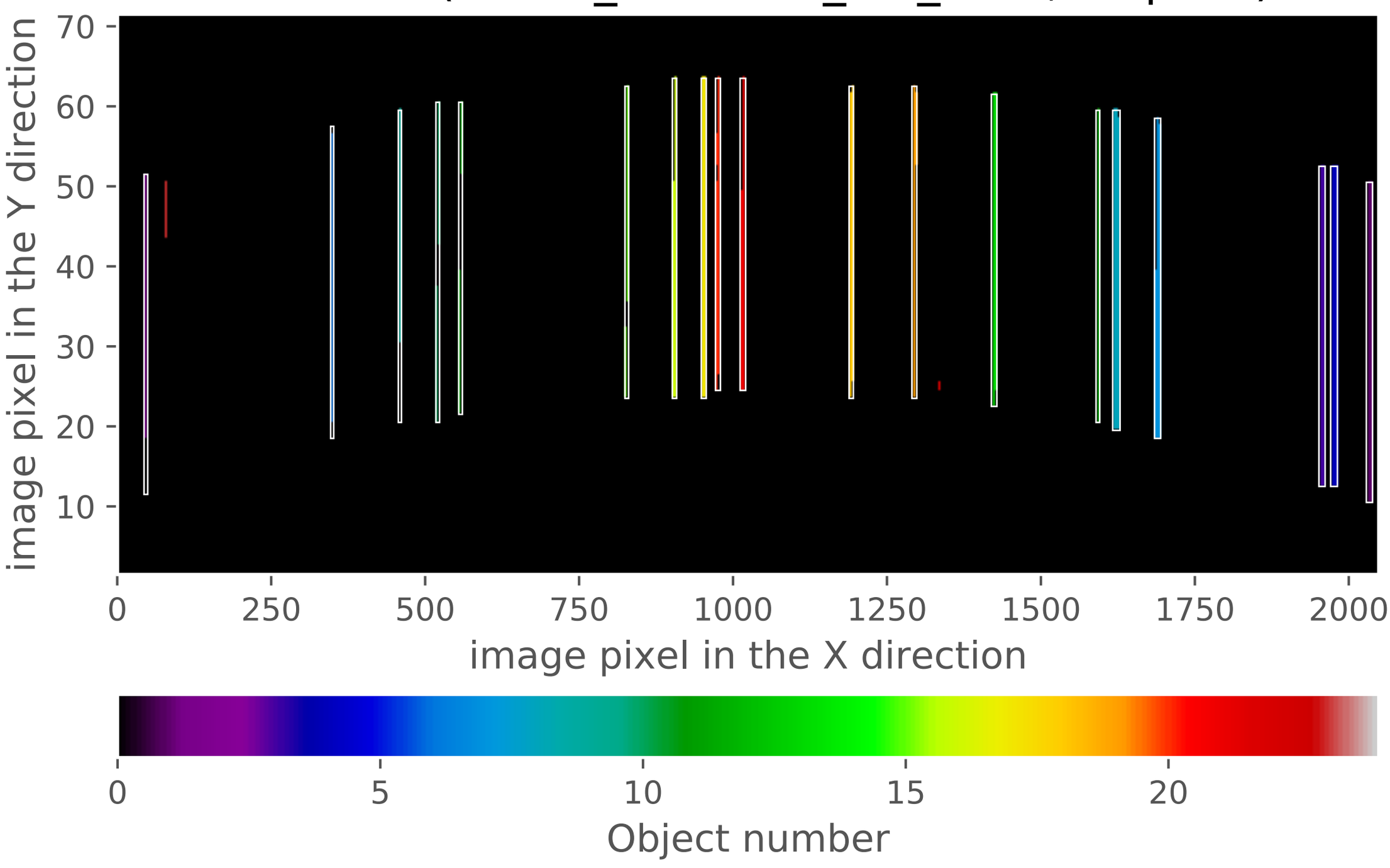
arc line detection



Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```

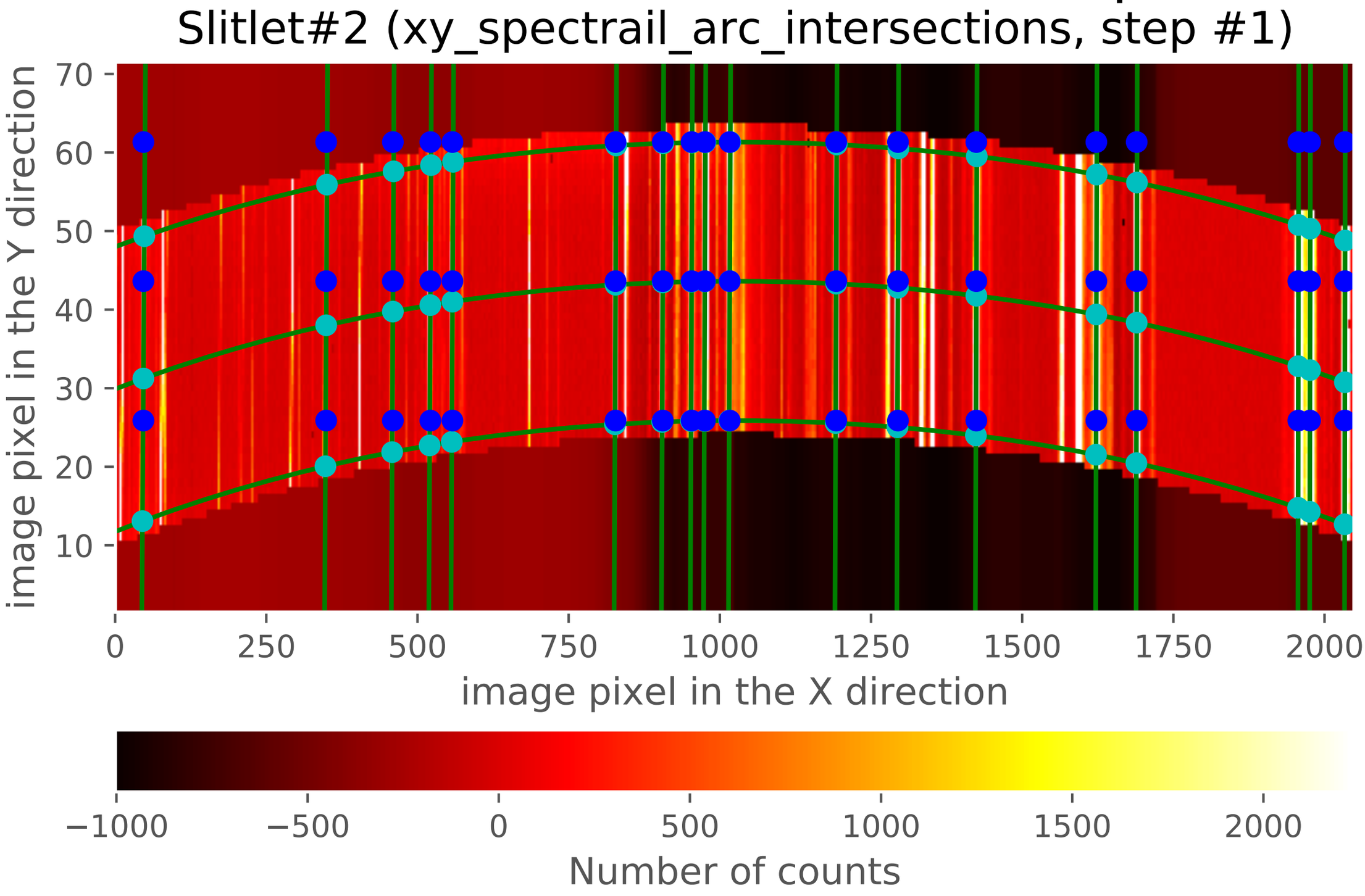
arc line bounding box



Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```

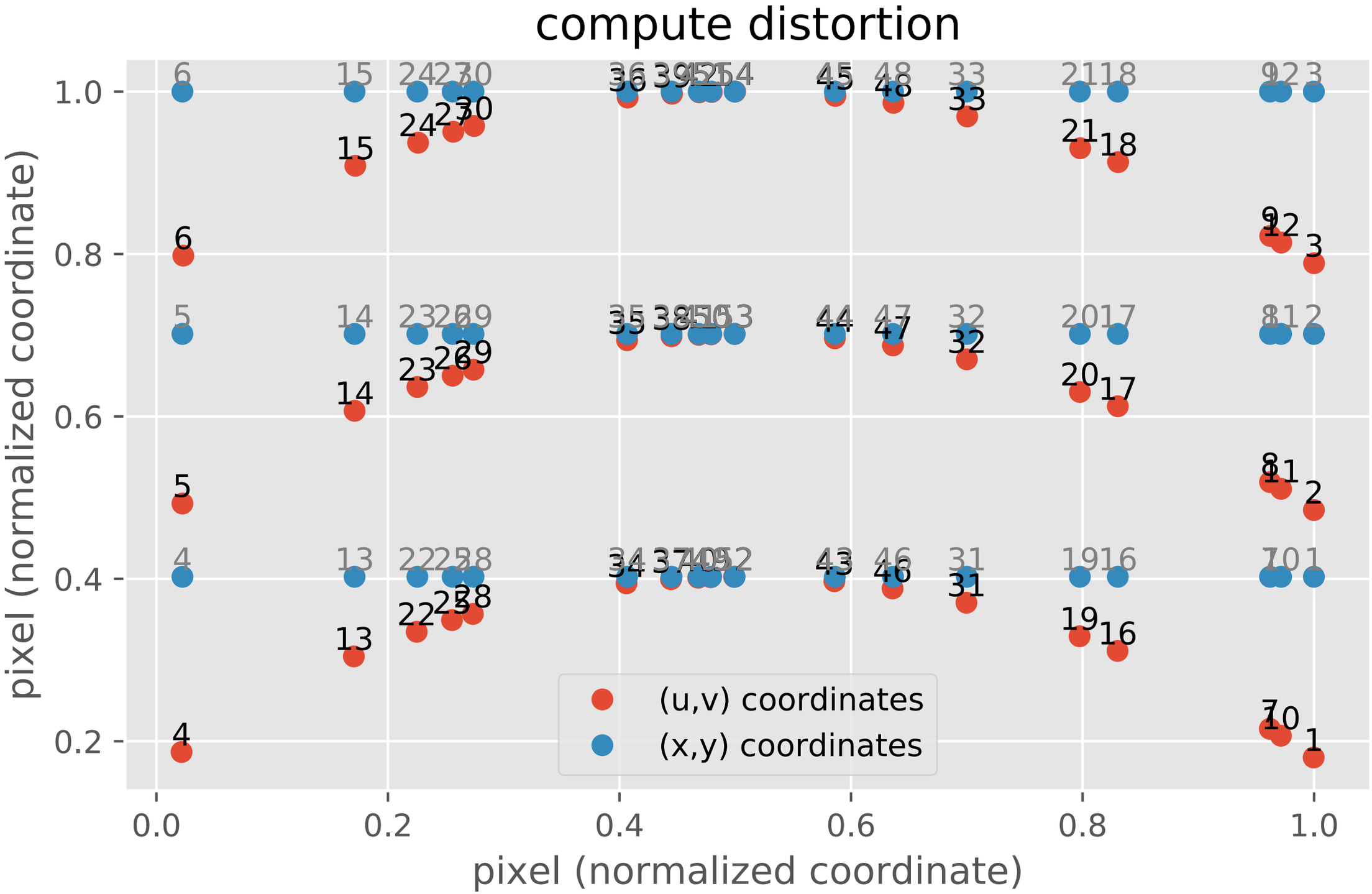
intersection between arc lines and spectral trails



Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```

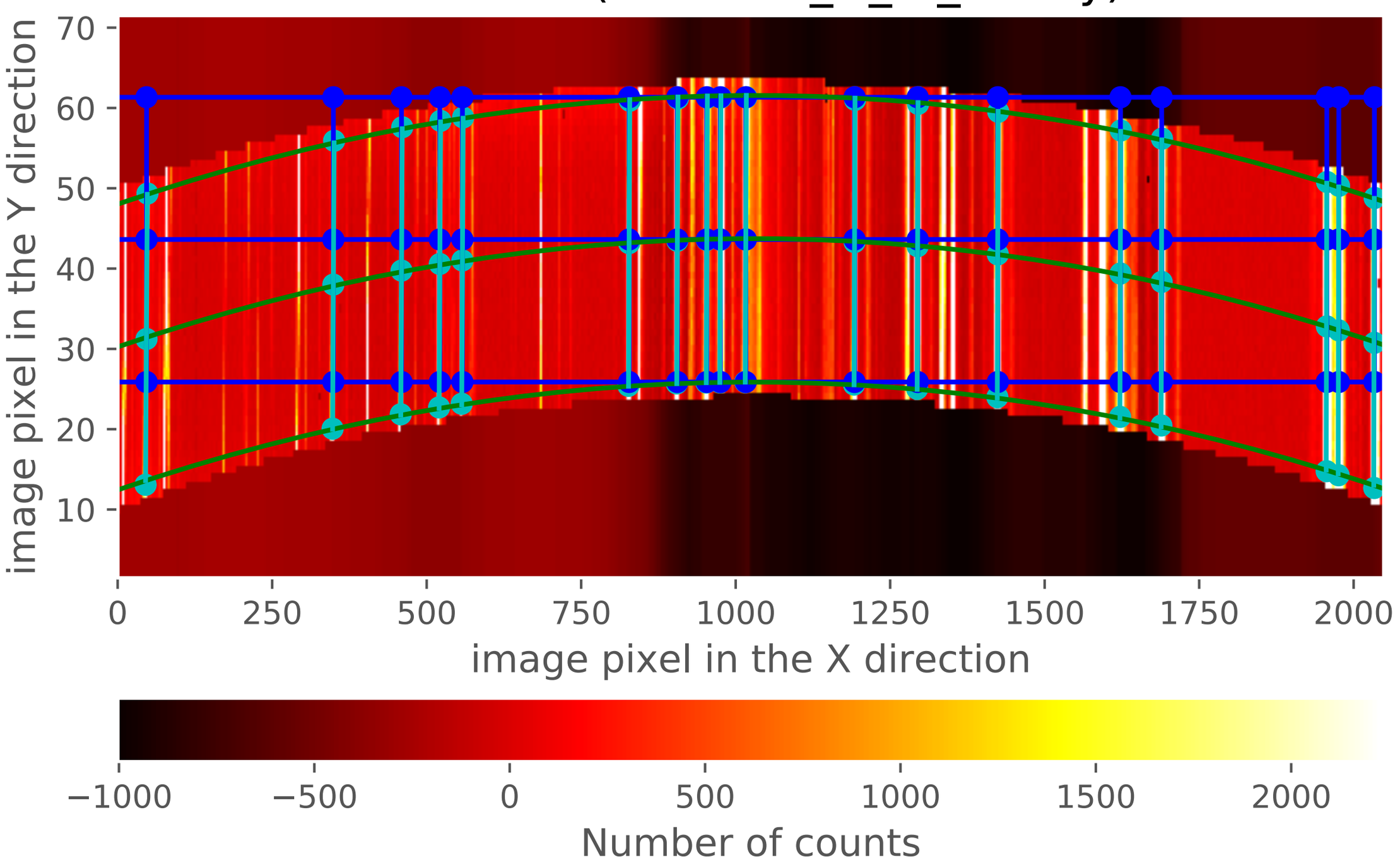
reference points for rectification



Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```

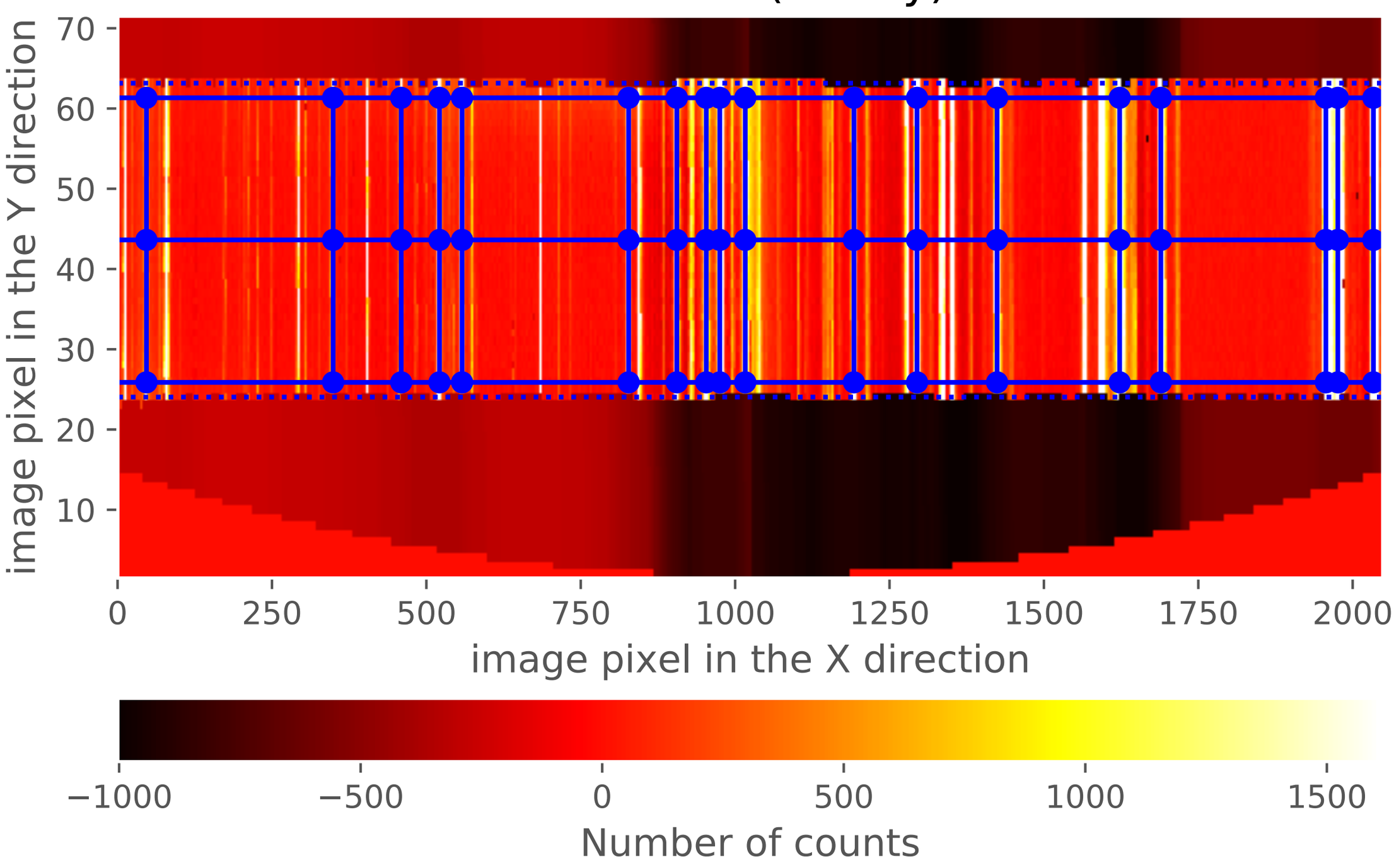
rectification transformation computation



Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```

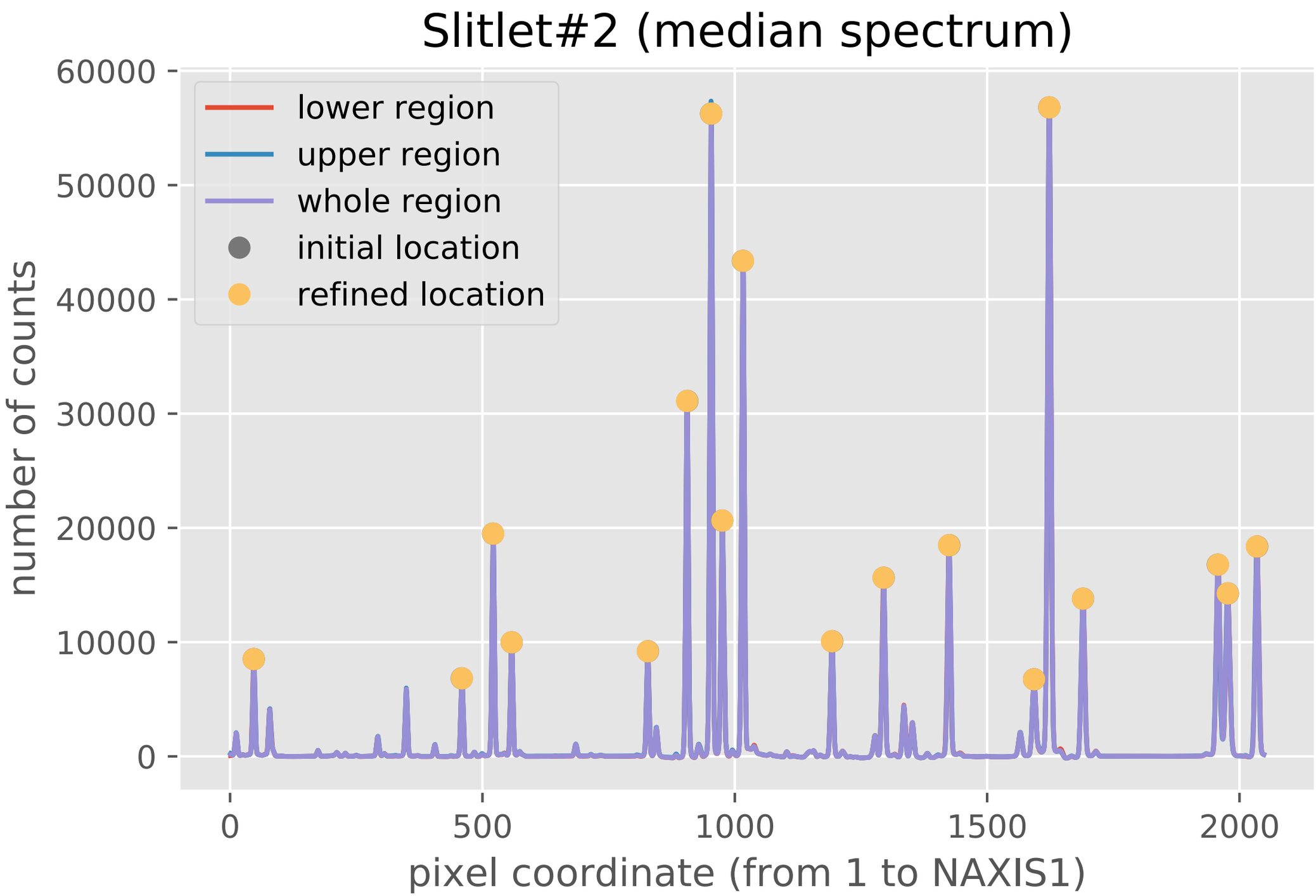
slitlet rectification



Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```

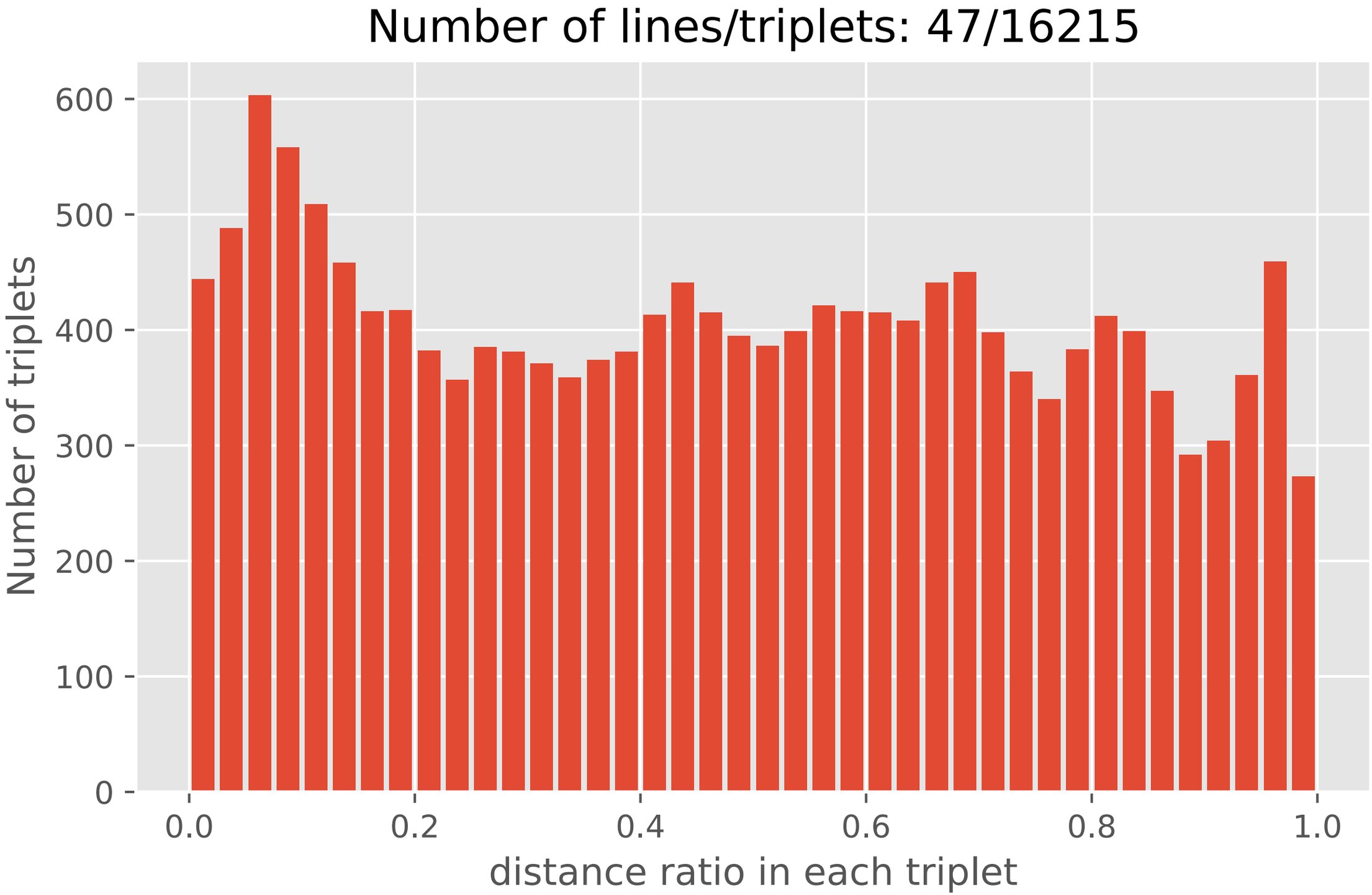
peak detection



Rectification and wavelength calibration

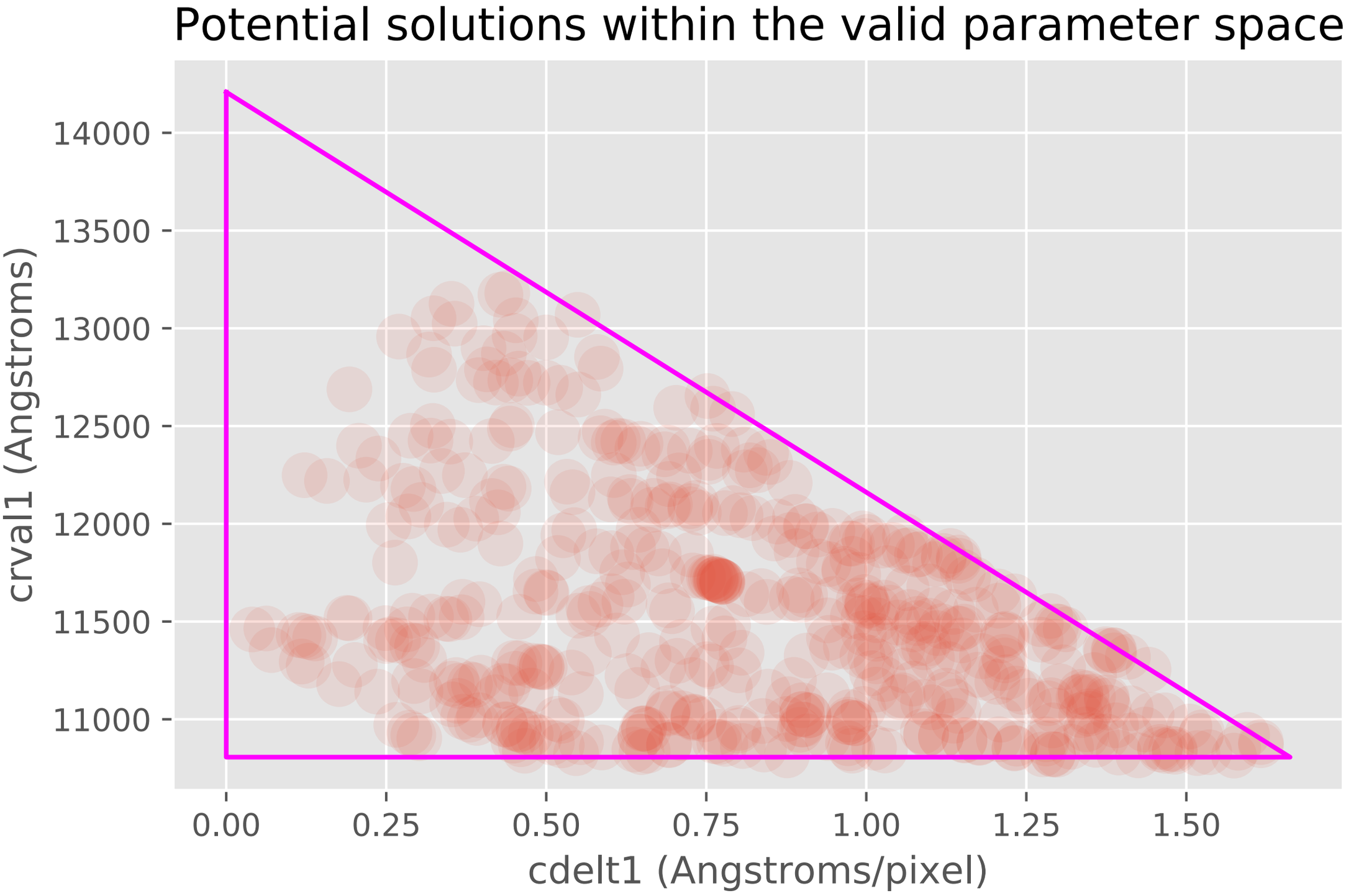
```
% pyemir-rect_wpoly_from_longslit
```

pattern matching with line triplets



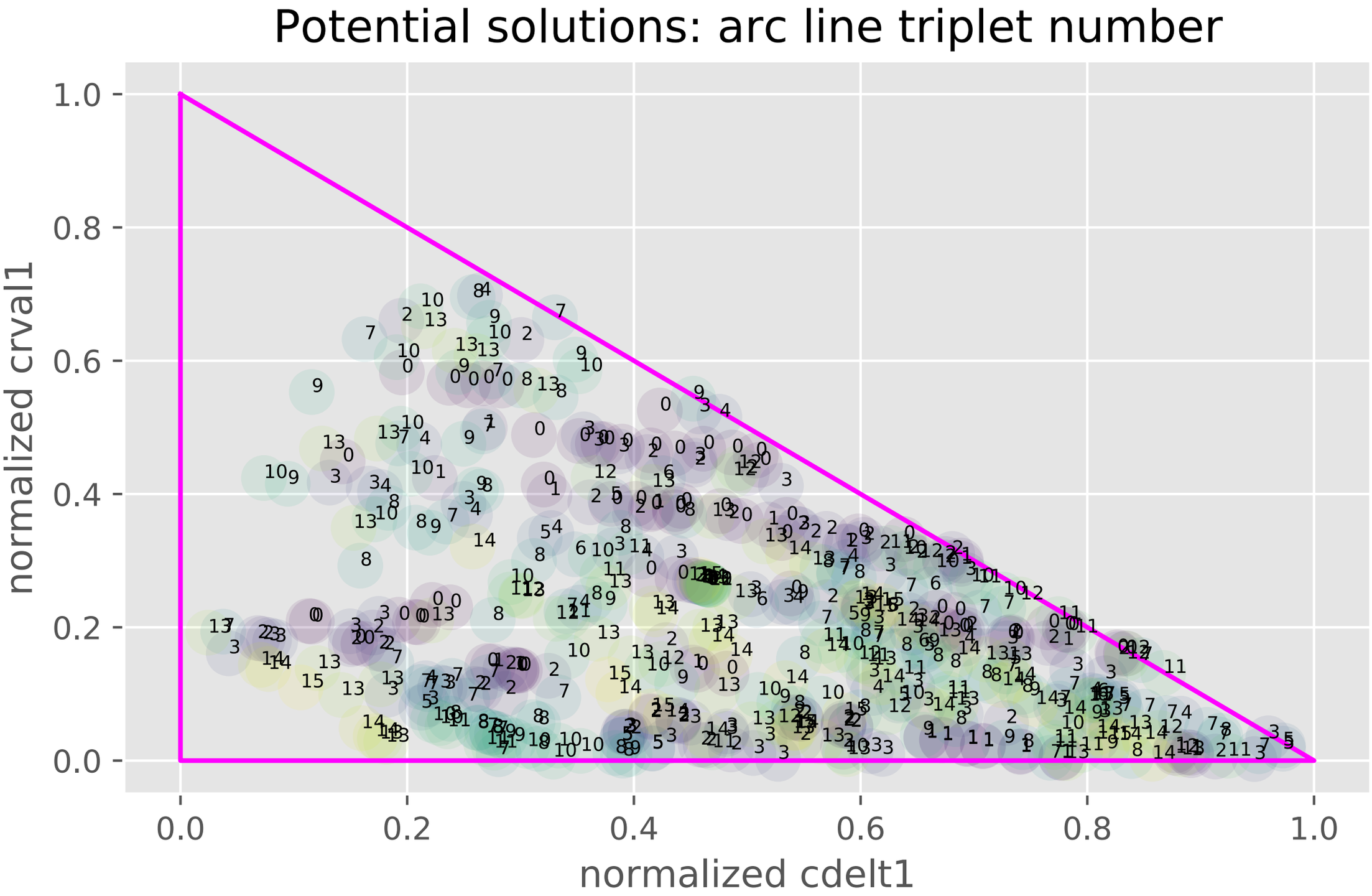
Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```



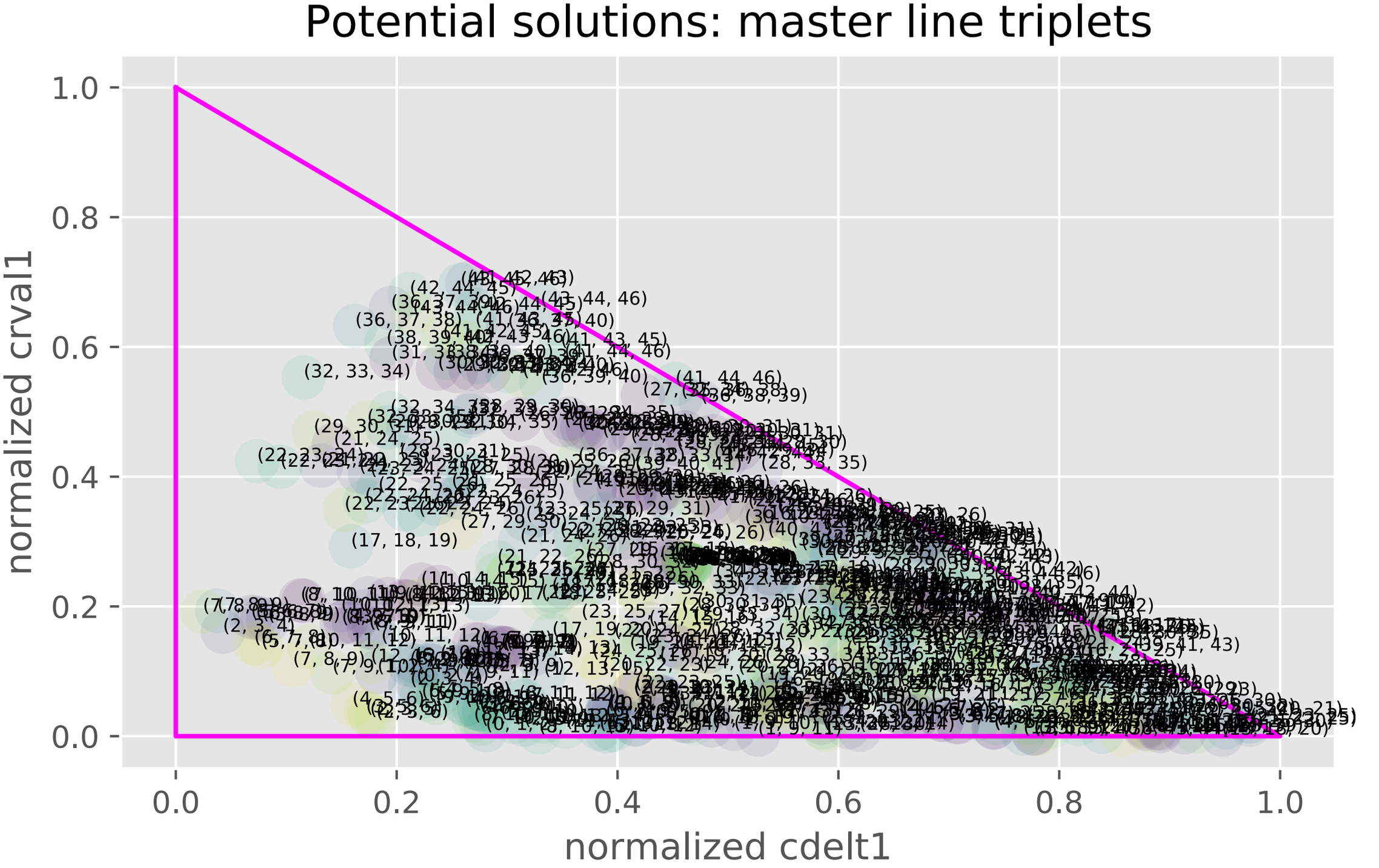
Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```



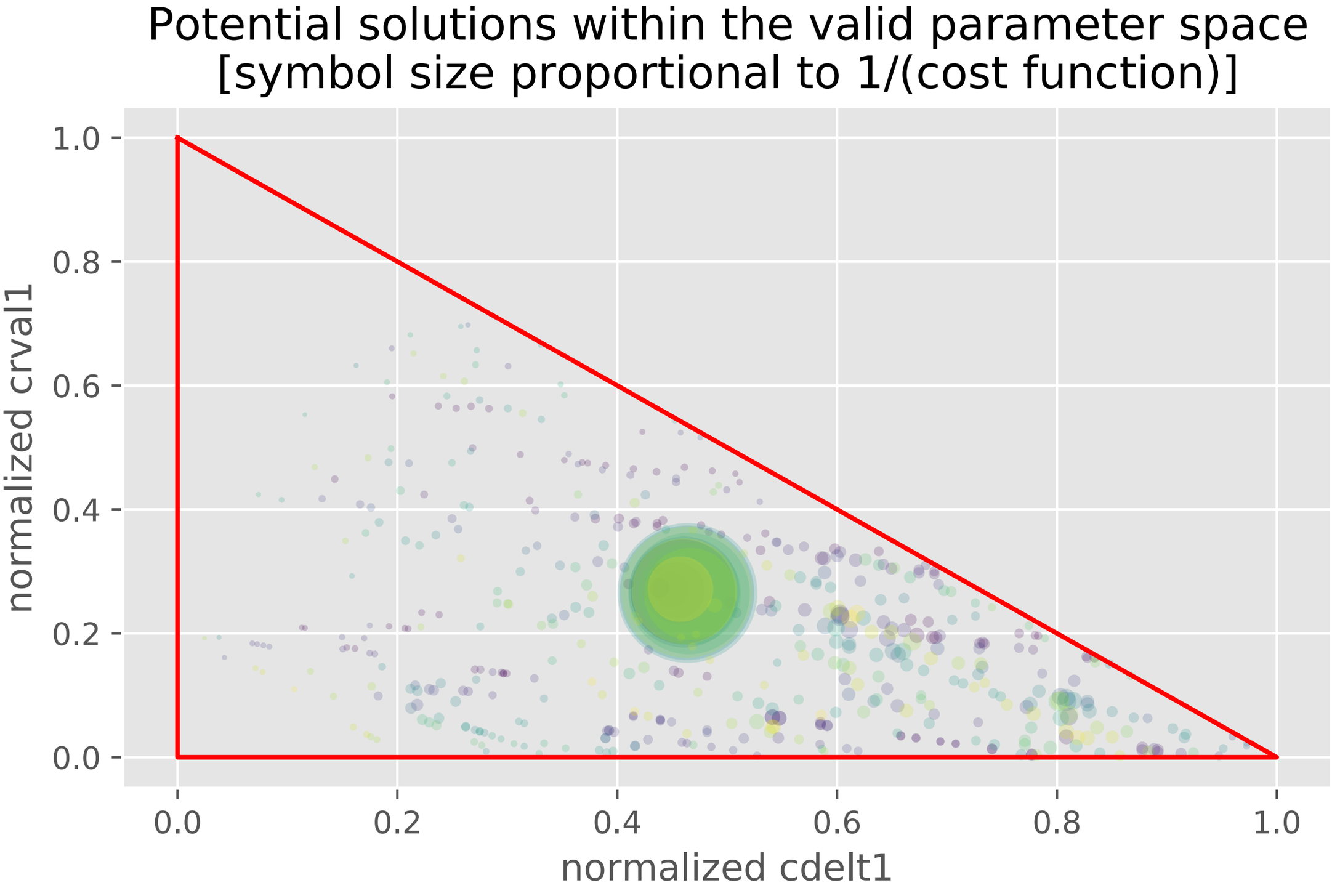
Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```



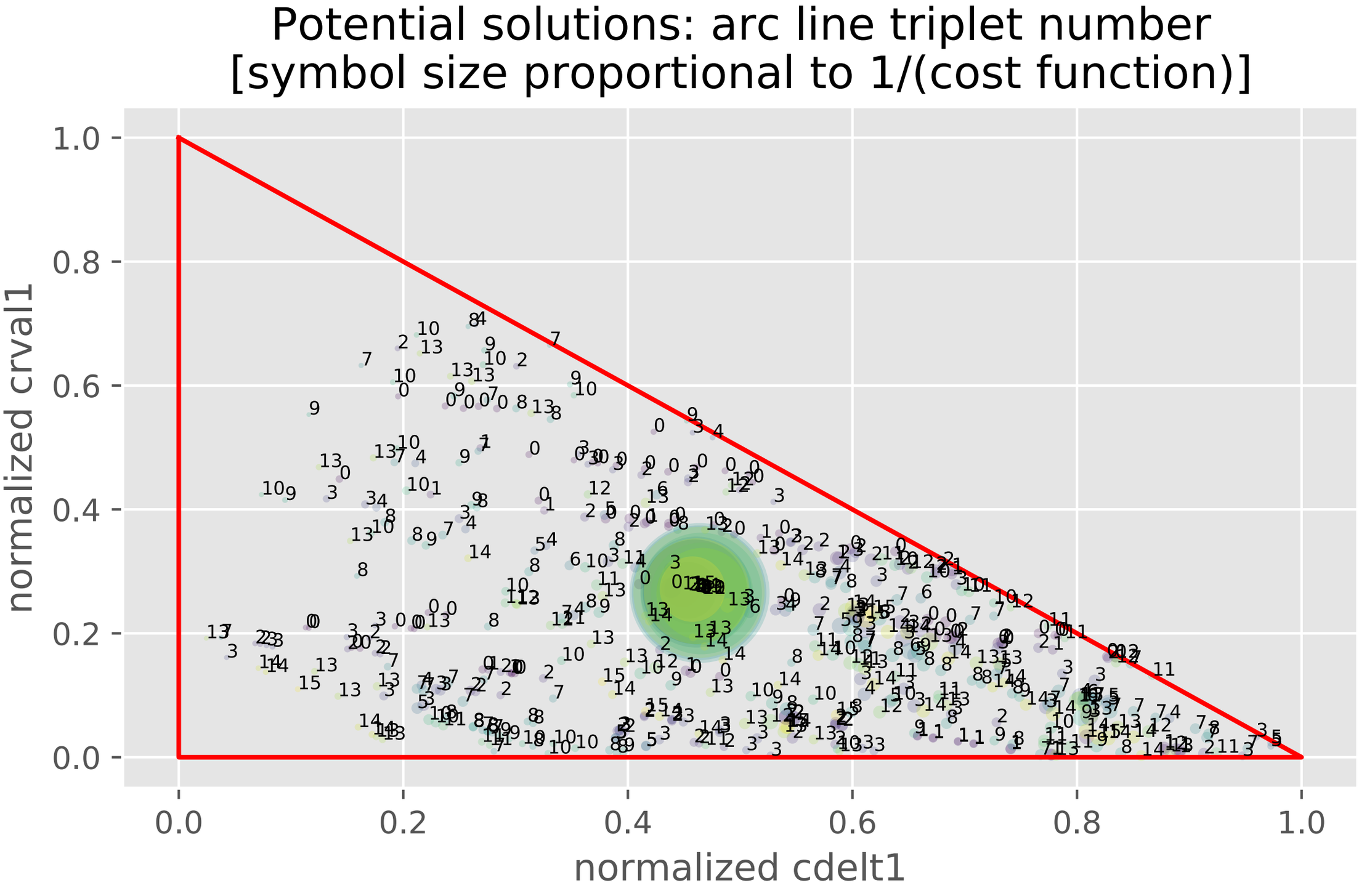
Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```



Rectification and wavelength calibration

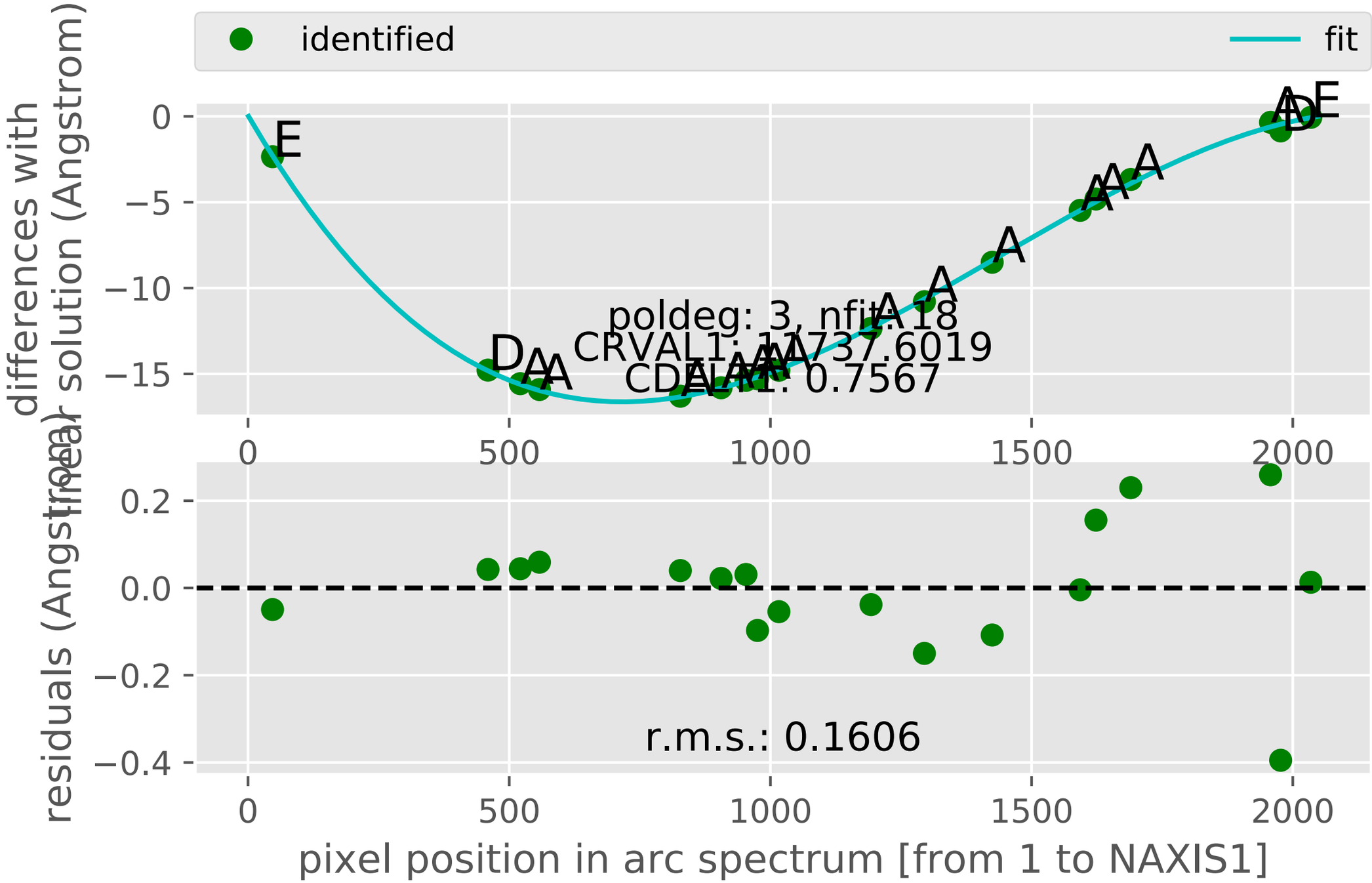
```
% pyemir-rect_wpoly_from_longslit
```



Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```

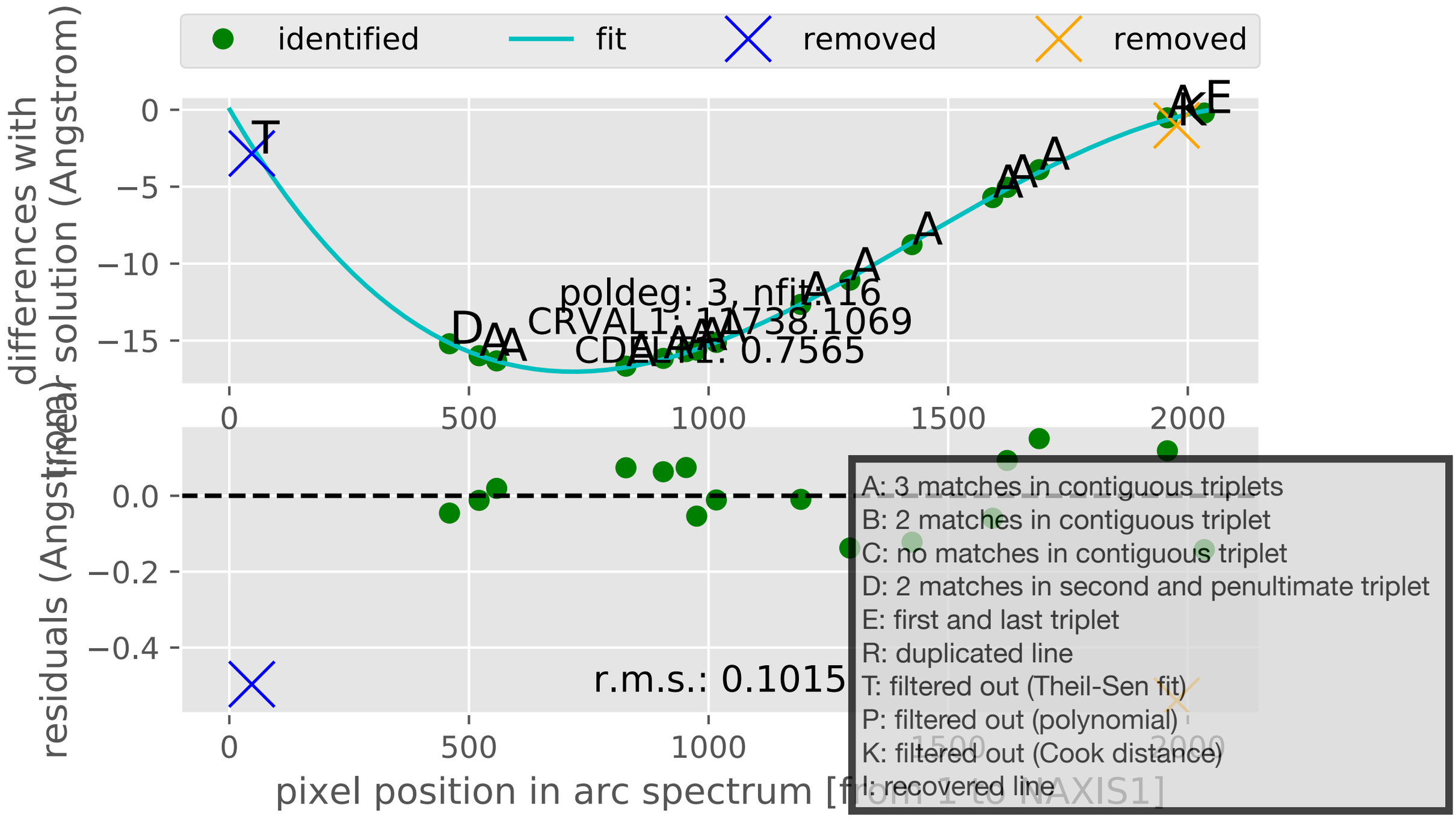
preliminary wavelength calibration



Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```

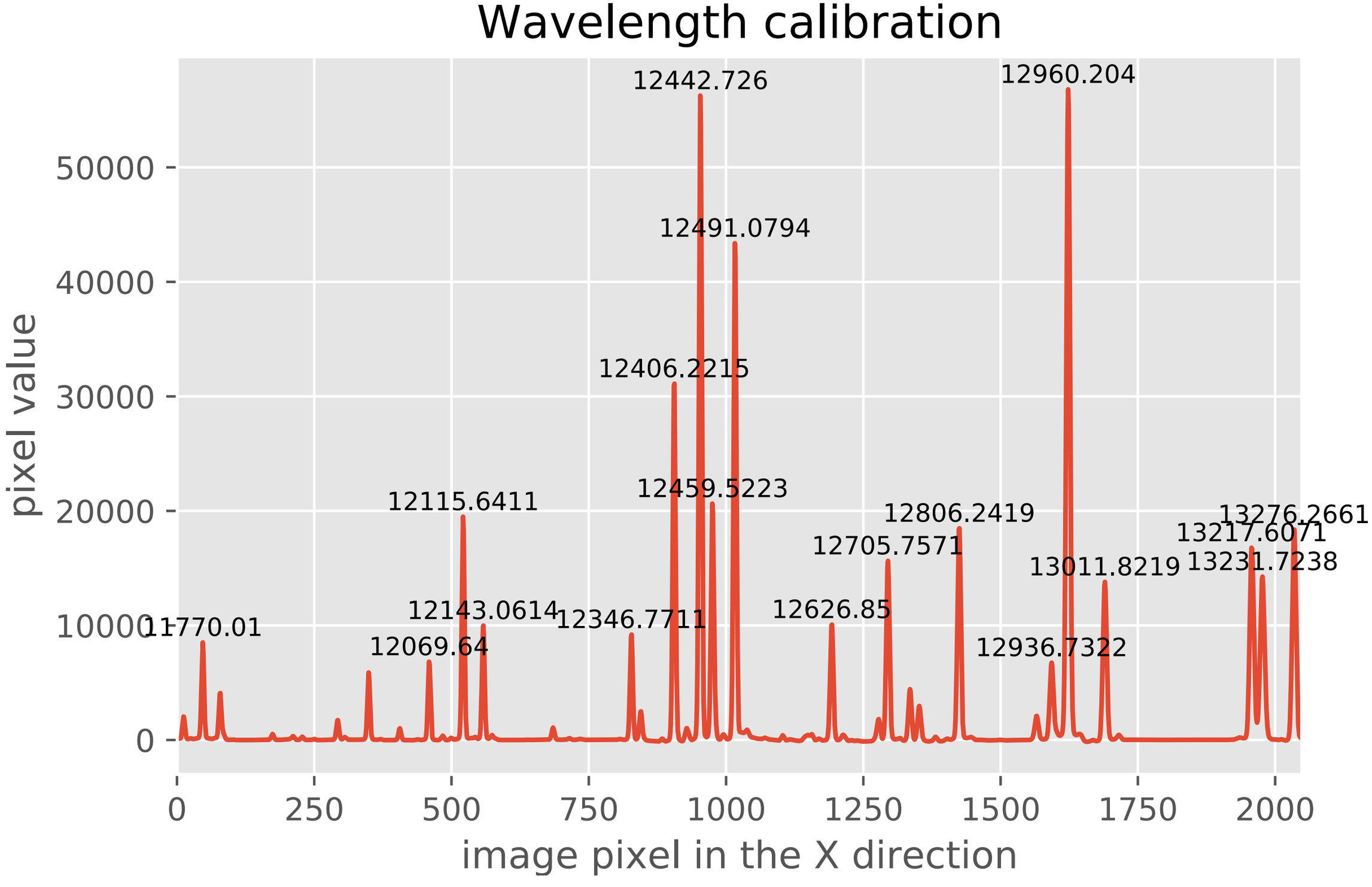
modified wavelength calibration



Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```

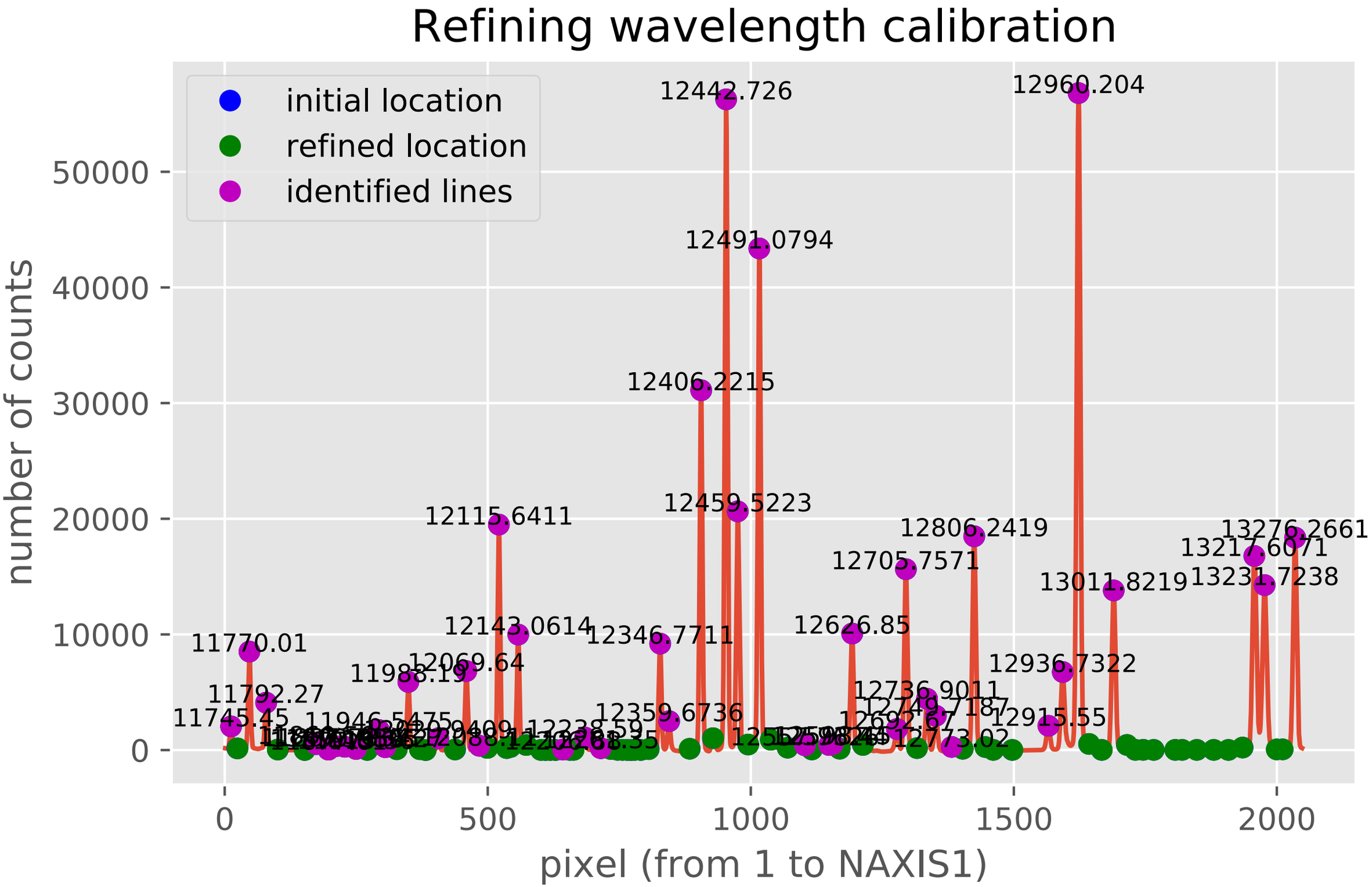
wavelength calibration



Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```

refined wavelength calibration



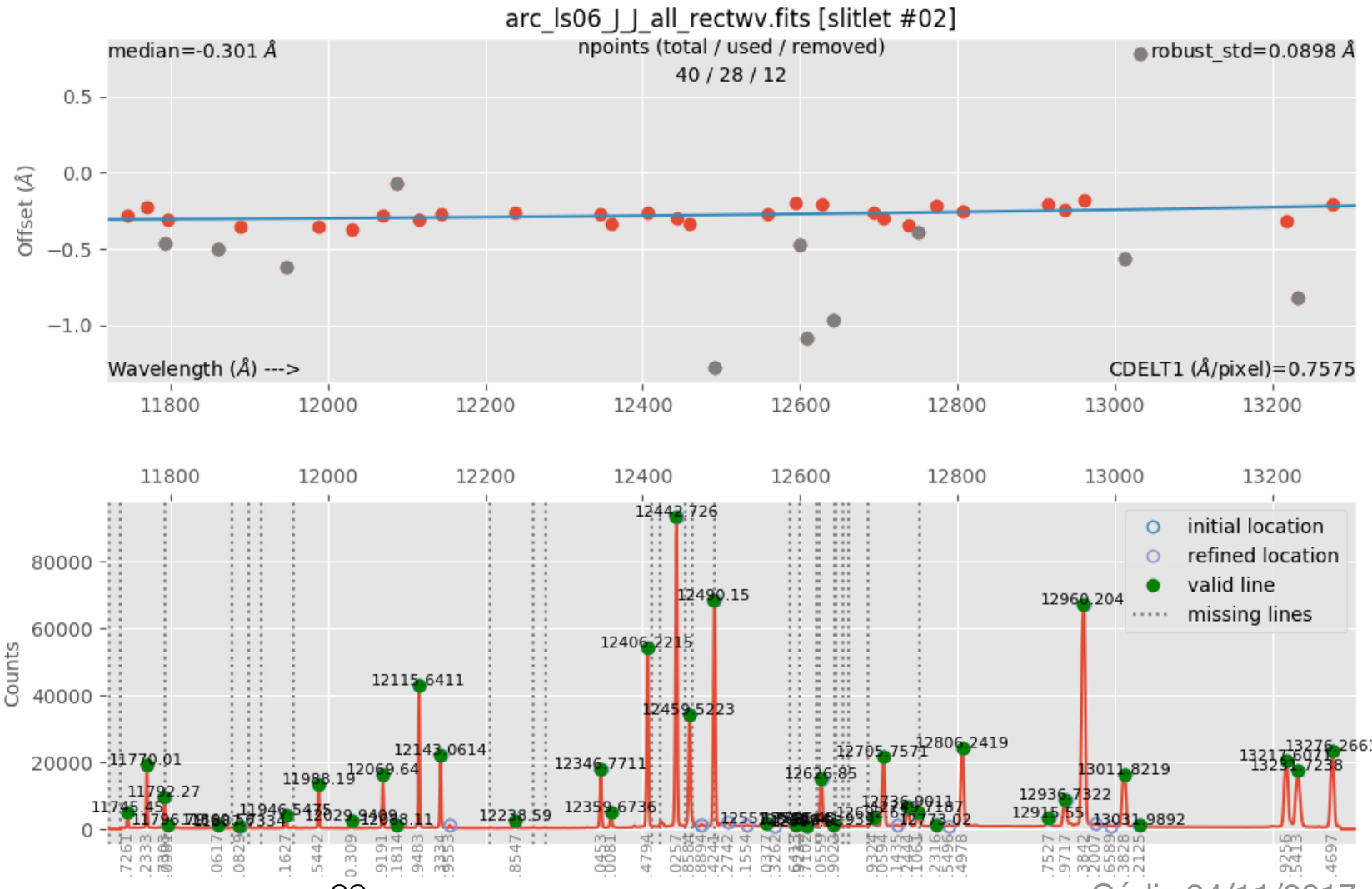
Rectification and wavelength calibration

```
% pyemir-rect_wpoly_from_longslit
```

wavelength calibration verification

output: coef_rect_wpoly_ls06_grism_J_filter_J_direct.json
(rect_wpoly_ls06_grism_J_filter_J.json)

```
% pyemir-verify_rect_wpoly arc_ls06_J_J_all_rectwv.fits \
  --coef_rect_wpoly coef_rect_wpoly_ls06_grism_J_filter_J_direct.json \
  --wv_master_file lines_argon_neon_xenon.dat \
  --verified_coef_rect_wpoly coef_rect_wpoly_ls06_grism_J_filter_J_direct_verified.json \
  --min_nlines 10 \
  --poldeg_residuals 2 \
  --threshold 1000 \
  --ntimes_match_wv 2 \
  --times_sigma_reject 3 \
  --interactive \
  --geometry 0,0,1300,800 \
  --debugplot -12 --echo
```



Rectification and wavelength calibration

`% pyemir-rect_wpoly_for_MOS`

bivariate polynomial rectification coefficients

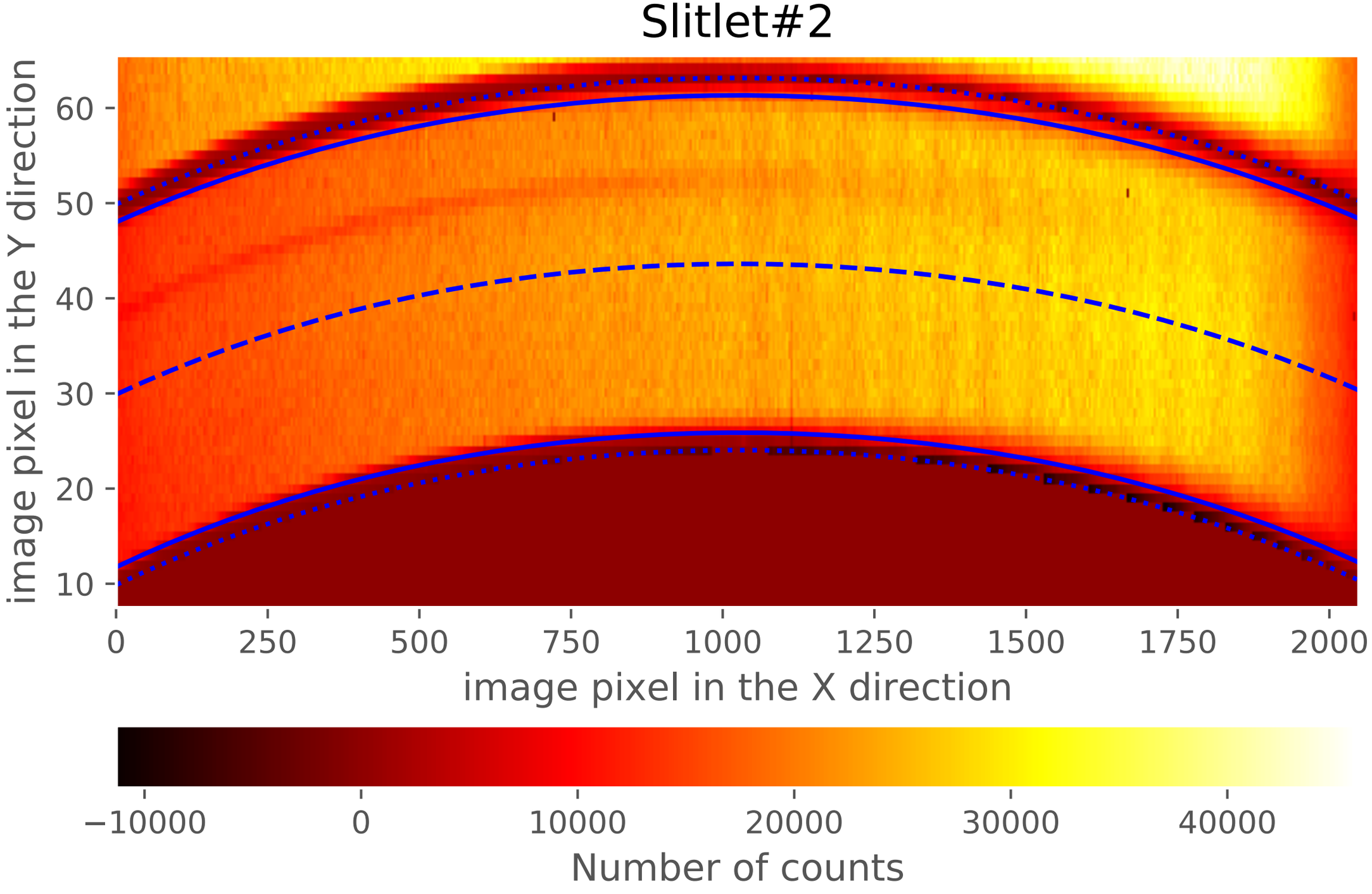
6 x 4 = 24 coefficients as a function of csu_bar_slit_center

`output: rect_wpoly_MOSlibrary_grism_J_filter_J.json`

Flatfielding

```
% pyemir-continuum_flatfield
```

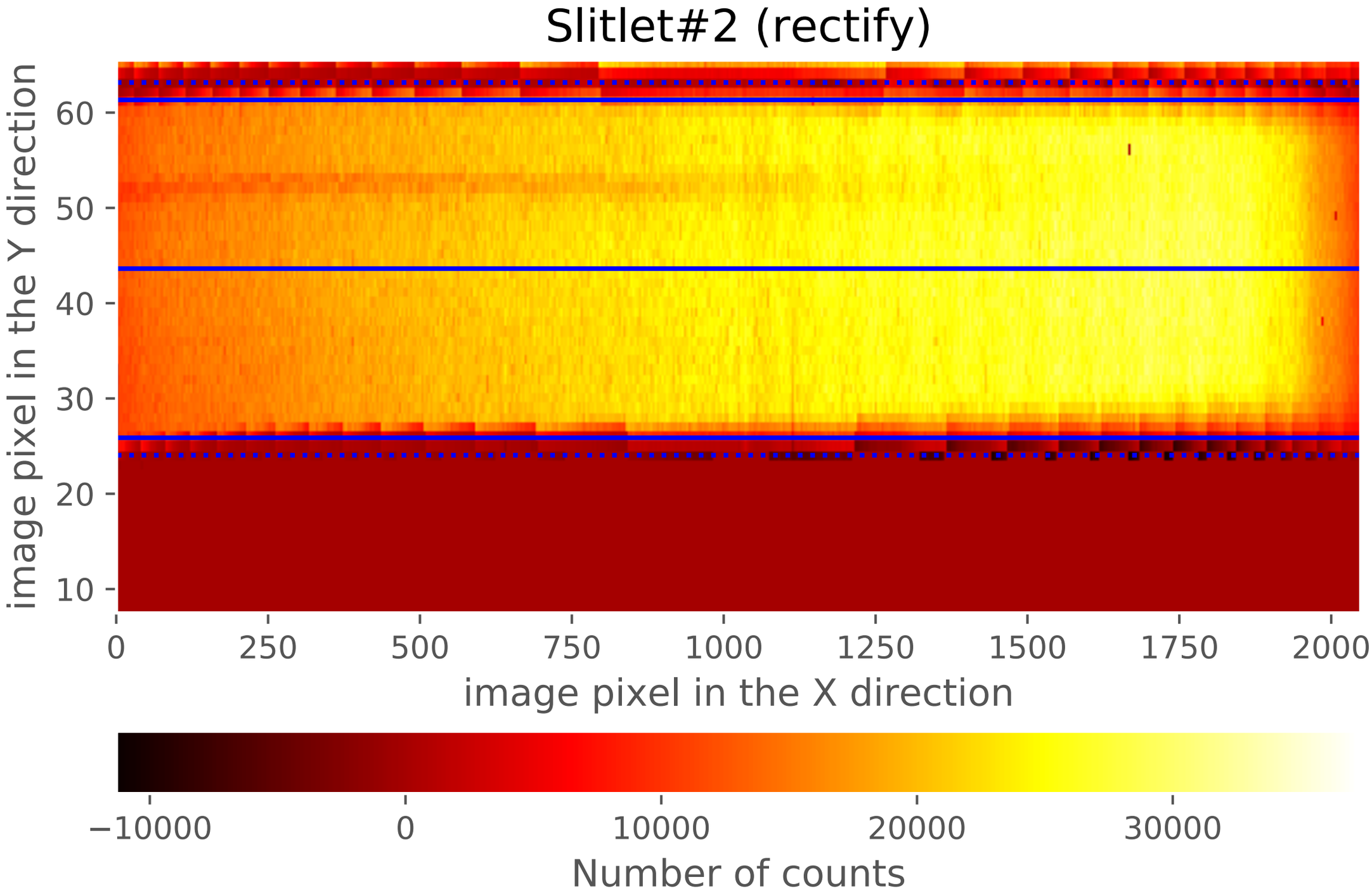
slitlet selection



Flatfielding

```
% pyemir-continuum_flatfield
```

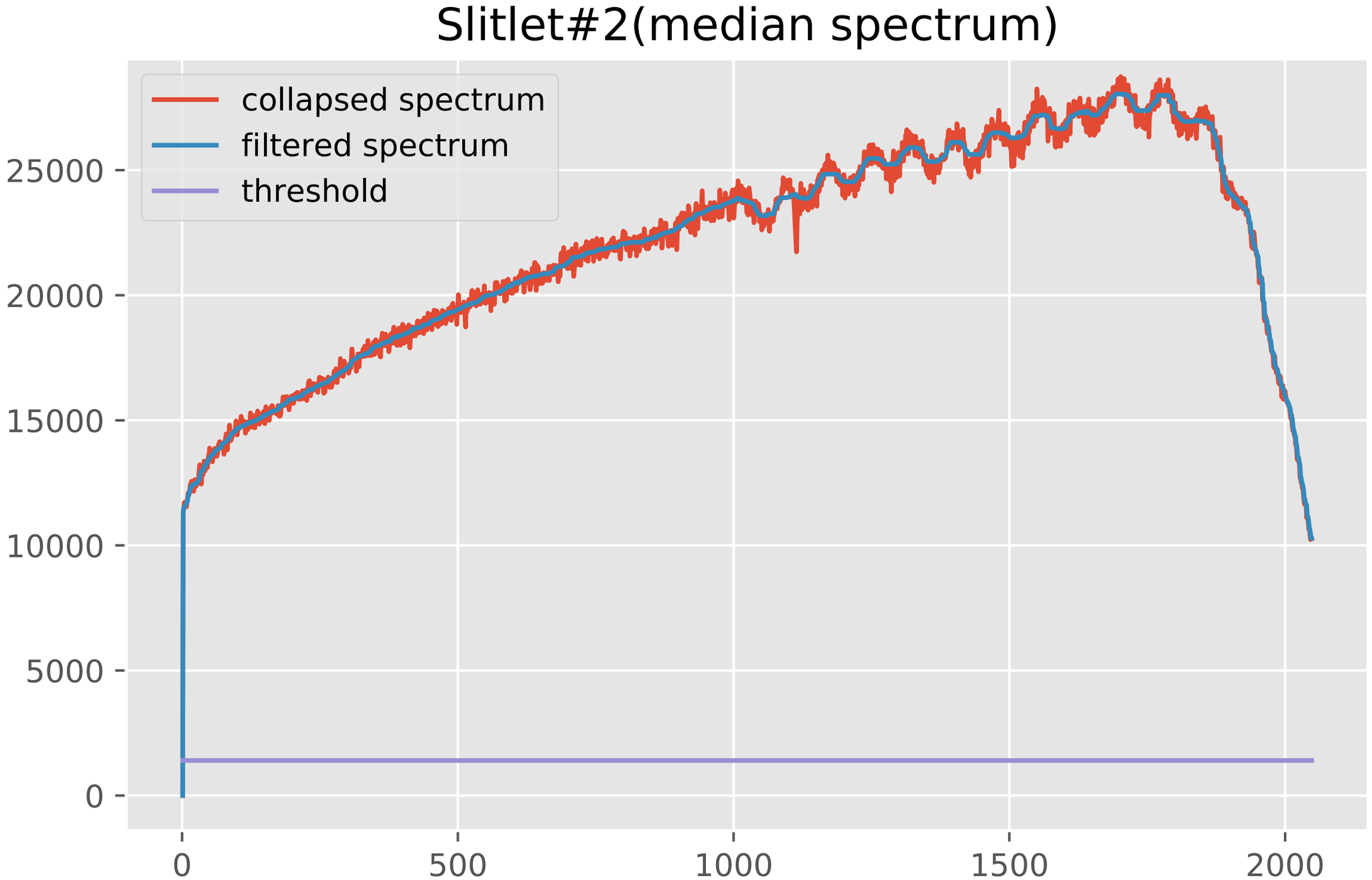
slitlet rectification



Flatfielding

```
% pyemir-continuum_flatfield
```

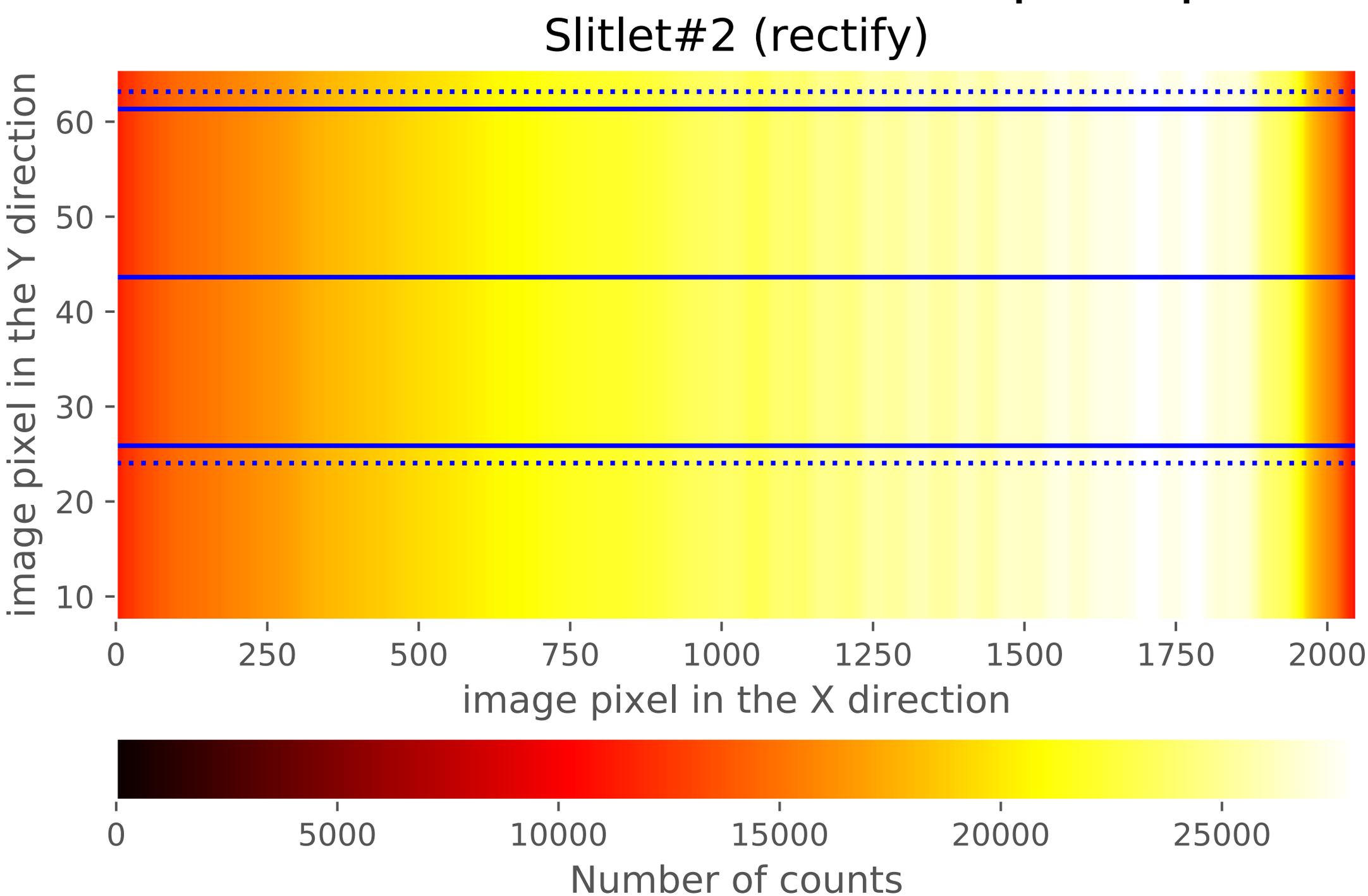
median spectrum



Flatfielding

```
% pyemir-continuum_flatfield
```

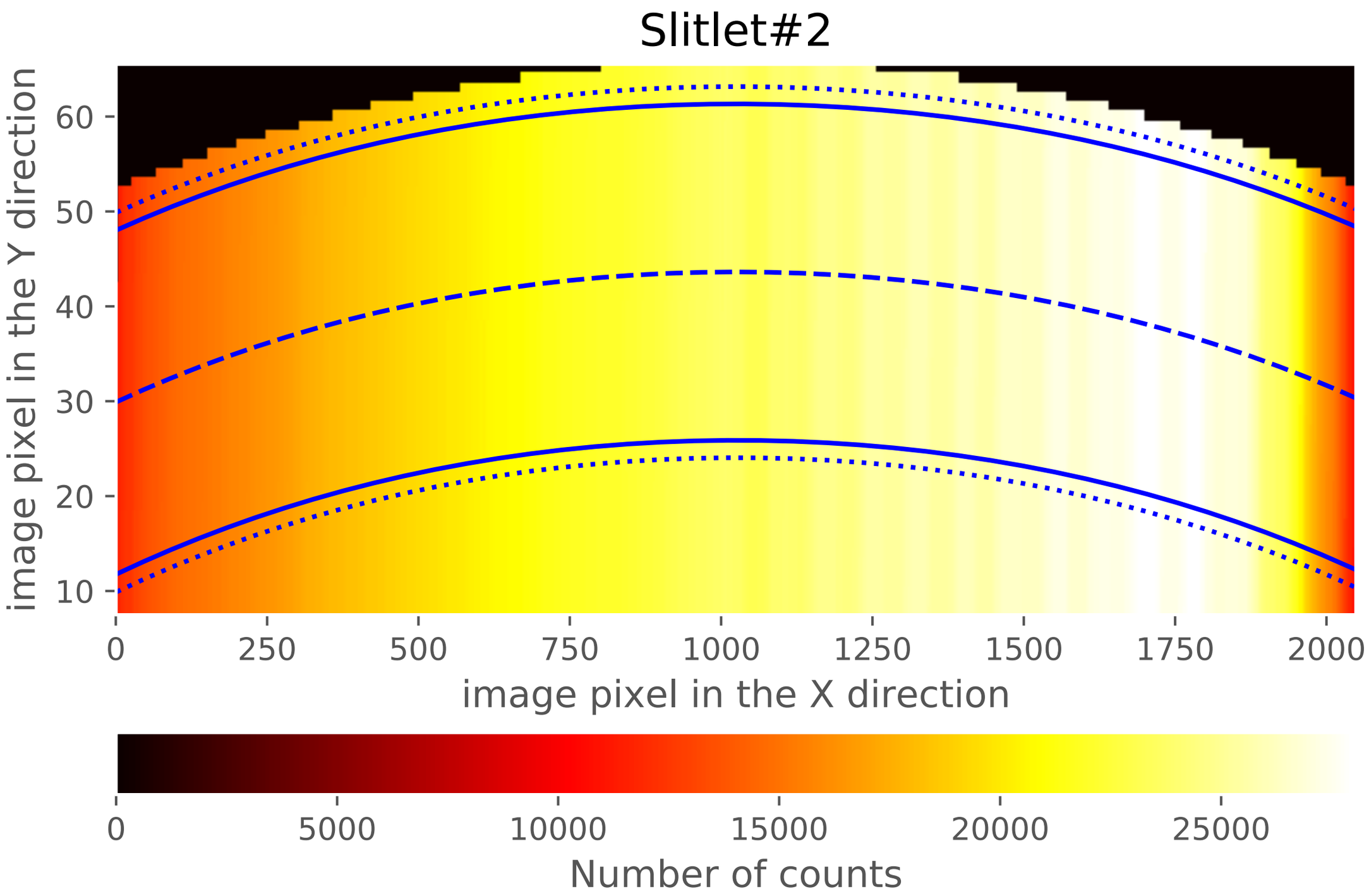
expanded spectrum



Flatfielding

```
% pyemir-continuum_flatfield
```

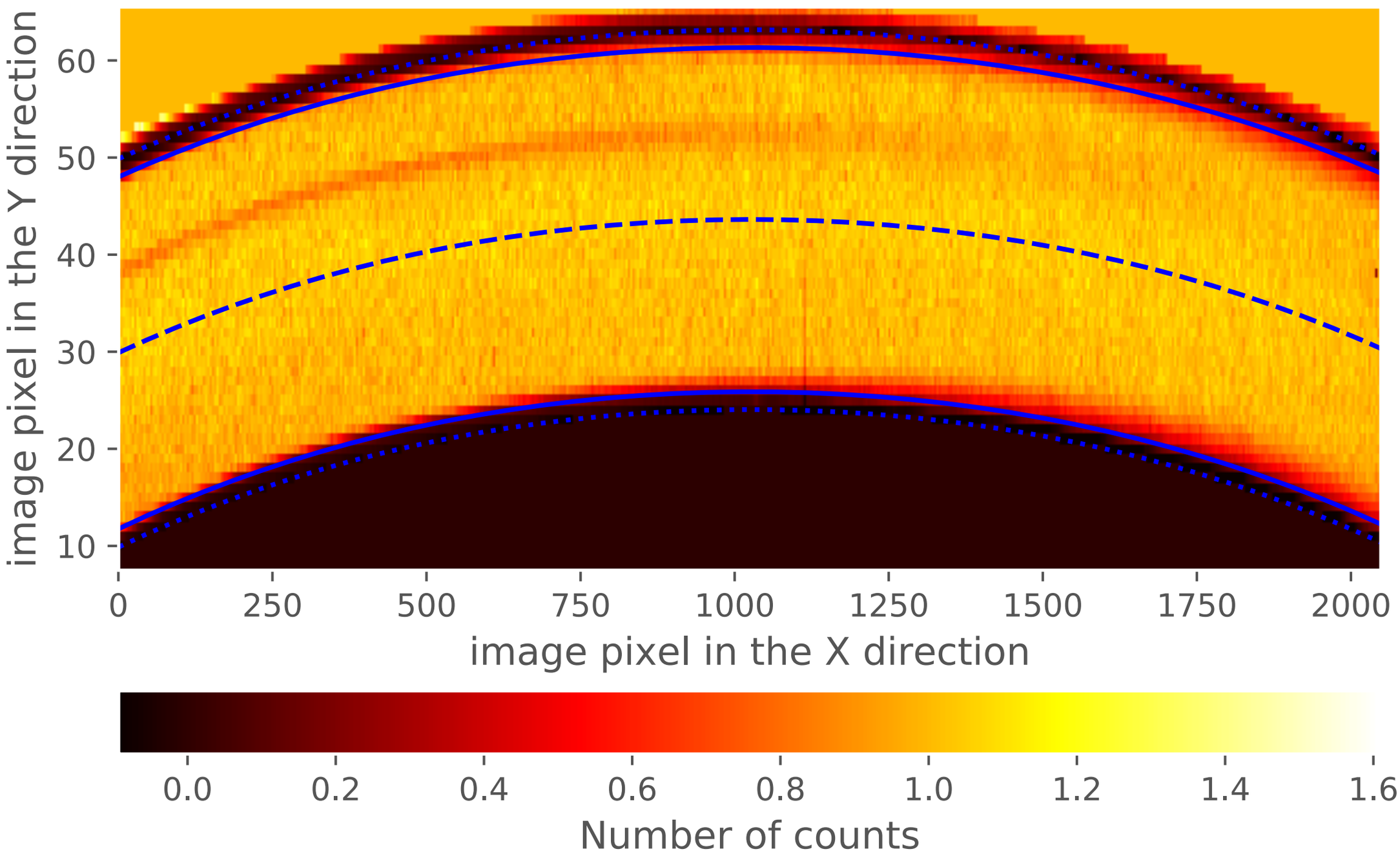
unrectified slitlet



Flatfielding

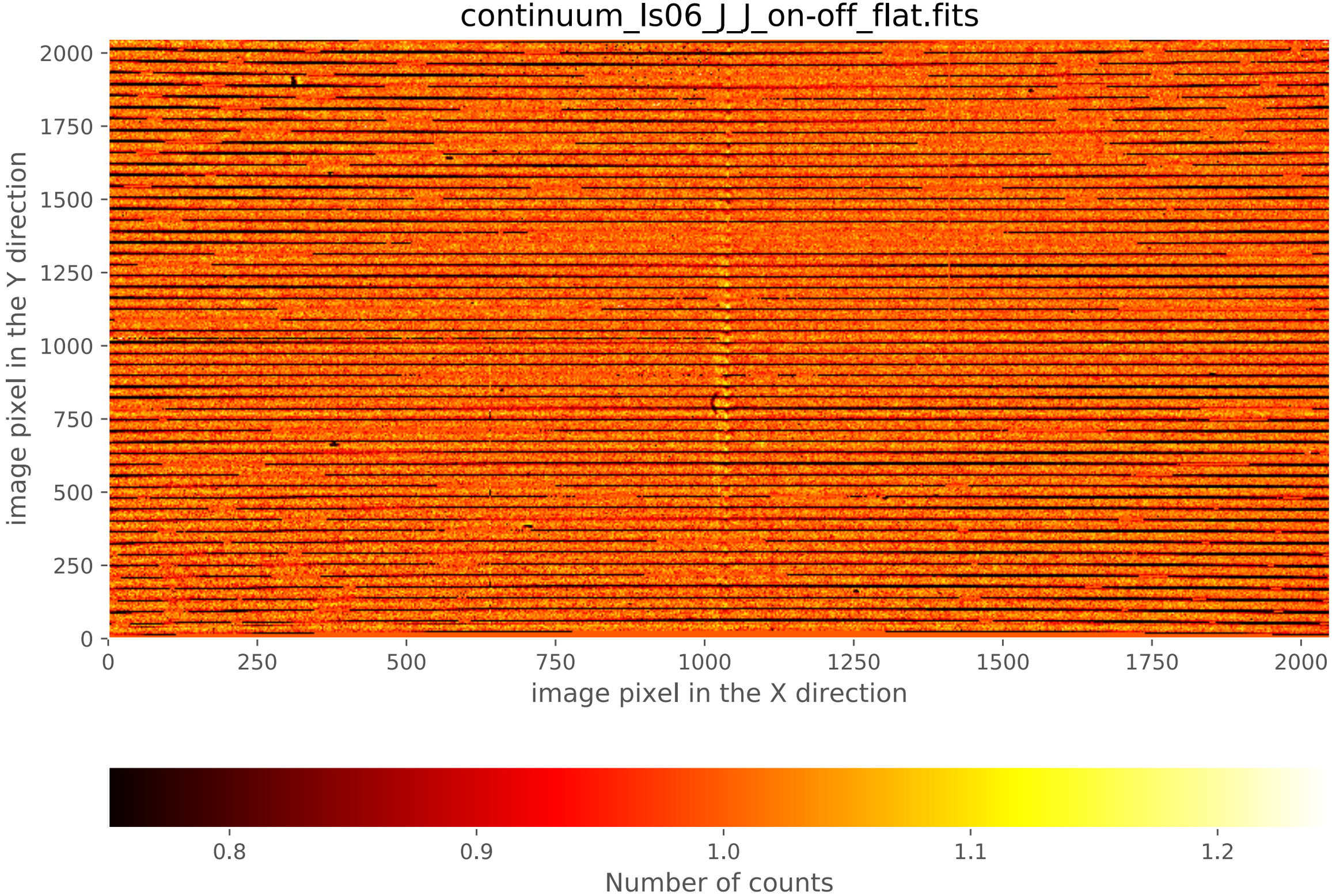
```
% pyemir-continuum_flatfield
```

original/smoothed

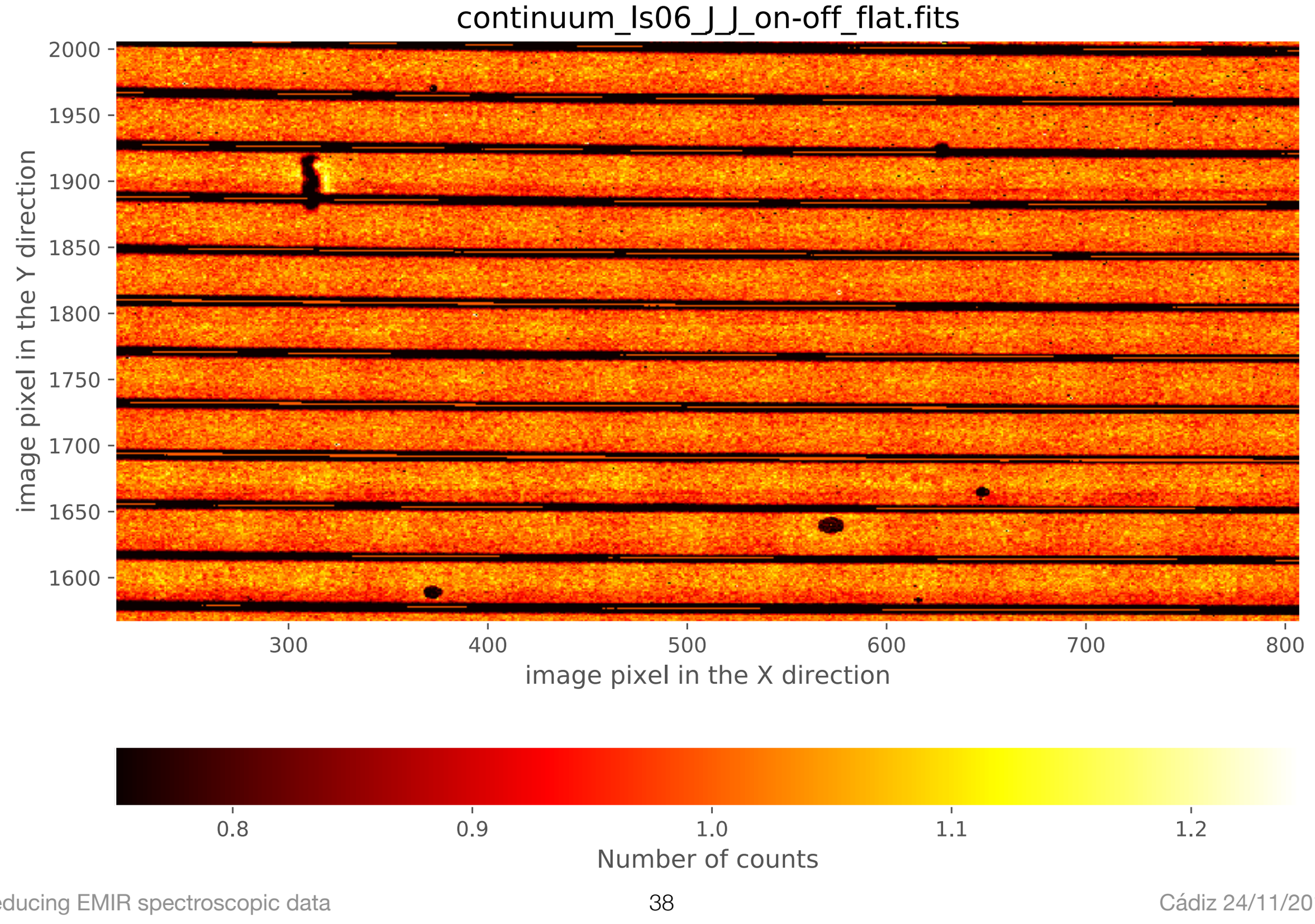



```
output: continuum_ls06_J_J_on-off_flat.fits
```

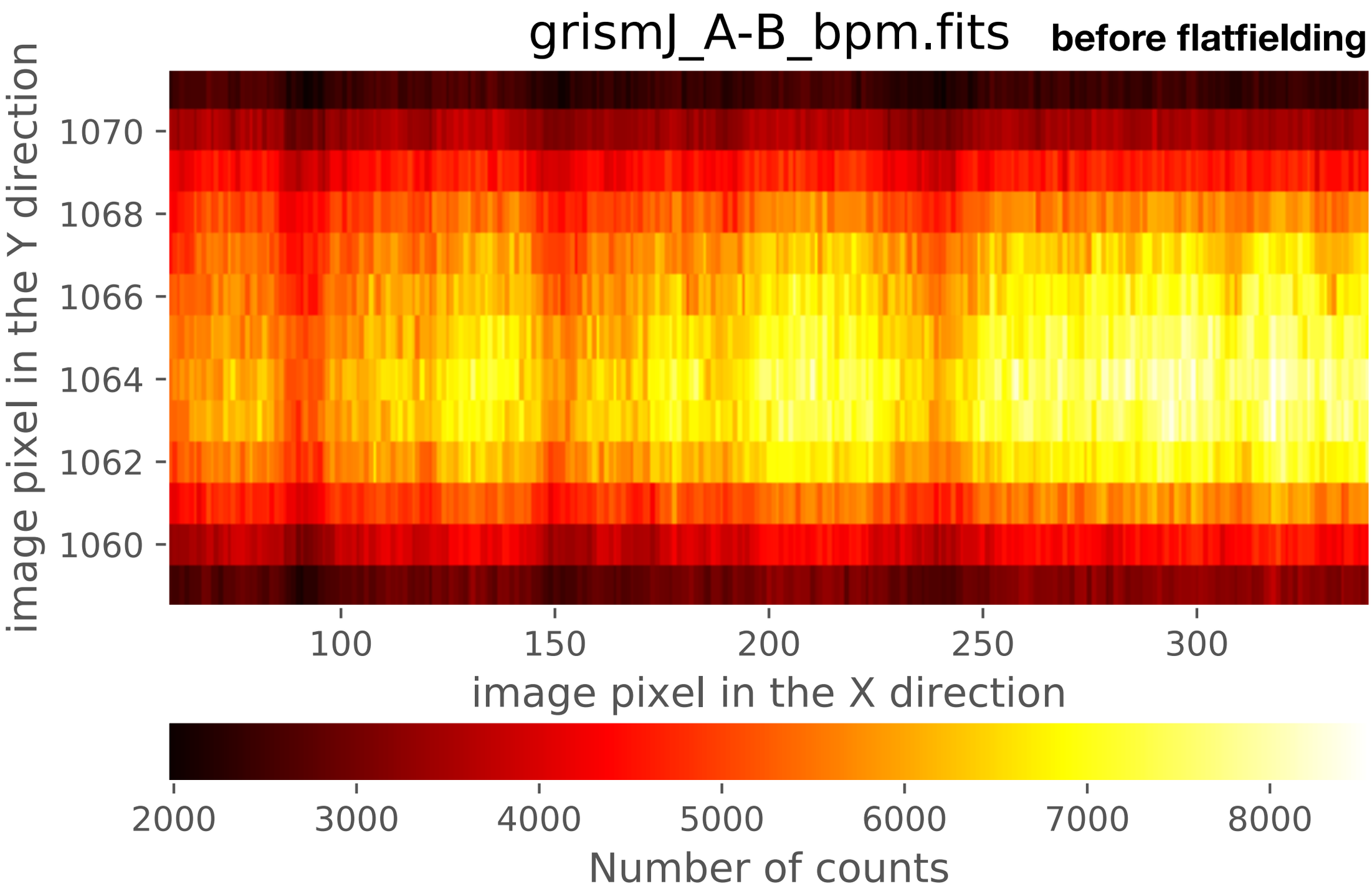
Flatfielding



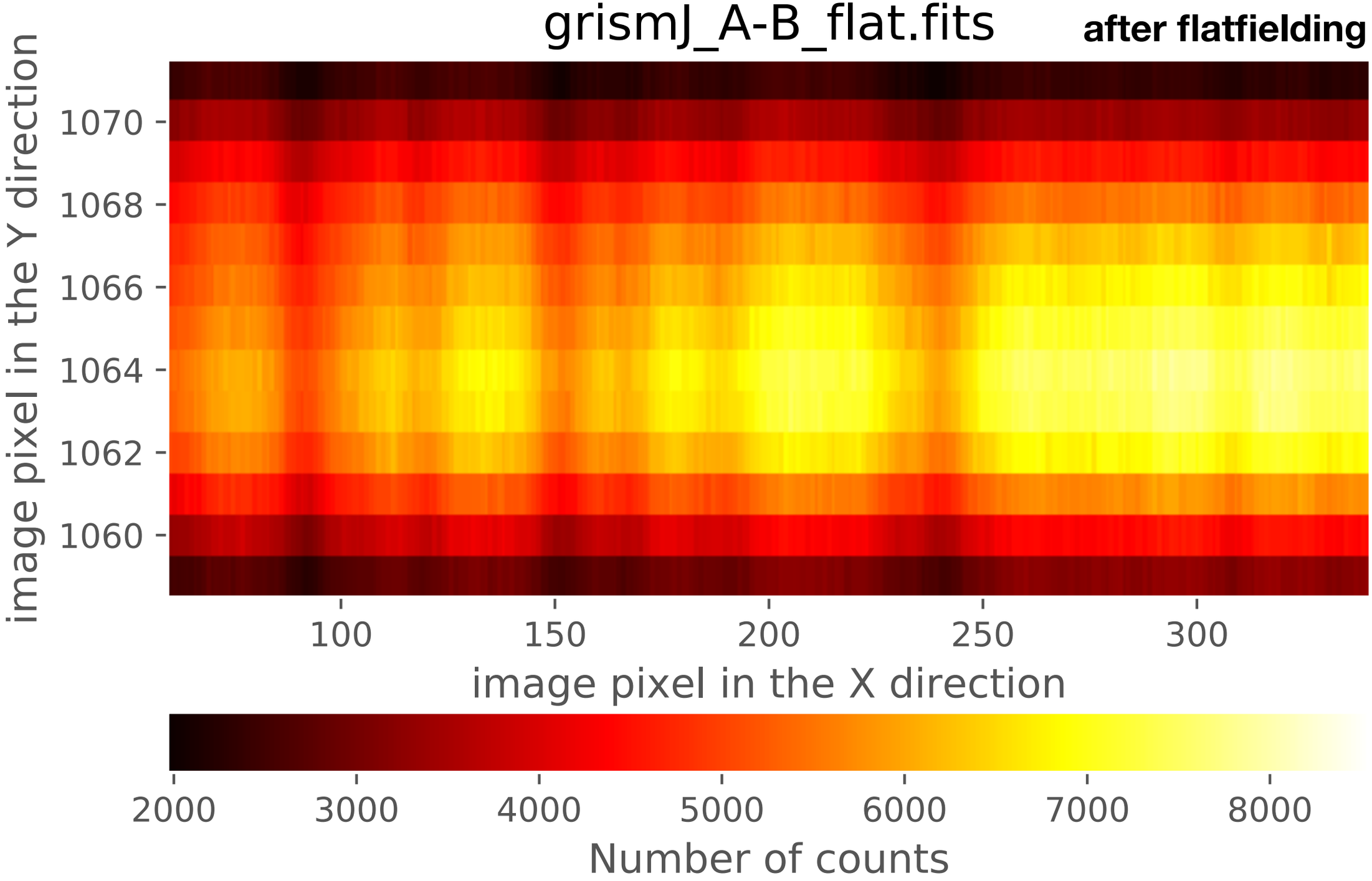
Flatfielding



Flatfielding



Flatfielding



All this functionality is already available as auxiliary python files distributed with **`numina`** and **`pyemir`**, but…

- It is still not running under the control of **`numina`** (it will do so for the forthcoming MOS commissioning), so for now the user must execute the code by invoking directly the python scripts (wait for the next part of the presentation!).

- Some calibrations are not finished / or completely verified. It's expected that all of them will be available before the end of 2017.

ToDo List:

- Improve the rectification interpolation (currently using Nearest Neighbour method): interpolate properly fractions of pixels
- Improve pixel-to-pixel flatfields:
  - Remove some ghosts
  - Compare with flatfields from imaging and replace the slitlet borders
- Generate low-frequency flatfields (from imaging?)
- …