Rectification and wavelength calibration of EMIR spectroscopic data with Python

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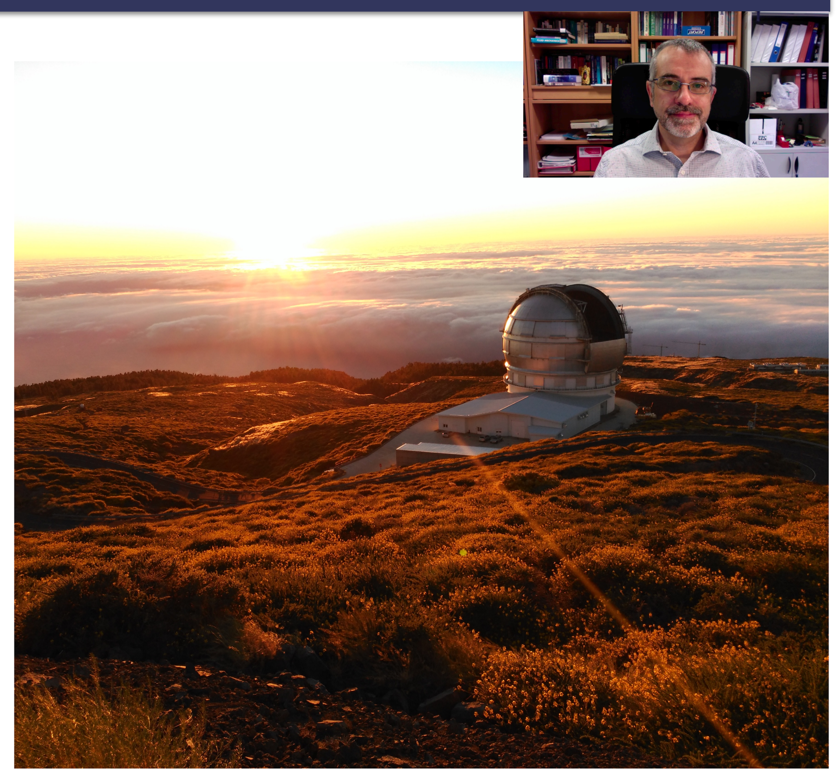
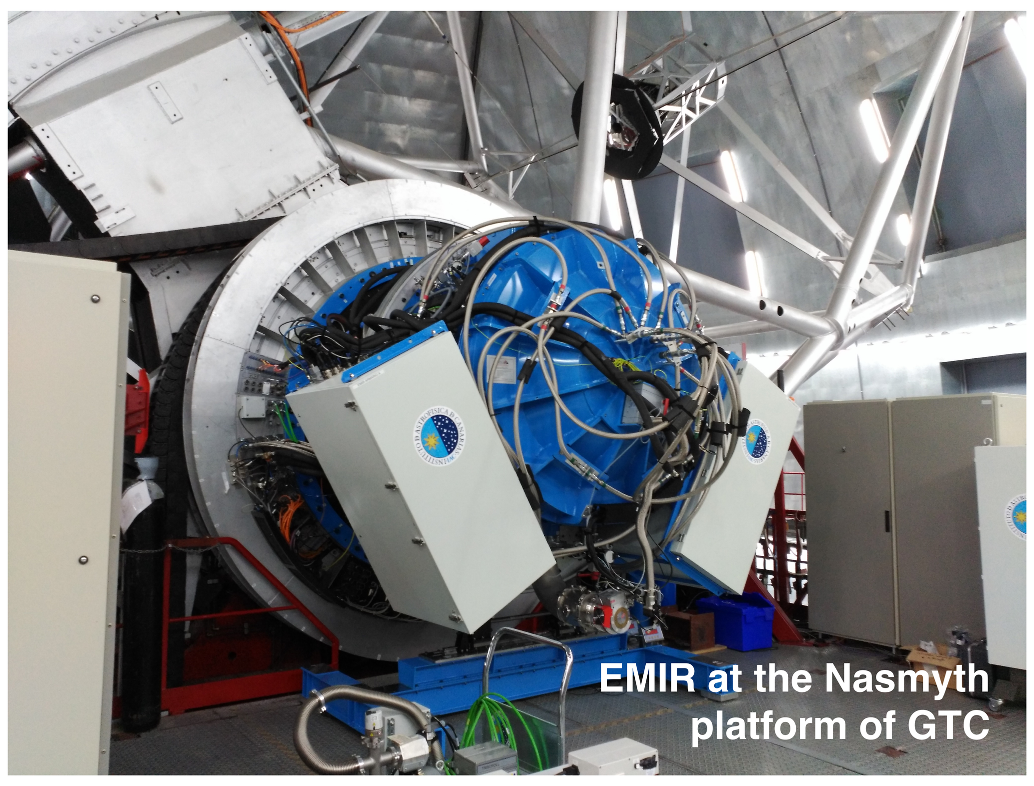




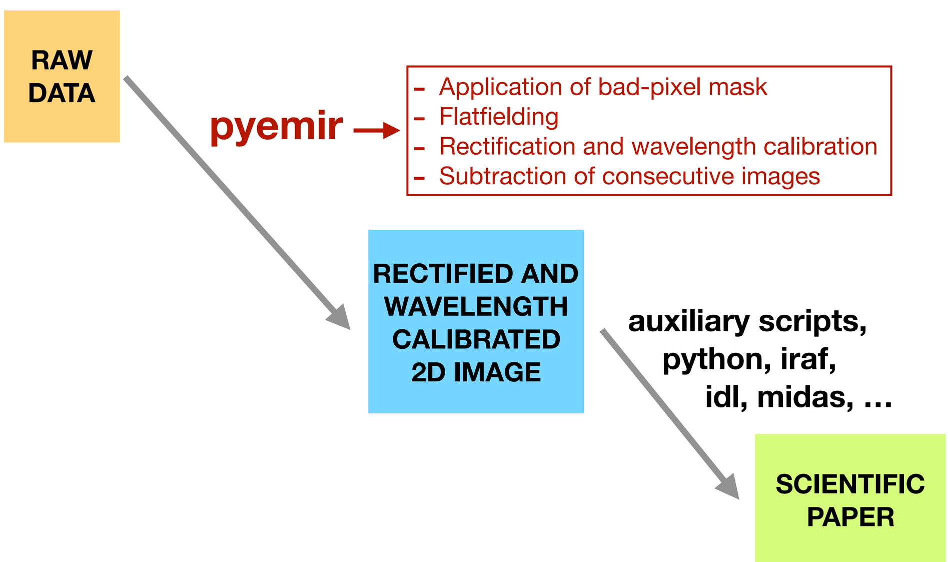
Summary

EMIR, the near-infrared camera and multi-object spectrograph operating in the spectral region from 0.9 to 2.5 μm, has been commissioned at the Nasmyth focus of the Gran Telescopio CANARIAS. One of the most outstanding capabilities of EMIR is its multi-object spectroscopic mode which, with the help of a robotic reconfigurable slit system, allows to take around 53 spectra simultaneously.

A data reduction pipeline, **`pyemir`**, based on Python, is being developed in order to facilitate the automatic reduction of EMIR data taken in both imaging and spectroscopy mode. This package, as well as the auxiliary package **`numina`**, are both available at GitHub (https://github.com/guaix-ucm). The user's guide is being currently written after the experience gained analysing the commissioning data, and will be soon available in the documentation hosting platform Read the Docs.

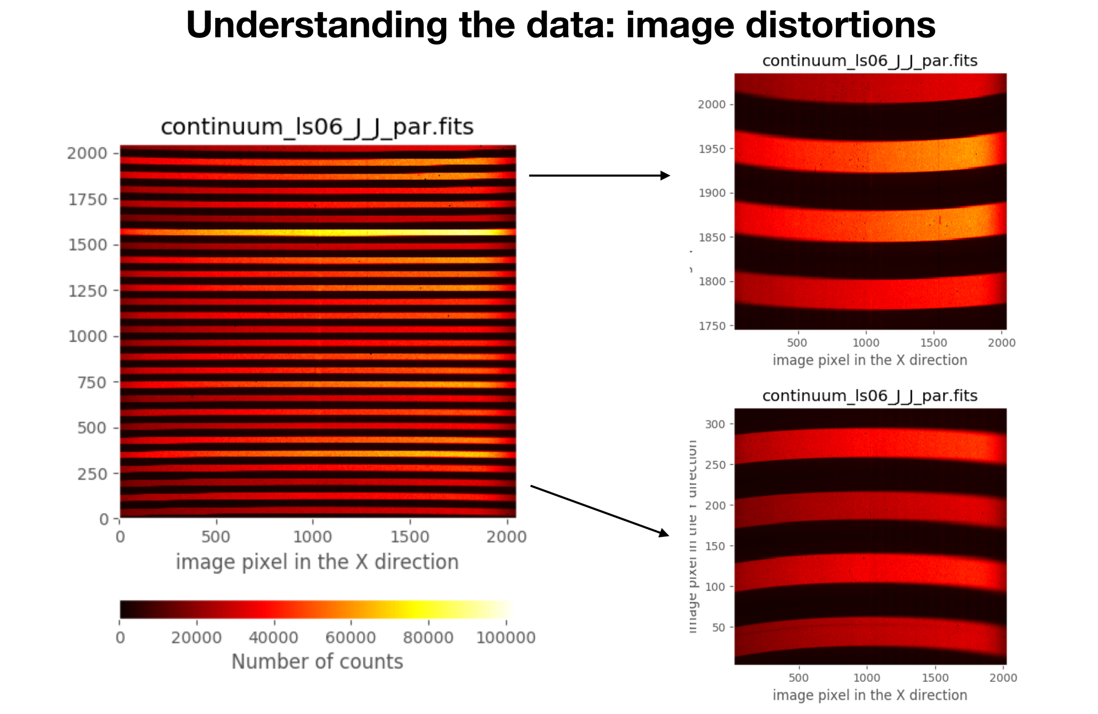
Focusing on the reduction of spectroscopic data, some critical manipulations are the geometric distortion correction and the wavelength calibration. Using a large set of tungsten and arc calibration exposures, both calibrations have been modelled for any arbitrary configuration of the multi-object slit system. This model can be easily employed to obtain a preliminary rectified and wavelength calibrated EMIR spectroscopic image without additional calibration images. This facilitates both the on-line quick reduction of the data at the telescope and the off-line detailed reduction of the data by the astronomer.

Reducing EMIR spectroscopic data with pyemir



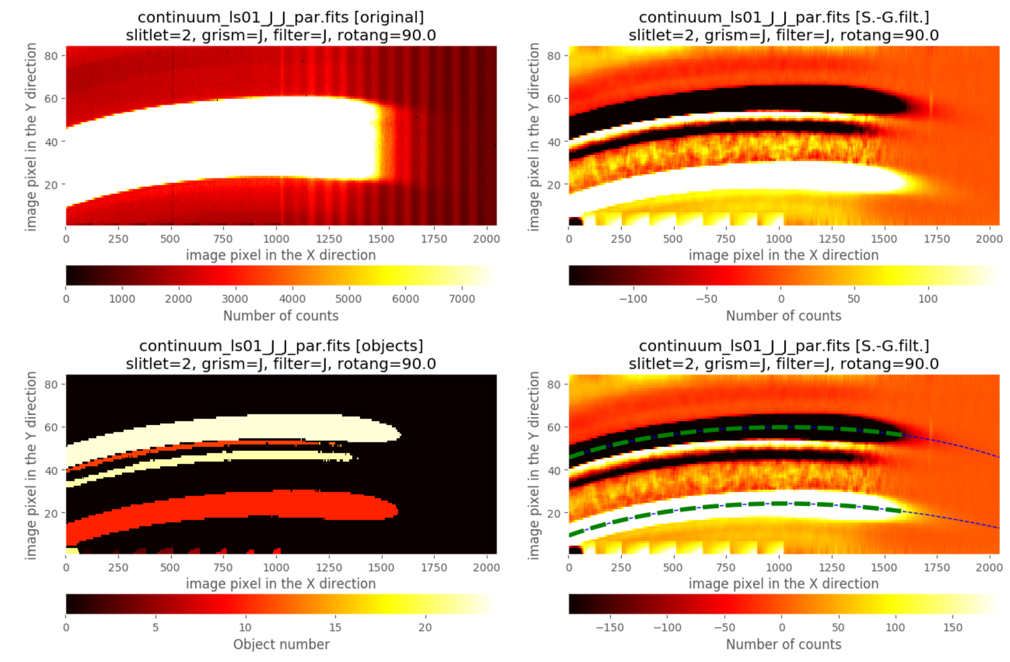
The Python package **`pyemir`** helps to generate a rectified and wavelength calibrated 2D image. From this point, the astronomer can use its favourite software to proceed with the spectra extraction and analysis.

Understanding the data: image distortions



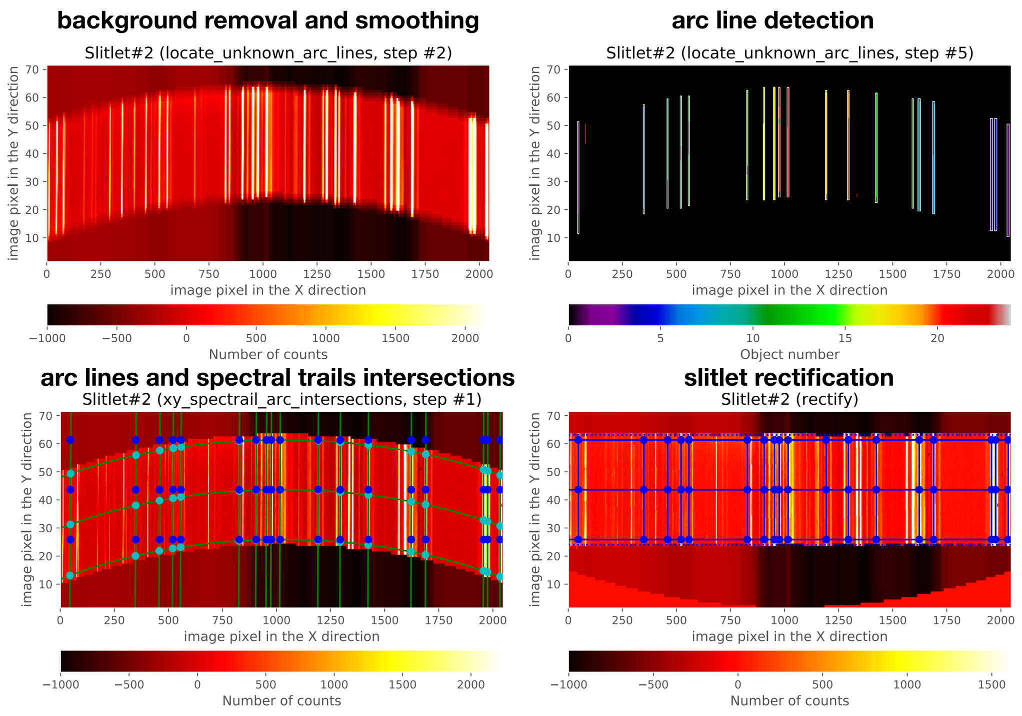
The raw EMIR 2D spectroscopic images exhibit geometric distortions. This effect is clearly noticeable in this sample continuum exposure, where only even-numbered slitlets are opened (the odd-numbered slitlets where closed).

Computing slitlet boundaries



Slitlet boundaries have been computed using continuum exposures with alternate even- and odd-numbered slitlets opened and closed. After smoothing the image to facilitate the task, the boundaries are determined using the first derivative of the signal when moving in the vertical (spatial) direction.

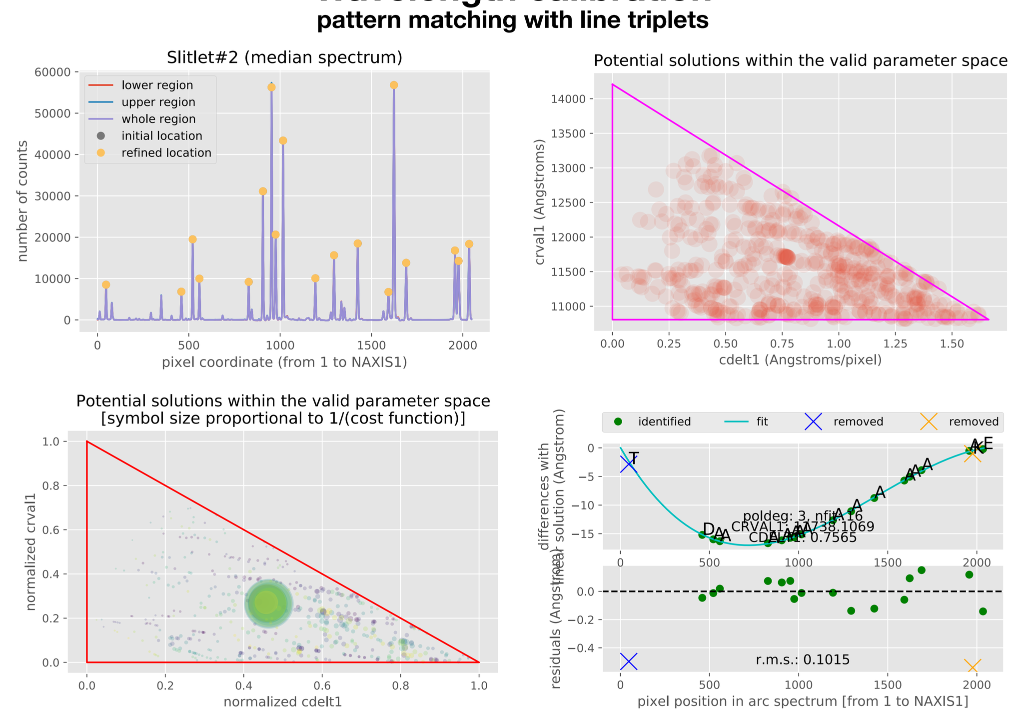
Rectification



Once the slitlet boundaries have been determined, it is possible to rectify each 2D slitlet. In this example, an arc exposure is being analysed in order to determine the intersections between arc lines and spectral trails. These reference points allows the computation of the rectification transformation.

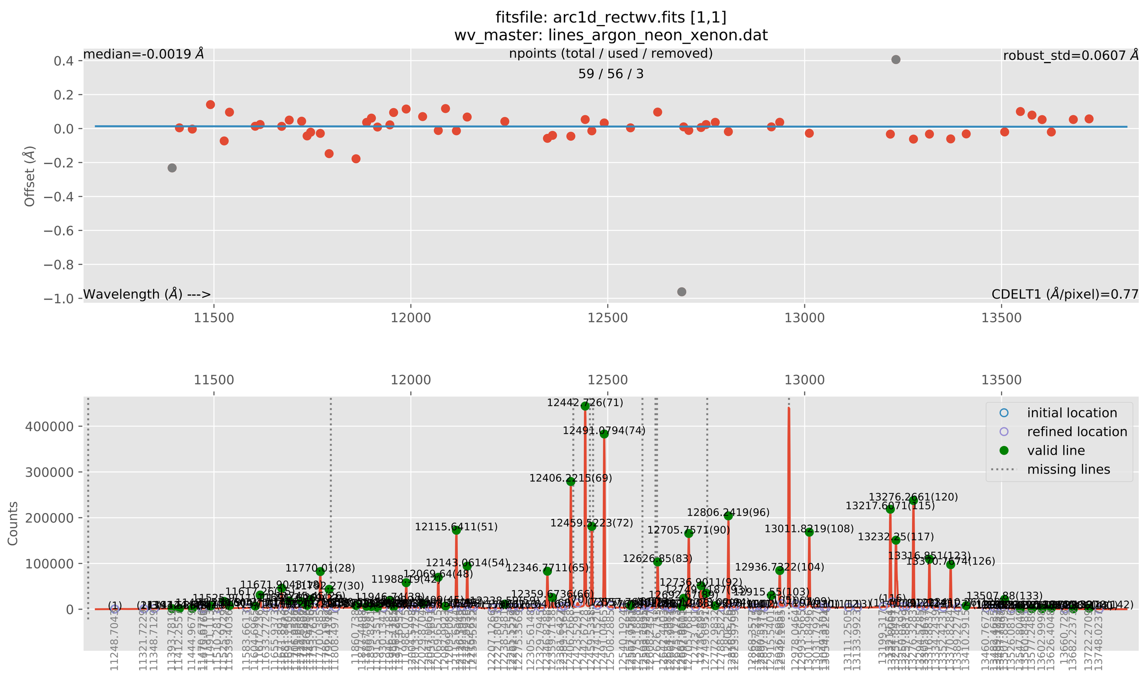
Wavelength calibration

pattern matching with line triplets



After rectifying the arc-exposure slitlets, the median spectrum of each slitlet is extracted, and a pattern-matching algorithm, specially developed for **`pyemir`**, is employed in order to derive an initial wavelength calibration solution.

Refined wavelength calibration



The preliminary wavelength calibration is then improved by using additional (faint) arc lines, in order to achieve a typical r.m.s. of the order of 1/10 pixel.

Library with rectification and wavelength calibration polynomials

```
// 20180711111254
// file:///Users/cardiel/Downloads/rect_wpoly_MOSlibrary_grism_J_filter_J.json

{
  "quality_control": "GOOD",
  "instrument": "EMIR",
  "tags": {
    "grism": "J",
    "filter": "J"
  },
  "uuid": "d8f19e18-8129-11e8-b469-720004508240",
  "meta_info": {
    "mode_name": "unknown",
    "instrument_name": "EMIR",
    "recipe_name": "unknown",
    "recipe_version": "unknown",
    "origin": {↔},
    "creation_date": "2018-07-06T14:35:36.822180",
    "dtu_configuration": {↔},
    "refined_boundary_model": {↔}
  },
  "type": "MasterRectWave",
  "type_fqn": "emirdrp.products.MasterRectWave",
  "total_slitlets": 55,
  "missing_slitlets": [
    1,
    55
  ],
  "contents": [↔]
}
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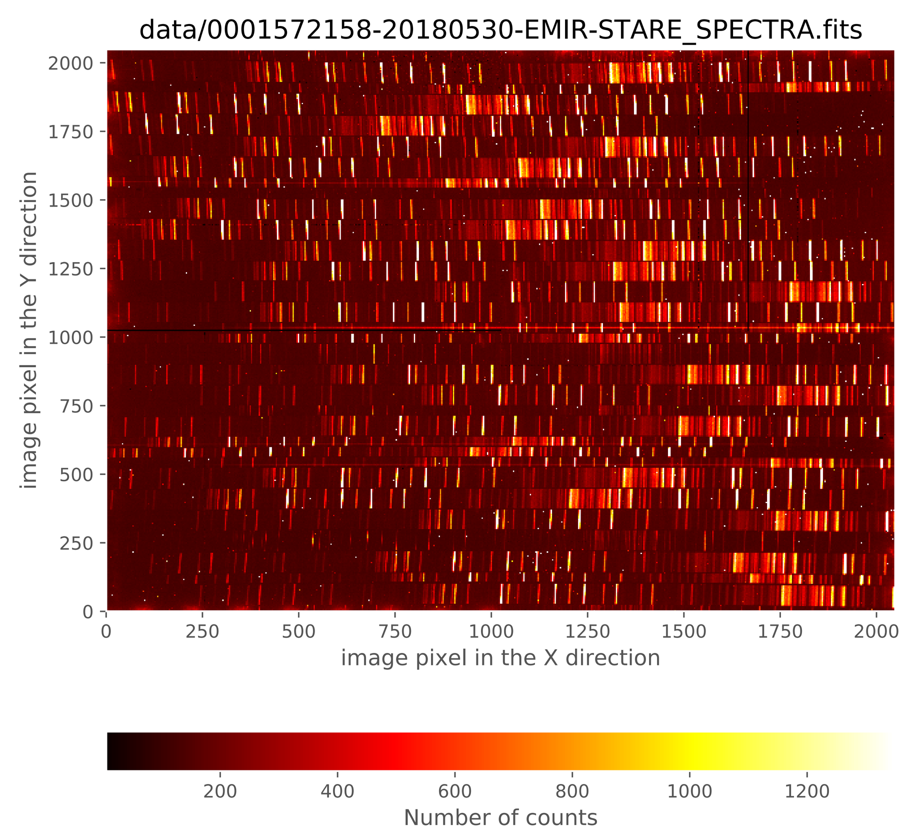
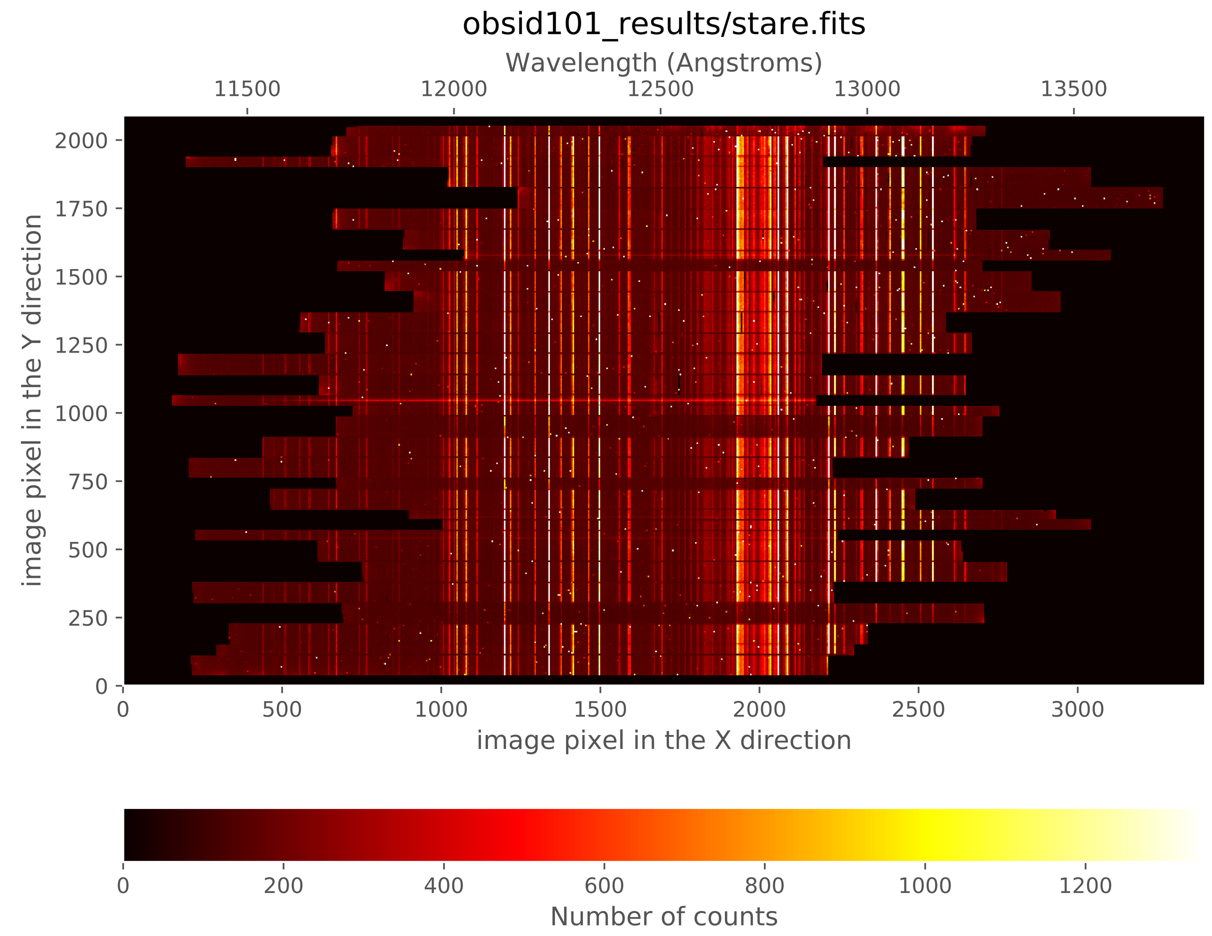
The rectification and wavelength calibration polynomials for a reasonable grid of MOS configurations have been computed and stored in JSON files (an open-standad file format that uses human-readable text). For illustration, the above file contains 40169 lines with all the relevant information corresponding to grism J and filter J. **These files can be employed to obtain, in a few seconds, preliminary rectified and wavelength calibrated images without the need of using any additional calibration image.**



Example of raw image obtained using grism J + filter J in multi-slit mode. The image exhibits the expected geometric distortions. Note that the wavelength coverage of each slitlet is different, depending on the location of the slit (bar opening) in the focal plane (cold slit unit).



The final rectified and wavelength calibrated image is obtained in two steps. First, a preliminary rectified and wavelength calibrated image is computed after applying the model derived using the library of calibration polynomials corresponding to the particular instrumental configuration. Then, a refined wavelength calibration is computed using cross-correlation of the observed OH sky lines with the expected location of those lines.

EMIR was integrated by a dedicated team composed by engineers and technicians of the IAC, in close collaboration with the GTC technical staff. All of them deserve special thanks for an extremely professional job executed in a short time under pressing conditions and with excellent results.

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