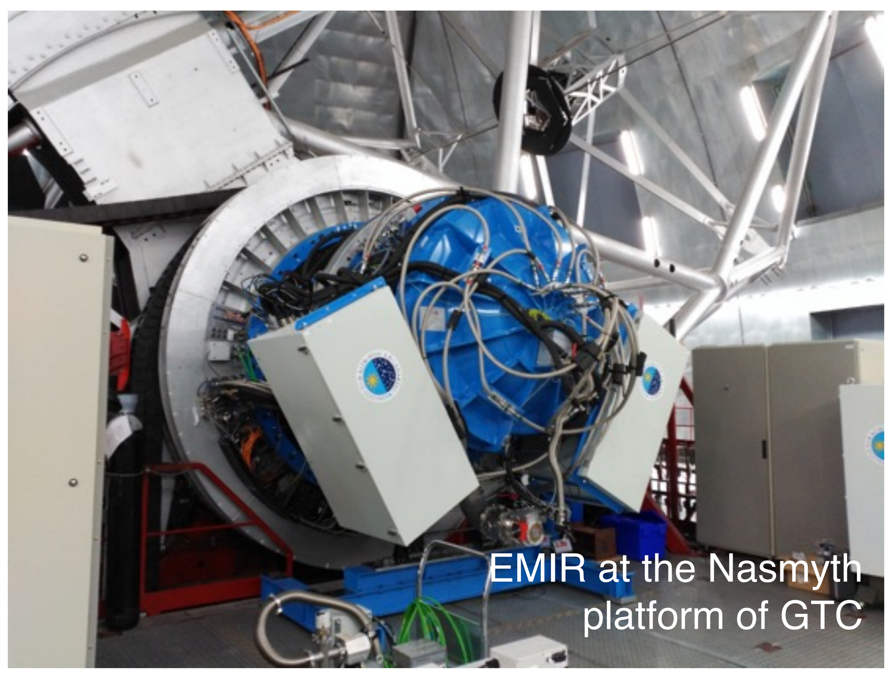
Improving the automatic wavelength calibration of EMIR spectroscopic data

Nicolás Cardiel[1,2], Sergio Pascual[1], Pablo Picazo[1], Jesús Gallego[1], Francisco Garzón[3,4], Nieves Castro-Rodríguez[5], Carlos González-Fernández[6], Peter Hammersley[7], Maider Insausti[3], Elena Manjavacas[3], Matteo Miluzio[3]

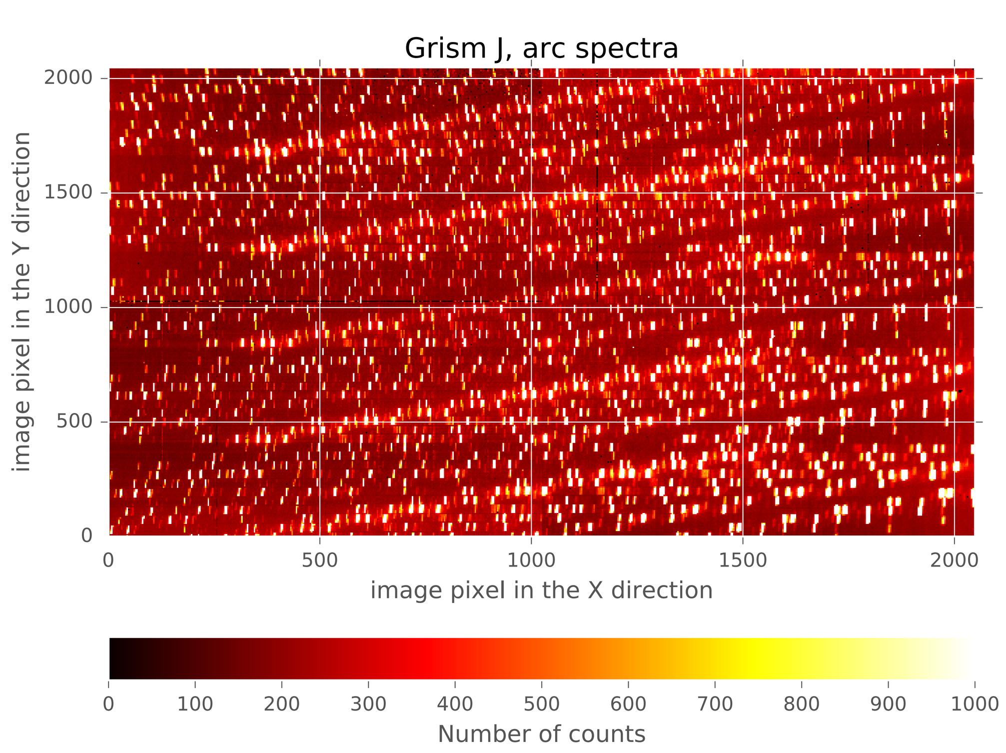
[1]Departamento de Astrofísica y Ciencias de la Atmósfera, Universidad Complutense de Madrid, Spain
[2]Instituto de Física de Cantabria (CSIC-Universidad de Cantabria), Santander, Spain
[3]Instituto de Astrofísica de Canarias, Tenerife, Spain
[4]Departamento de Astrofísica, Universidad de La Laguna, Spain
[5]Gran Telescopio Canarias, La Palma, Spain
[6]Institute of Astronomy, Cambridge University, United Kingdom
[7]European Southern Observatory, Garching bei München, Germany



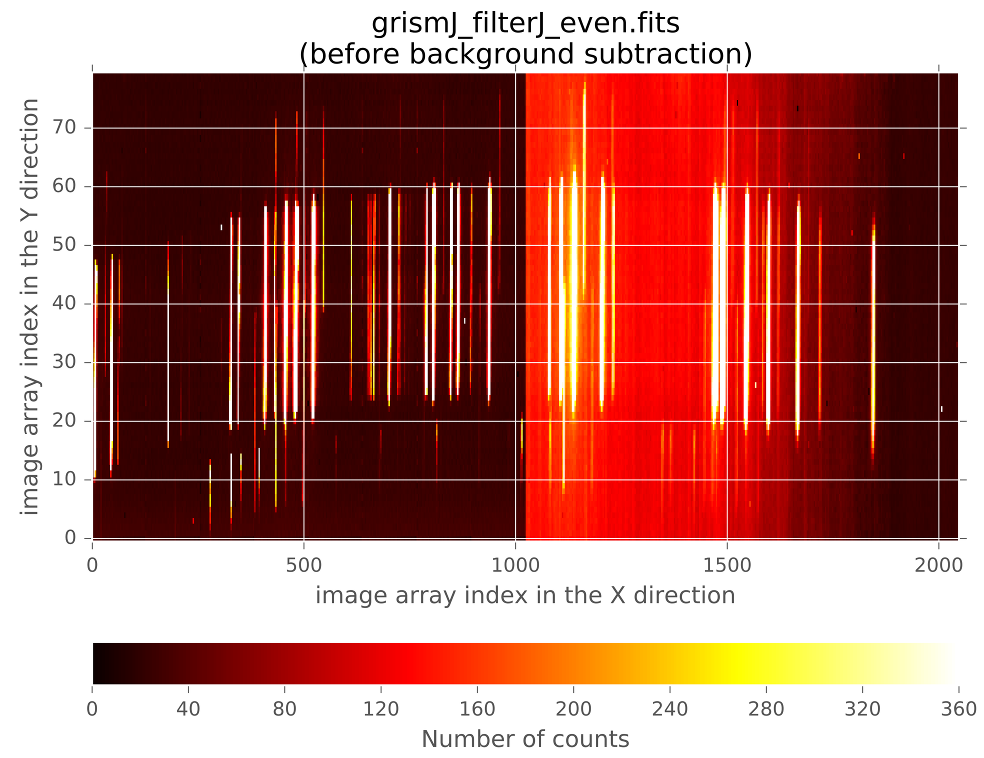
Summary

EMIR, the near-infrared camera and multi-object spectrograph operating in the spectral region from 0.9 to 2.5 μm, is being commissioned at the Nasmyth focus of the Gran Telescopio CANARIAS. One of the most outstanding capabilities of EMIR will be its multi-object spectroscopic mode which, with the help of a robotic reconfigurable slit system, will allow taking 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.

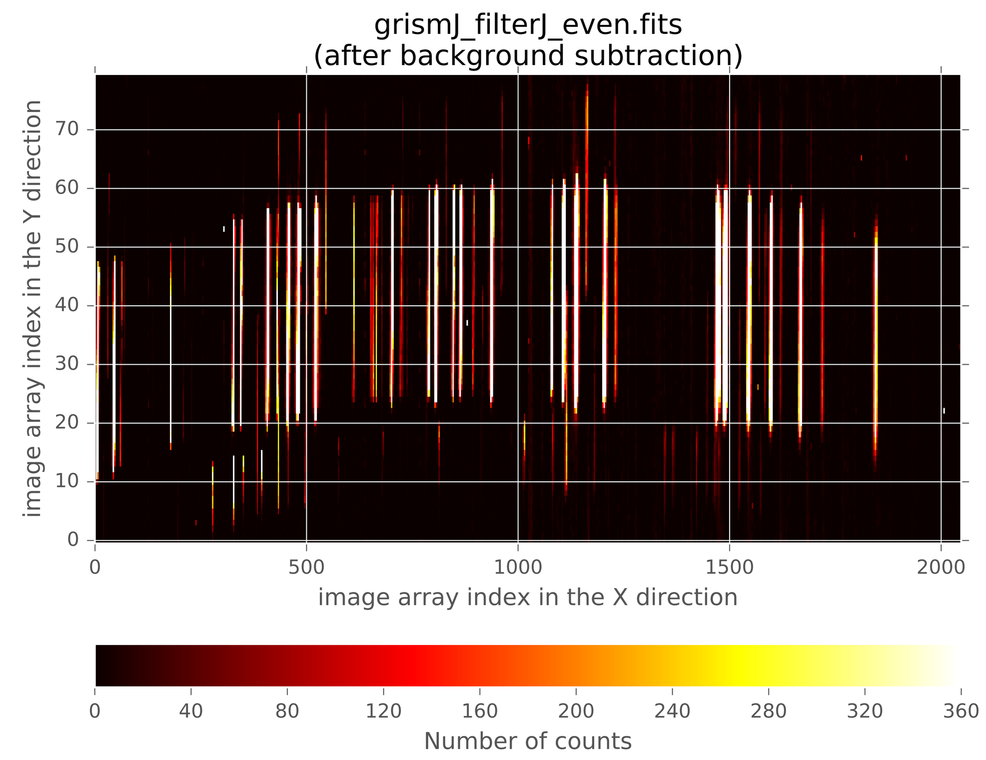
Focusing on the reduction of spectroscopic data, some critical manipulations include the geometric distortion correction and the wavelength calibration. Although usually these reductions steps are carried out separately, it is important to realise that these kind of manipulations involve data resampling and interpolation, which in addition unavoidably lead to the increase of error correlation and to resolution degradation. In order to minimise these effects, it is possible to incorporate those data manipulations as a single geometric transformation. This approach is being used in the development of PyEmir. For this purpose, the geometric transformations available in the Python package Scikit-image are being used.



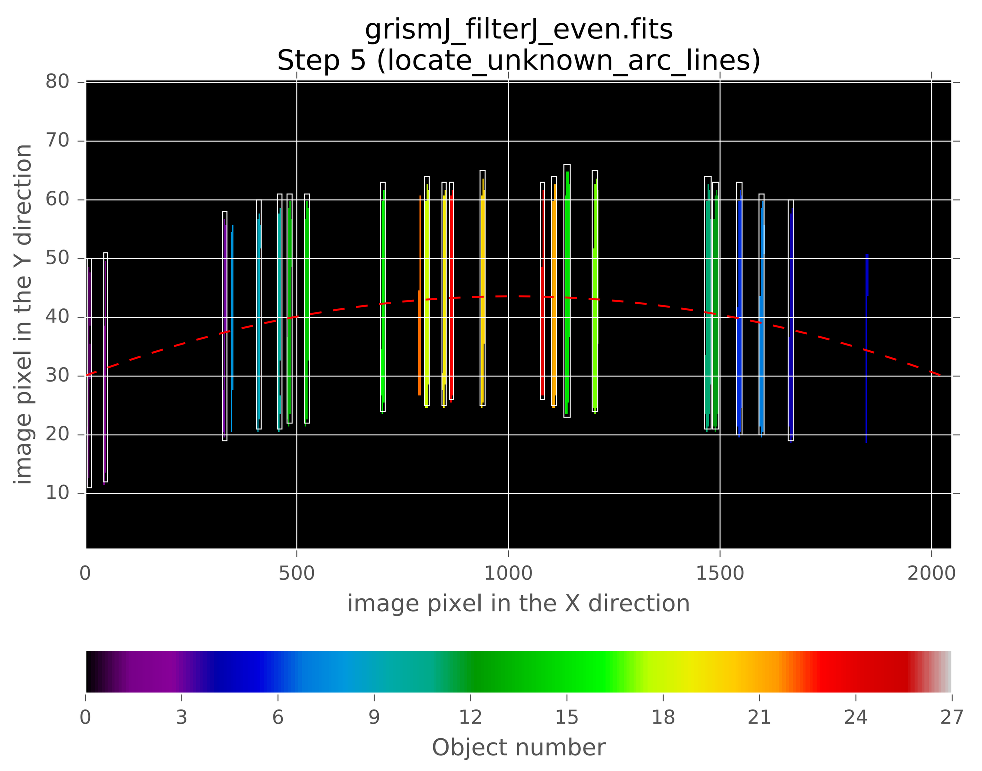
Arc lamp exposure obtained with EMIR in the J band, showing ~53 spectra. The EMIR Configurable Slit Unit is responsible for the multi-slit pattern in the instrumental focal plane. The X axis corresponds to the spectral direction whereas the Y axis is the spatial direction.



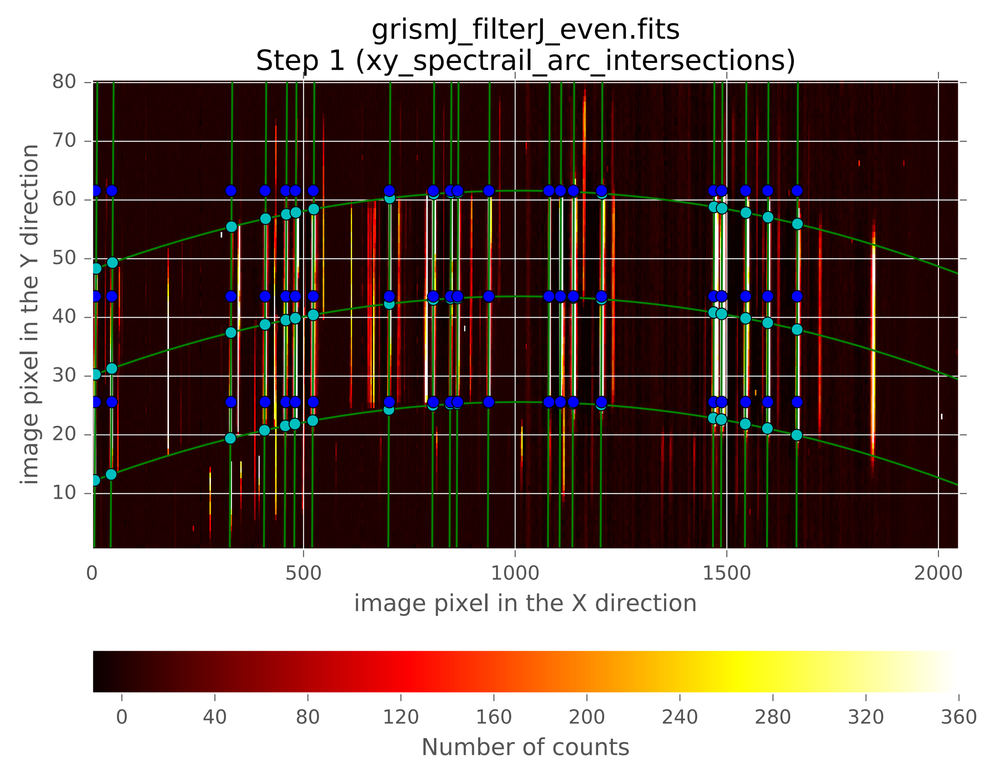
Example of arc spectrum corresponding to a single slitlet of EMIR (J band). The 2D image exhibits distortion in the spatial direction and is still uncalibrated in the wavelength direction.



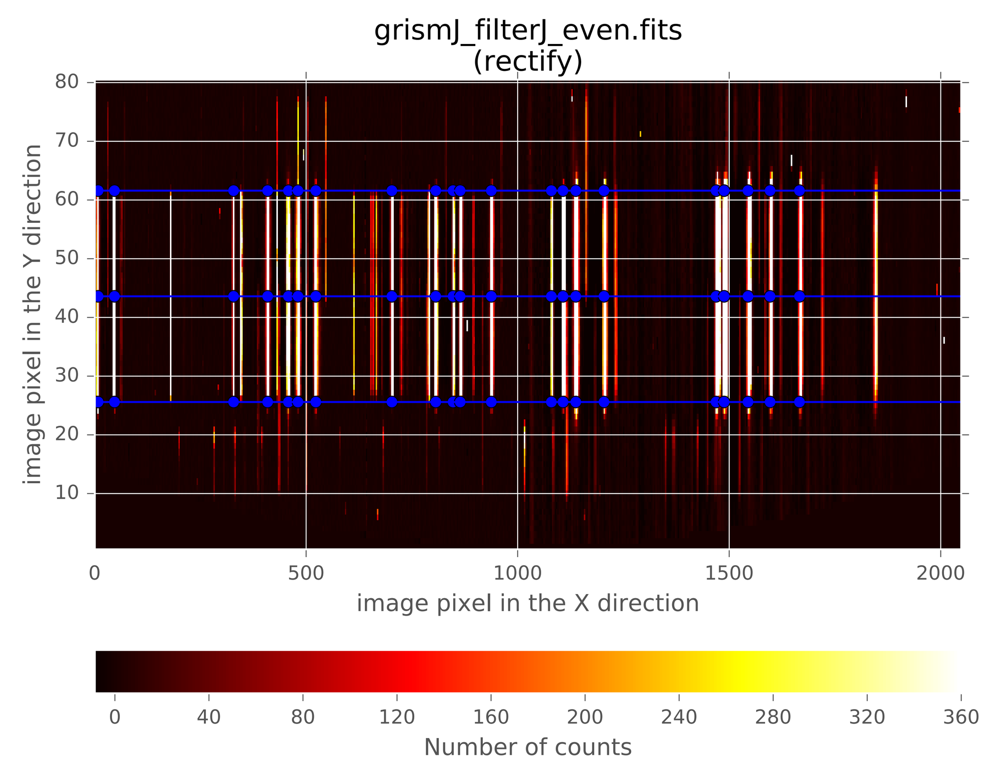
Features in a smoothed and background subtracted version of the previous image, above a given threshold, are identified using the Scipy image processing package ndimage.



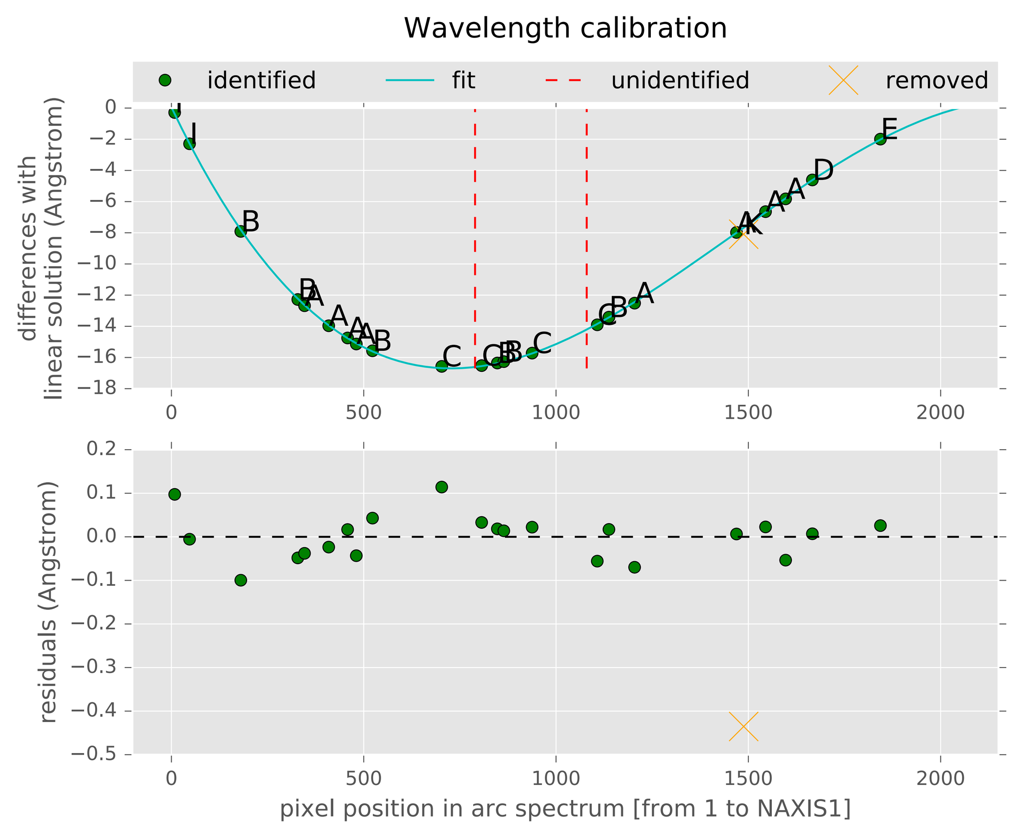
The image features are filtered imposing criteria based on expected arc line dimensions in order to identify individual arc lines. A tentative middle spectrum trail (dashed red line) is fitted to that selection of arc lines.



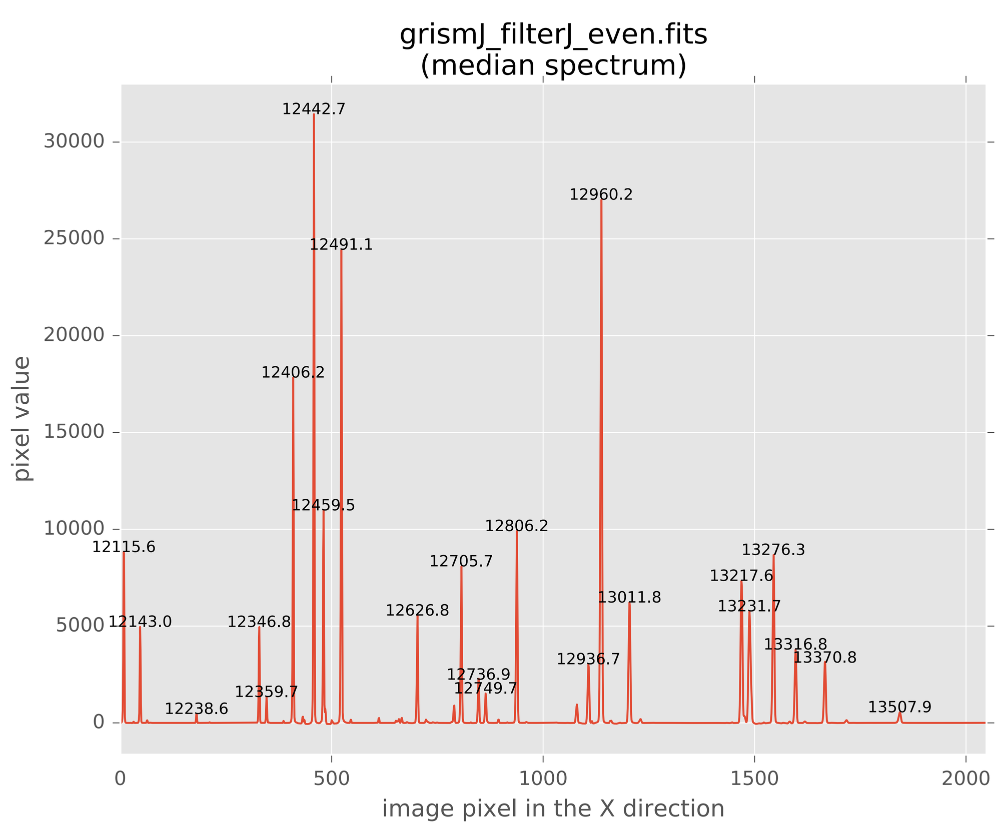
Intersections (green filled circles) of arc lines with expected spectrum trails are computed. The locations of those points in the rectified image (blue filled circles) are also determined. These points allow to compute the geometrical transformations required to rectify the image. They have been determined with the Python package Scikit-image.



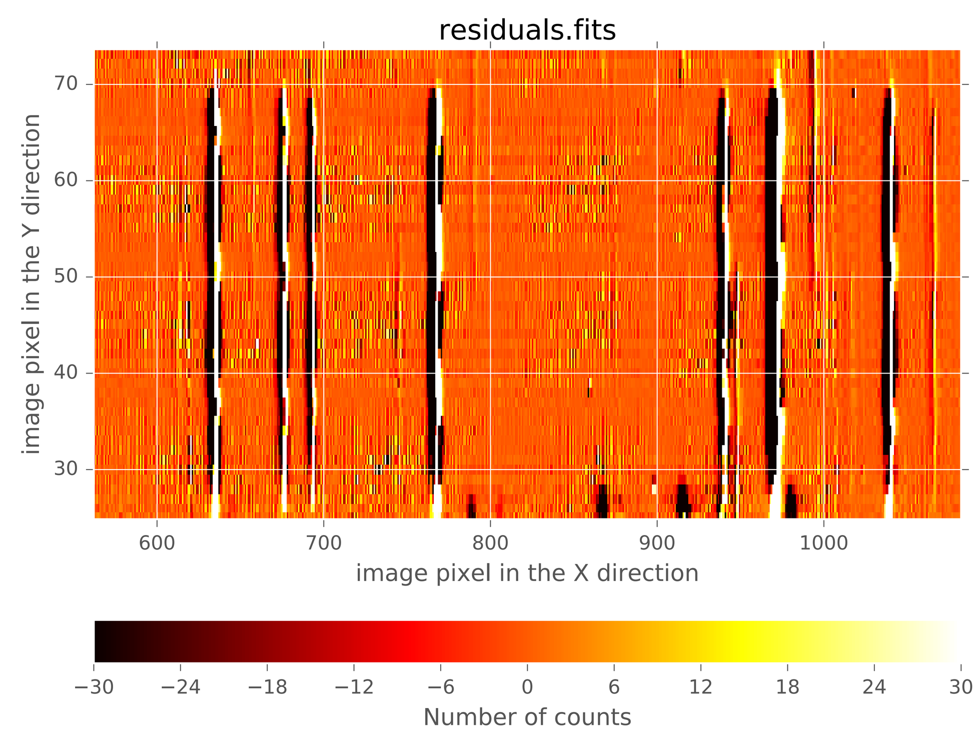
Applying the geometrical transformation to the original 2D image leads to the rectified 2D version of the arc image.



The rectified 2D image is collapsed to obtain a 1d spectrum with good signal-to-noise ratio. The line peaks are identified and a wavelength calibration polynomial is automatically computed. The different letters are labels that indicate the quality of the arc line identification.



Wavelength calibration solution of the collapsed arc spectrum. The associated polynomial can be mathematically merged with the initial geometrical transformation in order to carry out the rectification and wavelength calibration in a single step.



Detail of the image showing the difference when applying, in a single step, the rectification and wavelength calibration (white residuals), and when rectifying the image and then applying the wavelength calibration as separate steps (black residuals). It is clear that the second approach degrades more the spectral resolution than the first method, leading to wider arc 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 very short time under pressing conditions and with excellent results.

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