Fast spectrum extraction

from DSLR and FITS images

Christian Brock

Dresden Gönnsdorf Observatory

ASpekt 2021 – Annual Conference in Lübeck: 17. - 19. September 2021

Motivation

Exposure times are important, as under exposure reduces the SNR and over exposure invalidates the data. Finding correct initial exposure times or changing them due to variations in seeing conditions can be cumbersome. Often, especially for DSLR users this can be a manual process involving the use of image visualization software, e.g. Fitswork after the SD-card has been moved from the DSLR to a nearby computers. In our observatory the computer is located in a different room.

Figure 1: Dados and Canon DSLR mounted on a Meade SC16 at the Dresden Gönnsdorf Observatory. Photos provided by Josefine Liebisch

In our observatory we fixed this issue:

1. We control our DSLR using gphoto2 (see `http://gphoto.org/`).
2. In order to estimate the initial exposure time we calculate display image histograms for a range of time values (see figure 4).
3. For each science image we display the extracted spectrum image and the spectrum itself (see figure 5).

This article describes the third point above. It presents a quick-and-dirty image processing pipeline that finds, de-rotates and visualizes the observed spectra. Finding, i.e. segmentation of the spectrum is accomplished with background removal using sigma clipping [1]. The de-rotation angle is calculated from image moments [2]. The slit function as well as the spectrum are calculated from row averages and column-maxima of the de-rotated clipped image.

Pipeline overview

To extract the spectrum from the image we need to

1. locate the spectrum in the image and
2. detect whether the dispersion direction is tilted.
3. Once we have the image de-rotated and located we can extract the one dimensional spectrum as well as the slit function – if needed.

Slanting – if the spectrum is not only rotated but projected in such a way, that it forms a parallelogram – is out of scope of this paper.

1. Segmentation

Locating the spectrum in the image is a segmentation problem. In this pipeline we detect the image background with sigma clipping. Background mean (μ) and standard deviation (σ) are computed by first computing μ and σ for all image pixel I_{xy} and then iteratively recompute μ and σ for pixel with $I_{xy} \leq \mu + N\sigma$. It can be easily shown that this iteration must converge at some μ_b and σ_b. Having μ_b and σ_b we now discard all pixel $I_{xy} < \mu_b + M\sigma_b$. Remaining pixel belonging to the spectrum, are heavy noise or hot pixel. In the examples below N and M have been set to 3 and 10.

2. De-rotation

If the camera is tilted in respect to the spectrograph it can be seen as a deviation of the dispersion direction of the spectrum from the row direction of the image.
With the result in 1 we can use image moments to calculate the tilt angle. The tilt angle is the angle between the largest eigen vector of covariance matrix

$$\mathrm{cov}[I(x,y)] = \begin{bmatrix} \mu_{20}/\mu_{00} & \mu_{11}/\mu_{00} \\ \mu_{11}/\mu_{00} & \mu_{02}/\mu_{00} \end{bmatrix}$$

and the axis closest to that eigenvector where all μ_{xy} are central moments of the segmented spectrum. For further reading see [2].

3. Extraction

With the segmented and de-rotated image, we can again use image moments to find the center of gravity in slit direction y. It corresponds to the y-component of the centroid

$$\bar{y} = M_{10}/M_{00}$$

with M_{xy} being the raw moments – not to be confused with the central moments μ_{xy}. The slit size can be derived from the second central moment in y-direction – μ_{20}. It means something like the variance of pixel coordinates in the slit direction.
The extracted spectral images are displayed in figure 5.

Original images

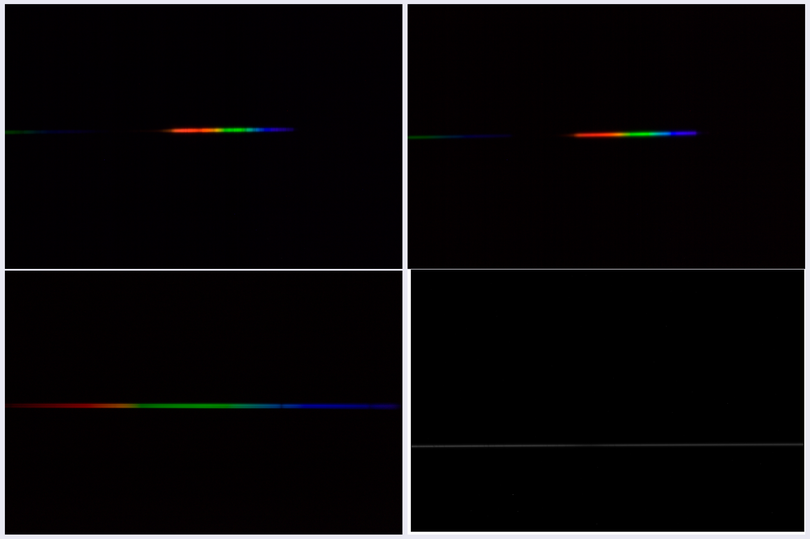

Figure 2: α Ori and β Ori in the top row are captured with a Dados 200l/mm grating and a Canon DSLR. α CMa on the bottom left was captured with a Dados 900l/mm grating and a Nikon DSLR. The last FITS image came from Bernd Bitnar with a LHires and a Sigma 1603.

Segmentation

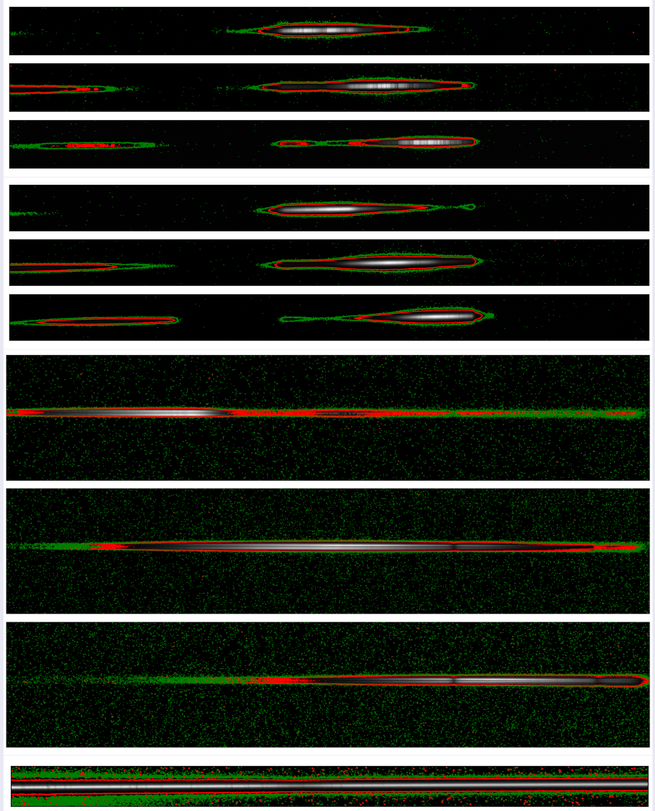

Figure 3: Segmentation of image layers. The contours of $\mu_b + 3\sigma$ are green and $\mu_b + 10\sigma$ red.

Histograms

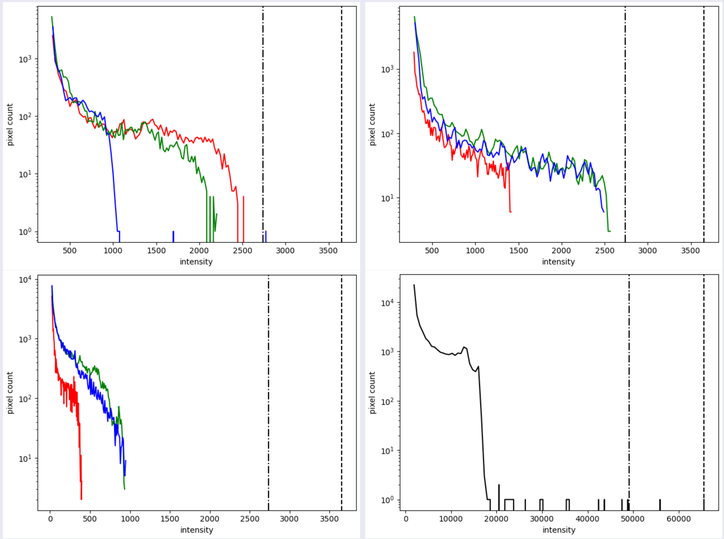

Figure 4: Pixel counts of the histograms are displayed on a logarithmic scale. Background pixel below $mu_b + 10\,\sigma_b$ are ignored. The vertical lines are placed at 75% and full well depth.

Extraction

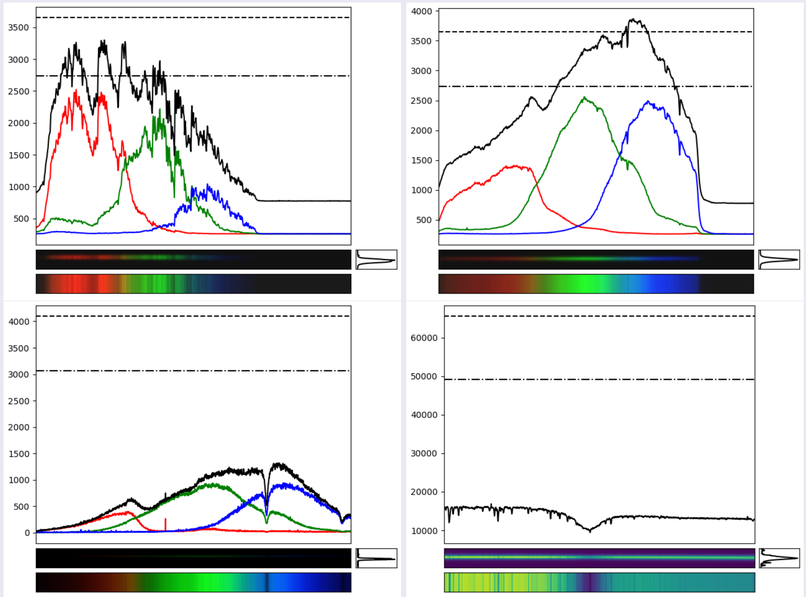

Figure 5: The extracted images, spectra and slit functions. For DSLR images, the sum of the three colors is displayed as black graph. The horizontal lines are placed at 75% and full well depth.

References

- astropy.org.
  Sigma clipping.
  `https://docs.astropy.org/en/stable/api/astropy.stats.sigma_clipped_stats.html`.
  Accessed on 2021-09-11.
- Wikipedia.
  Image moments.
  `https://en.wikipedia.org/wiki/Image_moment`.
  Accessed on 2021-09-11.