

FICUS – Fiber Coupler Unit for Spectrographs

User Manual v1.0

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1. Introduction

FICUS was designed and build by staff members of the Institute of Astronomy - UNAM , campus Ensenada B.C. The main goal of this instrument is to provide, first and foremost, observations in spectropolarimetric mode at San Pedro Martir – National Astronomical Observatory (SPM-OAN). FICUS can be described as having two main instrumental properties as it works as a coupler unit between the telescope and the spectrograph, and it allows to perform an analysis of the polarized states of light.

The design of FICUS is modular, consisting in two mechanical elements linked through optic fibers, (see Fig.1). The general design is based on Semel (1993), which is followed by most of the last generation spectropolarimeters such as NARVAL and ESPaDOnS.

In FICUS, the first module is attached to the stage of the telescope and the first optic element inside of this module is a mirror with a pinhole at the center. The mirror sends the image of the field of view to a camera that will be used to guide the telescope. The light from the punctual object of interest continues his trajectory through the pinhole. The circular polarization analysis of the light is then carried out using a Savart Plate (beam splitter) and a quarter wave plate (QWP). For the moment, it is not possible to obtain the linear states of polarization (Stokes Q and U), since the main scientific area of research of FICUS users is related to the measurement of magnetic fields in punctual sources, most of them stars, i.e. to the measurement of the circular polarization (Stokes V) in different spectral lines. Due to the beam splitter at the end of the Module 1, two optics fibers are required, each one transmitting an orthogonal state of polarization (see for example Landi degl’Innocenti 1982).

The fibers are thus the light transmission medium from Module 1 to Module 2. In the second module, the image of the optic fibers is correctly formed and oriented at the slit entrance. For this propose, we have a fine adjustment mechanism at the entrance of the second module (see Fig. 1 lower right panel) that permits to shift (displacements in XY plane) and to rotate the image of the fibers in order to properly align the two light beams in the slit direction (see Fig 2.4).

One important advantage of the fact the spectrograph is not attached to the telescope is the spectral stability. The mechanical efforts in the spectrograph (due to his own weight) that are inevitably present when the instrument is attached to the telescope, can be avoided with the use a decoupling system, as is the case in FICUS. In fact, during the observations the spectrograph is in a rest position on the ground, allowing to maximize the resolving power of each spectrograph.

In Table 1 we list some generalities of the FICUS main components.

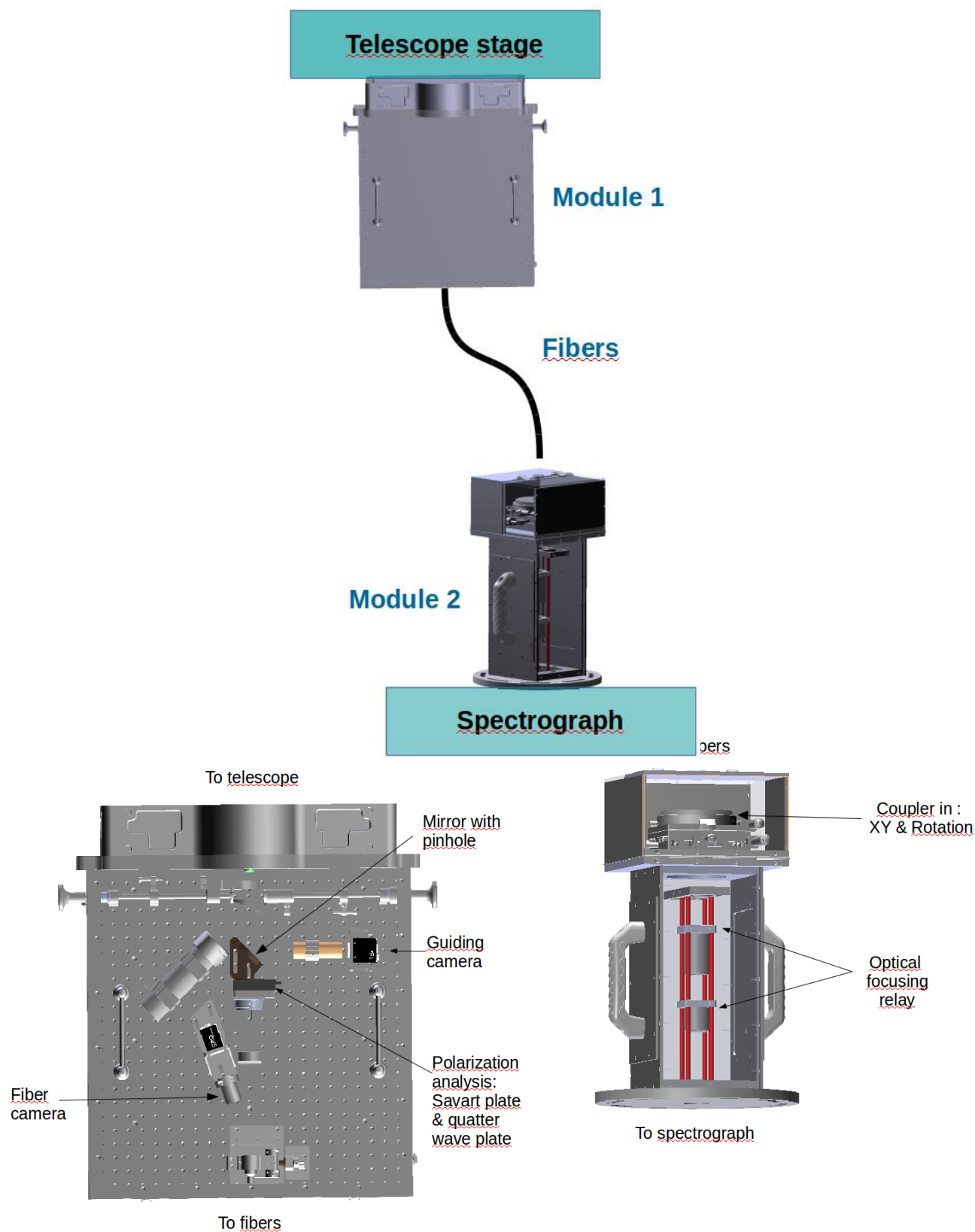


Fig. 1. Top: block diagram of FICUS. Left bottom : Internal components of Module 1. Righ bottom : Internal components of Module 2.

Table 1. Specifications of some of the components of FICUS

Savart Plate beam separation	$588 \pm 58.8 \mu\text{m}$	Pag. web
QWP retardance from 400 to 900 nm	$90 \pm 4 \text{ deg}$	Pag. web
Fibers	10 meters length 110 μm core 150 μm cladding > 95% transmission (from 450 to 950 nm)	Pag. web

2. Description of the User Interfaces

2.1 Main Window

Fig. 2.1 below shows the interface linked to the spectropolarimetric observations. In the following we briefly list the features that will be used with FICUS, the others are standard Boller & Chivens commands, and the reader is referred the corresponding manual. We also remind the reader that FICUS is set to measure circular polarization (**Stokes V**) only.

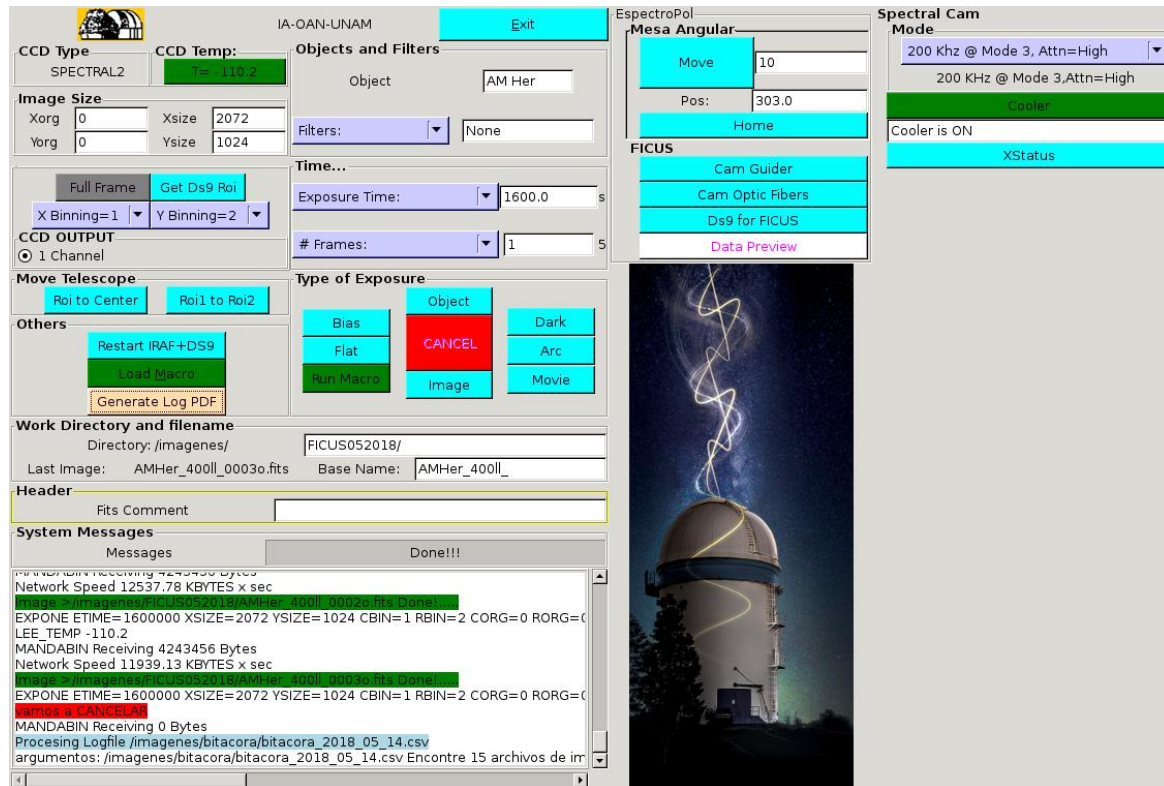


Fig 2.1 Main window of FICUS+Boller & Chivens

In the main window (under IA-OAN/UNAM):

CCD Type

X binning and Y binning: Used to set the binning in the spectral (λ) and spatial (flux) directions

Others

Restart IRAF+DS9: Re/launch the IRAF module as well as the display in case of problem.

Load Macro: Selection of the macro containing the observing sequence (33°,123°,213°,303°) and commanding the rotating stage (Mesa Angular)

Time

Exposure Time: Corresponding to 1 Stokes V exposure

Frames: Number of Stokes V exposure

Type of exposure

Bias

Arc

Run Macro

In Espectropol:

Mesa

Move: Steps in degrees performed by the rotating stage

Pos: Position (or angle) in degrees of the rotating stage

Home: Reset the rotating stage to its zero

FICUS

CamGuider : Click to launch the Guider

Cam Optic Fibers: Click to launch the camera to visualize the Fibers

DS9 for FICUS: Visualization in DS9 of the guiding window

2.2 Guiding Camera

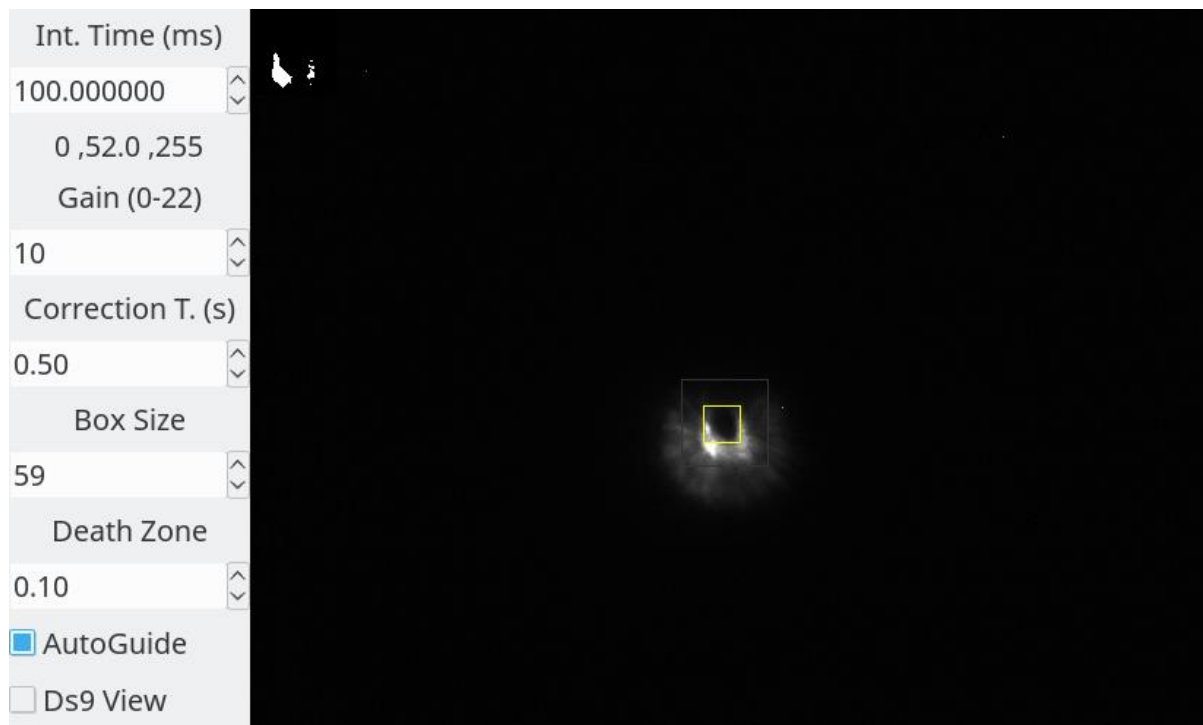


Fig 2.2 Main window of guiding camera

As we are using a system of fibers, the “only” collected light is that of the science target. For this reason, the latter is used to guide during the observations. This system provides a strong and stable guiding during the whole exposure time. Fig.2.2 shows the halo of the star and the dark pattern is the evidence

that most of the starlight has gone through the pinhole (which contour can be seen in the dedicated yellow box) and then through the fibers. A mirror of the emission in the guiding (grey) window is present in the upper left corner. The main entries are:

Int Times: The integration time in millisecond which has a limit of 20,000.00 ms

Gain: The gain which has a limit of 23.

Correction T. (s): Time for reloading the images

Box size and Death zone: Parameters set to define the grey box outside which the guiding is considered as lost.

AutoGuide: Click to launch the guiding

DS9 view: Click to display the same window in DS9

2.3 Fibers Camera

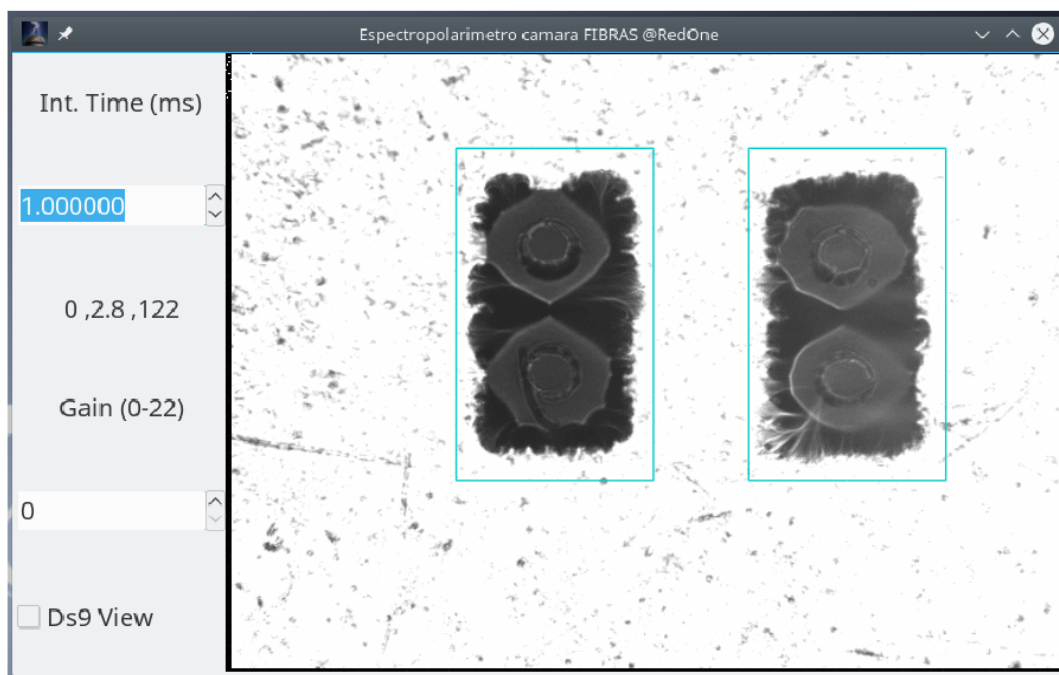


Fig 2.3 Fibers camera

Fig 2.3 shows the interface of related to the camera pointing at the fibers. Each set is seen within the rectangles. This interface is mostly for control and would mostly be used during the installation of FICUS as it is useful for correcting the position of the bundles of fibers (“tacon de fibras”). The integration time, gain and DS9 view can be modified by the user (similarly to the guiding camera) IF ABSOLUTLY needed.

2.4 Boller & Chivens Camera

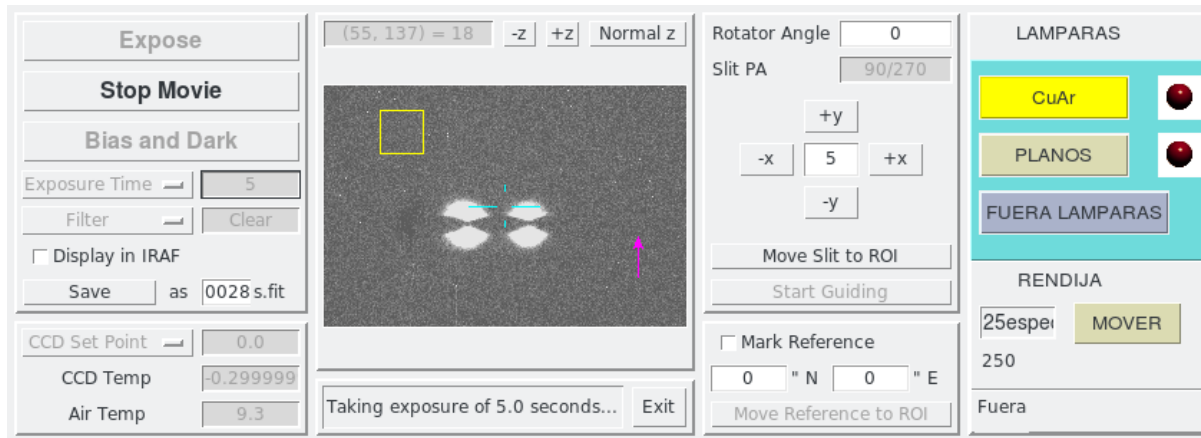


Fig 2.4 Spectrograph camera

The camera of the spectrograph allows us i) to check the position of the entries of the fibers on the slit (*see also the installation manual*), ii) to switch on/off the lamp for the obtention of the calibration lamp spectra (arc) and iii) to increase or decrease the slit width. All these features are those of the spectrograph and the only change is the double image of the object due to the polarimetric setting.

2.5 Resulting Spectrum

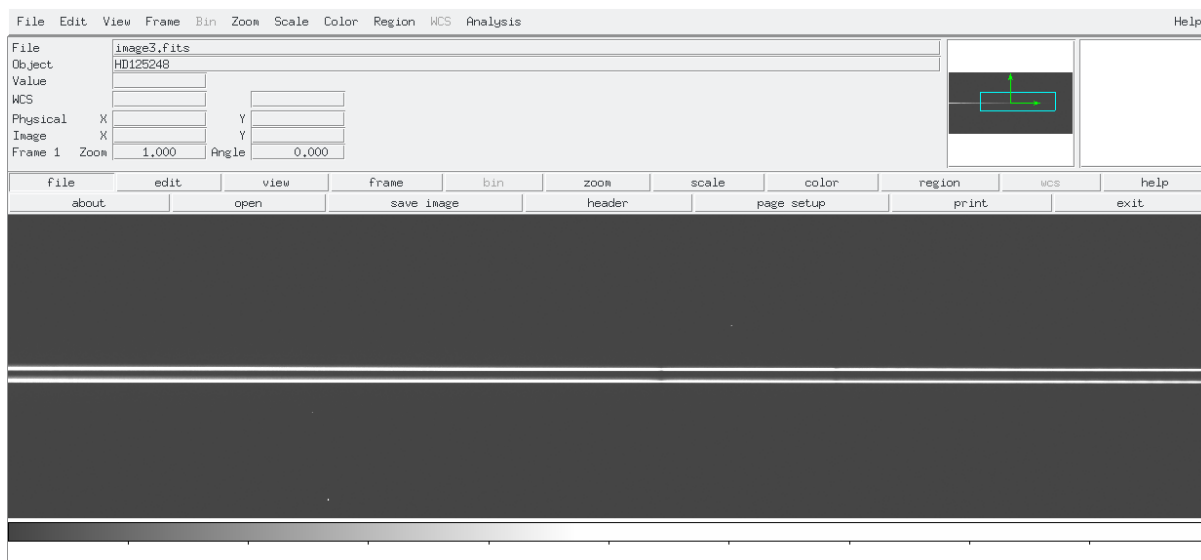


Fig 2.5a Spectropolarimetric spectra

The result of each spectropolarimetric observations are two spectra in one frame: one for the ordinary and one for the extraordinary ray. The denomination is not important, but what matters is that the spectrum called ordinary (or extraordinary) is always the same in the four exposures. Both dataset will be extracted and combined with the 6 others spectra (from the other 3 runs) so as to detect the Zeeman signature.

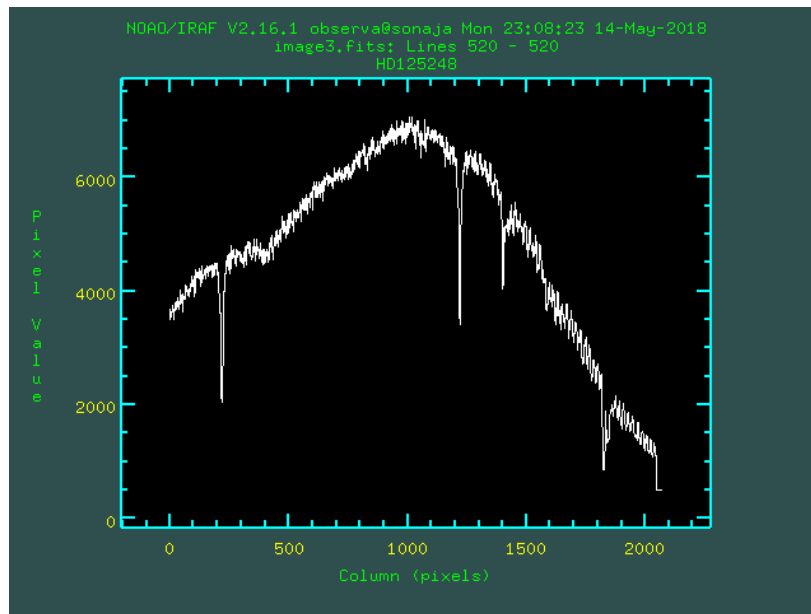


Fig 2.5b Extracted polarized spectrum from one of the two rays

3. Observing with FICUS

3.1 Focus

The first step is to set the focus. For an optimal data acquisition, we recommend verifying the focus every night. The best focus is found when the maximum of the light passes through the pinhole, you therefore ensure that you obtain most of the signal from your object. The steps are the following:

Select a star (which can be your target) not too bright but enough to have suffience amount of count is a relatively short exposure time.

In the main window, click on: FICUS > **Cam Guider**.

If needed, use the telescope pad to center the star in the yellow box.

Adjust **Int. Time** and **Gain**.

Manually move the value of the telescope focus and for each step acquire a frame in:

Type of exposure > **Object/Image**

As mentioned above the best focus is found when the maximum of the starlight passed through the pinhole. In this case the guiding system will emit a **BEEP sound**. This alert is set to tell the user that the intensity of the light, near or in the pinhole is low, and then can be related to a loss guiding. In this case, this will help us in identifying the optimal focus.

For a set of defined positions, calculate the mean total intensity (ray-o + ray-e) for each frame and plot the data versus the focus.

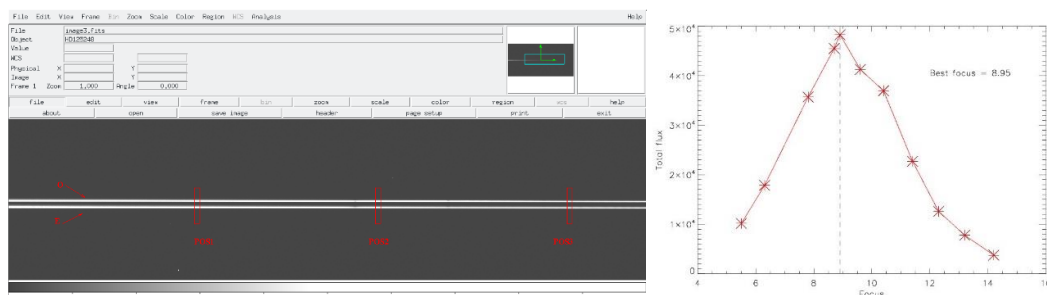


Fig 3.1 Example of flux measurements to determine the best focus

3.2 Observing strategy

A predefined Macro is already set in the macros directory: **FICUS.macros**.

- 1- Go to the object of interest.

Start the guiding (section 2.2) :

- Click on **Cam Guider**

Center the star in the yellow box.

Adjust **Int. Time** and **Gain**.

If you want to display the guider view in DS9: first click on **DS9 for FICUS** in the main window, then click of **DS9 view** in the Guider display.

Click on **AUTOGuide** to start the guiding process.

Check in the spectrograph camera that the two beams are well aligned and with similar brightness (section 2.4). At the time, **select the Slit width**.

Then click on **Load Macro** and go to the correct directory to select **FICUS.macros**. The macros contained the predetermined angles which combination will allow the circular polarization to be derived.

Select the **exposure time** which will be the same for all 4 exposures (or angles)

Click on **Run Macro** ...and you are all set !

IMPORTANT NOTES & TIPS:

- 1- The entry **FRAME** should **ALWAYS** be 1. If you want to repeat the sequence (4 expositions) re-rerun the macro!
- 1- Bias and Arc can be taken at any time in the same way as for “normal” spectroscopy. For the arcs, as the spectrograph is on the ground (and not attached to the telescope) there is no flexion to worry about.
- 2- We suggest a binning of 1 (spectral axis) x 2 (spatial axis) to optimize the use of the quick data reduction and viewer code provided.
- 3- The highest resolution grating, 1200l/mm, is preferred as it will give the optimum results for single (o few) line analysis.

4. Observing Specifications

4.1 Exposure time variation vs Magnitude

During the commissioning of the instrument several exposures of objects of different magnetics were taken and the results are shown below:

Exposure time (seconds)	Magnitude (mv)
640	6.4
240	4.8
240	5.2
500	6.4
240	5.0
1800	9.7

4.1 Magnetic field Intensity

As FICUS is coupled to the low-resolution spectrograph Boller & Chivens we are limited in the magnetic field intensity that can be detected. With the current configuration (and using the 1200 ll/mm grism) we establish that longitudinal field as low as 700-800 G can be reached.

However, the standard detection limit for FICUS+B&Ch is around 1 kG