Improvement of the low-dispersion spectroscopy at Rozhen NAO

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Abstract. The paper presents the ideas for improvement of the equipment for the low-dispersion spectroscopy at Rozhen NAO (National Astronomical Observatory) and their realizations. The design and tests of the new slit unit revealed that it allows increasing 2.2 times the observed spectral range, substantially shortens the time for positioning, increases the quality of the spectra, allows for automatic change of observed spectral range. On the other hand the new grism for the red channel of the 2-channel focal reducer FoReRo2 would give considerable increase of the spectral resolution. The higher time efficiency as well as the higher quality of the spectra are sure prerequisites for the successful solution of more astronomical tasks based on observations in this mode.

Key words: Astronomical spectroscopy

Introduction

Considerable part of the interesting astronomical objects are not accessible for high resolution spectroscopic observations due to their faintness. This mainly concerns the late stars. As a result they are insufficiently studied although they present the most numerous objects in our Galaxy. The low-resolution spectroscopy gives some possibility to overcome this problem. It allows to extract information about the emission of the faint stars into spectral lines as well as about their energy distribution into different spectral ranges.

In order to expand the possibility for a spectral study of faint objects (for which Coude spectroscopy is impossible) at Rozhen National Astronomical Observatory we undertook improvement of the equipment for low-dispersion spectroscopy with the 2-channel focal reducer FoReRo2 attached to the 2-m telescope.

1 Motives to improve the low-dispersion spectroscopy

Tests for low-dispersion spectroscopy at Rozhen NAO are made by the spectrograph UAGS (Popov, 1983; Mihov et al., 2006). Another attempt for low-dispersion spectroscopy was performed by the single channel focal reducer FoReRo.

A new better possibility to get low-dispersion spectra arose with the bringing into service of the 2-channel focal reducer FoReRo2 (Jokers et al. 2000). It offers several modes of observations: broad-band imaging; narrow-band imaging; long-slit spectroscopy.

A color dividing (dichroic) beam-splitter in the parallel beam of the focal reducer reflects the blue part of the spectrum and transmits the red part. Camera lenses in each "channel" form reduced images of the Ritchey-Chretien focal plane which are recorded by two CCD's. Filters and grating prisms can be put into the parallel beam after the color divider.

This device allows a long-slit spectroscopy with grating prisms (transmission grating cemented on a prism) and a slit at the Ritchey-Chretien focal plane. All parameters and the optical scheme of the focal reducer FoReRo2 can be found at the site of the Rozhen NAO: http://www.astro.bas.bg/forero/info.

The red channel of FoReRo2 has IR objective and CCD camera VersArray:512B (512 x 512 pixels, 24 x 24 μm). The grating prism (grism) of the red channel has 300 grooves/mm. This camera with the present grism gives, with slit width 110 microns (equivalent to 1.5 arcsec on the sky), spectral resolution 5.223 A/pix in the range 5000-7000 A.

The low-dispersion spectra made by the available equipment led to a number of significant results in different astronomical tasks so far. In the framework of this project we established that it would be possible to improve considerably the quality of the obtained low-dispersion spectra and to increase the time effectiveness of this mode of observations with relatively small resources and efforts.

Improvements could be searched for in several areas:

(1) Increase of the observed spectral range which is very important for many astronomical tasks. At present the extent of the observed spectral range is 1050 A in the blue channel and 2700 A in the red channel of FoReRo2.

(2) The change of the wavelength range to be done with a computer control but not manually. This would save time and achieve precise setting of the desired range.

(3) To seek a possibility to use the same flat field for different positions of the telescope. Currently, this is impossible due to mechanical deflection of the FoReRo2 construction.

(4) Visual control of the position of the object relative to the slit in order to accelerate the process of targeting and to allow guiding.

The current procedure for inserting the object into the slit includes 7 steps and takes more than 10 minutes. The manipulations are (Fig. 1): removing grism; removing the slit and making an exposition of the field to determine the location of the object onto the CCD matrix; setting of the slit and making direct image in order to determine the location of the slit projection on the matrix of the CCD camera; calculation of the correction of the telescope offset required to reconcile the position of the object and the slit; set the calculated correction; making control exposures with slit to estimate the light from the object passed through the slit (these short-cadence images cannot be used for science further); exposures after additional minor corrections of the telescope position to test the optimal position of the object by the best signal/noise ratio; setting of the grism and exposing the science frame. Some of the foregoing steps are made using the cart. When the telescope is pointing to the west the needed movements of the cart takes much time that extends considerably the "dead time".

The maximum exposure duration depends on the quality of the guiding (Bonev & Dimitrov, 2010) for a given telescope position but does not exceed a few minutes.

This long procedure is repeated for each new object as well as after several exposures during patrol observations for a given object. This results in gaps of the patrol, i.e. a low coefficient of the time covering of the cycle.

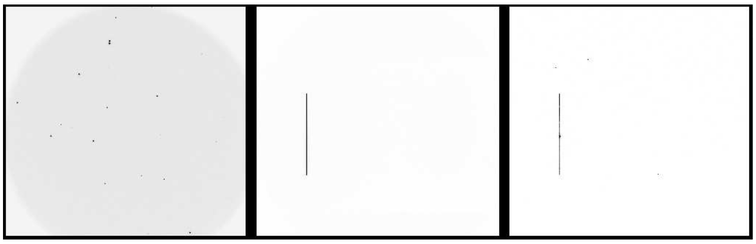

Fig. 1. Three of the seven steps (see text) of positioning

The slow and complex procedure of the inserting of the object into the slit leads to less than 50 % time efficiency of this mode of observations. Additionally, half of this prolonged procedure is made outdoors, sometimes under chilly winter conditions.

2 The new slit unit

One of the main shortcomings of the present low-dispersion spectroscopy at Rozhen NAO is the small spectral range. The solution seems simple: to change the smaller detector CCD VersArray:512B with the available VersArray:1300B which working area is 2.2 times larger and its inverse linear dispersion is 4.77 A/pix.

But it turned out that using the new CCD caused a new problem: the system design does not allow sealing of the space between the lens and detector. As a result a condensation began at the center and gradually spread outward and covered the whole entrance window of the camera within of 1-2 hours (Fig. 2). The reason for this condensation is the low-temperature cooling of the CCD VersArray by liquid nitrogen.

Solution of the condensation problem was found by blowing dry nitrogen vapors through newly-made holes in the space between the lens and the CCD window (Fig. 3). This method was borrowed from the solution of similar problem with the camera VersArray:1300B at the direct focus of the 2-m telescope. In our case the shutter of the camera VersArray:512B serves as a transient link between the focal reducer and VersArray:1300B, so holes had to be drilled in the shutter housing.

The use of the new CCD camera led to another problem as well: appearing of unwanted fringes. In principle, they should be cleaned by the flat field reduction. But it turned out that the flat field is different at the different positions of the telescope due to a mechanical deflection of the construction. The solution of this problem is creating of a moveable slit which can be shifted to compensate the deflection.

Such a slit whose fine motion is achieved by computer controlled stepper motor could also solve the problem of fast and precise change of the observed spectral range.

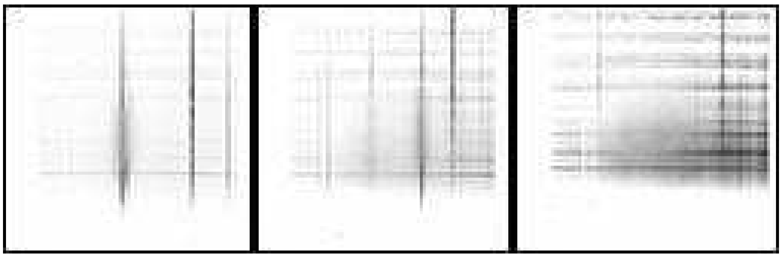

Fig. 2. Bad frames after the spread of the condensation

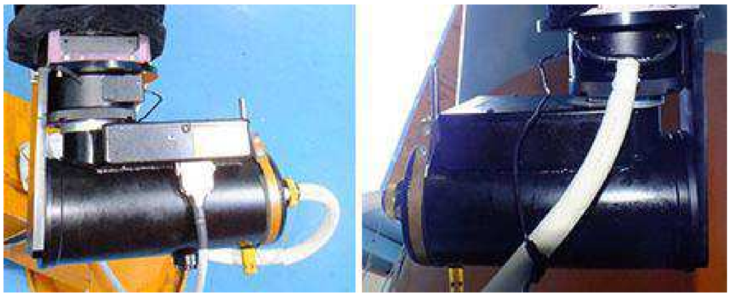

Fig. 3. The blowing of dry nitrogen vapors

We designed a scheme of a slit which is monitored by a camera and whose movement is remotely controlled. The block diagram of slit control is presented on (Fig. 4). Further we provide information about its realization.

The mirror slit itself (Fig. 5) is made of two polished stainless steel plates with a squared shape and size of 30 mm. The width of the slit can be changed manually in the range 0-1 mm whereas the distance between the plates is fixed by steel sheet with a calibrated thickness. The two slit plates are mounted on support which allows tilting of the slit plane about an axis parallel to its length. The slit is driven by a stepper motor controlled via USB. A screw with thread M 10 x 1.5 converts the rotation of the motor axis into a linear motion of the slit (Fig. 5). There is a possibility to change the speed of the rotation of the stepper motor within broad range: from 1 steps/s to 1000 steps/s.

To remove the side glimmers and interference pictures a screen was made. It is set below the slit and moves together with it (Fig. 6).

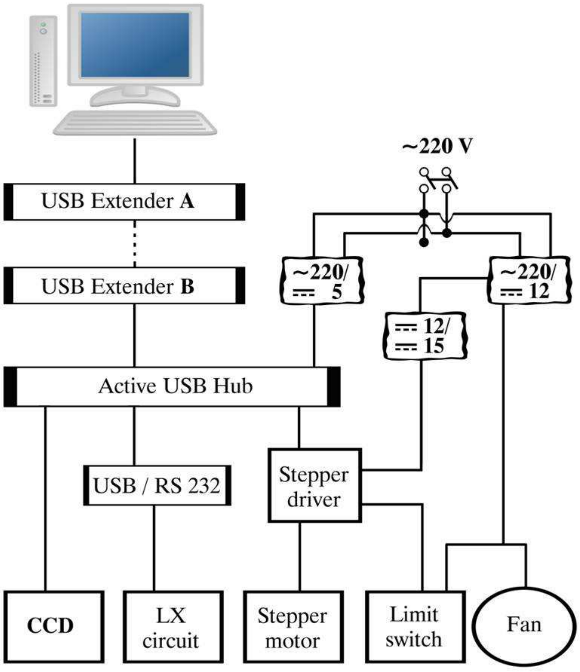

Fig. 4. Scheme of the remote control of the slit movement

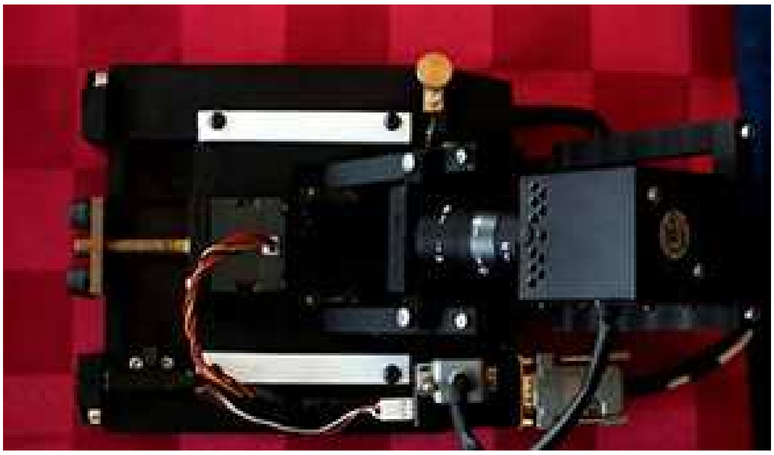

Fig. 5. The moving mirror slit

The choice of CCD camera that "looks" at the slit is not a trivial task because the sizes of the standard astronomical CCD cameras are large and they could not pass through the entrance space for the slit unit. The solution was Webcam-based color CCD matrix 640 x 480 pixels Sony ICX098 BQ, modified for long exposures using Steve Chambers method(http://www.pmdo.com/). Earlier such a modified webcam was used for the photoguiding in the Coude focus of the 2-m telescope (Popov et al., 2006).

Fig. 6. The screen removing the side glimmers

The camera of the new slit unit is hanged on a swivel allowing it to "bow" in order to pass through the entrance space as well as to adjust the tilt angle of optical axis to achieve mirror reflection from the slit and avoid vignetting of the working field (Fig. 7).

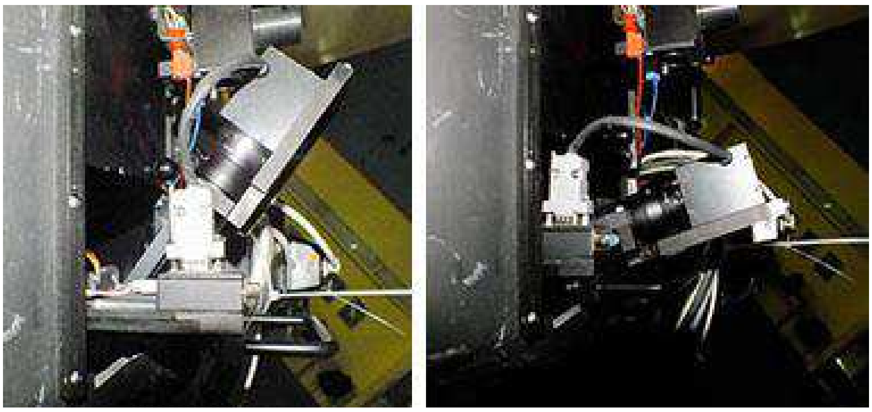

Fig. 7. The webcamera hanged on a swivel

The power supply unit of the new slit is fixed near the detecting part of FoReRo2. A special box was made to save the slit unit in non-operating status (Fig. 8).

3 Results of the tests of the new slit unit

The probation and tests of the new slit unit revealed that it fulfills the project goals.

(1) There is a full reproducibility of the dependency of the pixel position of the slit projection onto the CCD frame on the number of motor steps.

(2) The time for change of the observed spectral range by the new equipment is several seconds that is negligible compared to the several minutes spent so far for this procedure.

(3) The high accuracy of the slit positioning allows solving the problem of the flat fields due to deflection of the telescope.

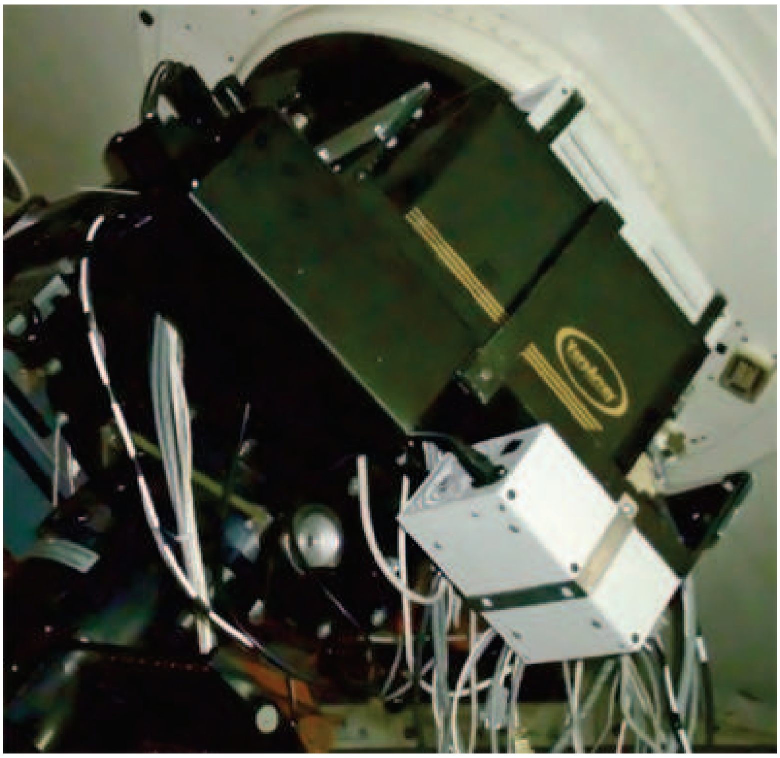

Fig. 8. The power supply and box saving the non-working slit unit on FoReRo2

(4) The new targeting takes a minute that is considerably faster than the time for the old procedure.

(5) The new slit unit allows positioning and guiding of objects of 15 mag.

(6) The tests revealed that often when the observer centered the telescope to next near star, it turned out directly into the slit without any additional corrections.

(7) One motor step changes the position of the slit by 7.5 microns and projects on the CCD as 2.6 microns (1/7.7 of the pixel size). This high precision is illustrated in Fig. 9.

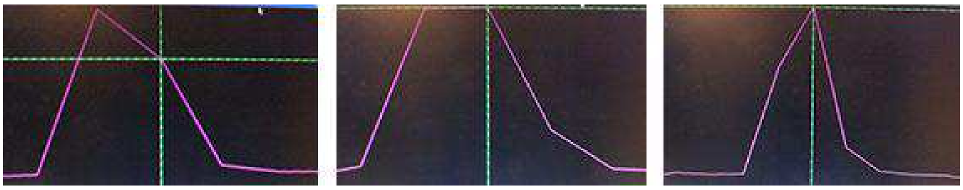

Fig. 9. The change of the contour of the slit projection for the shifting by 3 steps, i.e. with less than 0.5 pix

(8) The remote control and visibility of the slit simplified the observations and shortens considerably the time for preparation of the science exposure.

4 And the forthcoming improvement ...

Currently, the low-dispersion spectroscopy in the red channel of FoReRo2 is with a lower resolution than that in the blue one as the grism in the red channel has 300 grooves/mm while that in the blue channel has 600 grooves/mm. The new CCD VersArray:1300B attached to the red channel of FoReRo2 requires a new grism to improve considerably the low-dispersion spectroscopy for the red channel. The first criterion for its choice was to allow measurement of radial velocity of 12-13 mag stars with an accuracy of 10-15 km/s. The second criterion was the new device to give a possibility for investigation of the profiles of the spectral lines and more precise measurements of their EW. The last criterion for the new diffraction grating prism was to provide a possibility for getting Hα and Hβ lines simultaneously on the same spectrum of VersArray:1300B (important requirement for many astronomical tasks: spectral classification, chromospherically active stars, Be stars, cataclysmic stars, symbiotic stars, etc.).

We chose transmission grism 65999SP07-111R of the producer NewPort (USA) with parameters: 720 grooves/mm; nominal blaze angle of $43^0.1$; apex angle 50^0; ruled area: 110 x 72 mm (centered); efficiency $\geq$ 45 % absolute average S- and P-polarization peak efficiency at 550 nm; material is transmission grade BK-7 with broadband A/R coating; central wavelength 550 nm.

The new grism is expected to be available in August 2012. It will improve the quality of the low-dispersion spectroscopy at Rozhen NAO considerably because its inverse linear dispersion 2 A/pix will be 2.4 times higher than that of the present grism. Thus, we will approach the parameters of a moderate-dispersion spectroscopy.

5 Conclusion

The new slit unit and the new grism expand considerably the possibilities and quality of the low-dispersion spectroscopy at Rozhen NAO trough:

(a) increasing of the observed spectral range;

(b) substantial shortening of the time for positioning;

(c) increasing of the quality of the spectra;

(d) automatic change of the wavelength range;

(e) increasing of the spectral resolution.

Ultimately, the new equipment allows to observe about 4 times more objects per night and the obtained spectra are of higher quality. This naturally leads to widening of the range of the possible tasks based on observations in this mode.

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