UPGRADING THE SOLAR INSTRUMENTS FOR SPACE WEATHER OBSERVATIONS AT AIRA

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Abstract. In this article, we describe our work for upgrading the solar instruments at the Bucharest Solar Station belonging to the Astronomical Institute of Romanian Academy (AIRA). Our goal was to achieve the acquisition of full-disk and high-resolution images, useful for Space Weather programs and solar synoptical observations.

Key words: Sun – photosphere – chromosphere – astronomical instruments – CCD camera.

1. INTRODUCTION

Solar Station at AIRA was established in 1956, by endowment of a dome with optical instruments produced by Carl Zeiss Jena. The instruments existing from that times are 3 refracting telescopes, with the diameter of the lens of 130, 110 and 80 mm respectively, all have a F/15 scale/focal ratio. The mount, which is still in use today, is a German Equatorial mount produced by the same company (Carl Zeiss), with tracking provided originally by a DC motor having a rheostat for fine adjustment (sidereal, solar, lunar tracking). The refractors were named Ref A (130/1950 mm), Ref B (110/1650 mm) and Ref C (80/1200 mm) and we use these names throughout this article.

Before the current upgrade, the Solar Station was endowed with a Herschel prism for white-light observations and a small Skyris 274 camera (1600x1200 pixels, 4.4 microns/pixel, 8 bit colour resolution) for Ref A , while Ref B was equipped with a Solar Spectrum H-alpha filter and a CCD camera - ATIK 4000 (Dumitrache *et al.*, 2016).

The H-alpha filter requires highly parallel incoming light beams, therefore a telecentric focal length extension called TZ2 was installed on Ref B using a custom made cylindrical adapter. The optical scheme of Ref B existing in 2016 is presented in Fig. 4. Unfortunately, this set-up did not offer full-disk images of the Sun, suitable for synoptic observations. Sample of images obtained before upgrade are shown in Fig. 2. In the right image a 0.5X focal reducer was used and the vignetting is bad.

Our purpose was to perform synoptic solar observations for space weather programs. This objective imposed us to envisage few upgrading task of our instruments.

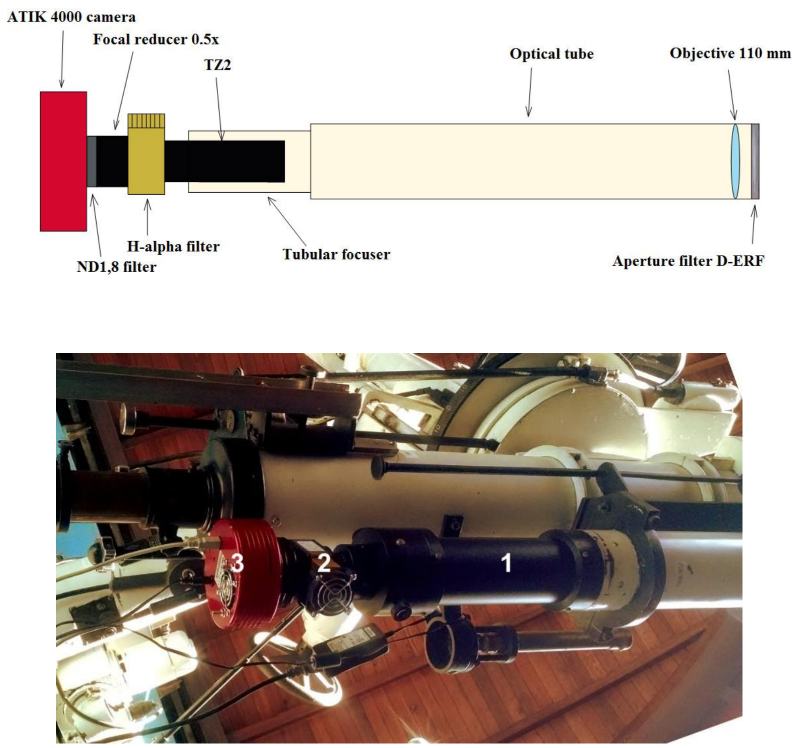


Fig. 1 – Optical scheme and photo of Ref B before upgrade: (1) TZ2 adapter, (2) Ha filter, (3) ATIK 4000 CCD.

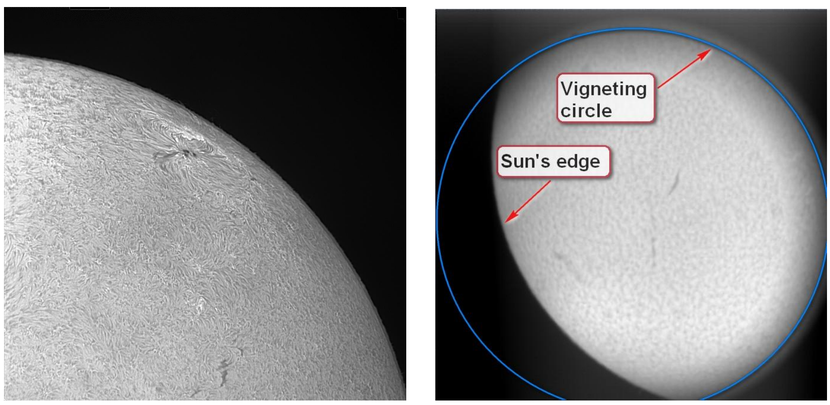


Fig. 2 – a. Halpha images without reducer before upgrade (left)
b. Vignieting with 0.5X reducer (right).

2. IDENTIFYING THE PROBLEMS AND SOLUTIONS

In our attempt to technical improve our instruments we have identified the following problems and steps in resolving them:

1. Attaining full disk images of the Sun with a better resolution than 1 arcsec/pixel, in accordance with ESA requirements for Space Weather patrol observations.

2. Installation of the third refractor Ref C on the same mount and align it with existing ones. This refractor, according our estimations displayed in 3 should have allowed us to get a full disk image of the Sun.

3. The polar alignment was inaccurate, since the mount was installed in 1956. That is why the drift could be seen over longer image series and, if the field is narrow, the solar disk is getting out the field of the camera.

4. The H-alpha Solar Spectrum Filter has a sensitive layer and must be kept at a positive 5°C temperature. If the outside temperature is lower, the filter could be irreversibly damaged. On winter we must carry the filter in the office and realign the system everyday, so a heating system had to be designed and manufactured.

2.1. FULL DISK IMAGES

The first problem was solved by choosing CCD cameras with specifications that in combination with the telescopes meet ESAs specific requirements. In the table displayed in Fig. 3 there are two camera types that meet requirements both for Halpha and white light. We obtained a new ATIK 11000 camera for Ref C (H-alpha), which become the dedicated camera for Ref C (H-alpha) and the ATIK 4000 was changed on Ref A for white light image acquisition. In the table displayed in 3 are printed the parameters of the instruments before and after upgrade.

Other technical challenges accompanied the changes of camera. We required a new ERF filter for Ref C to block most of the radiation coming from the Sun, with a narrow window at the H-alpha wavelength (656.3 nm +/- 50 nm). The filter had no frame, so we used a set of custom clamps, made from thin a sheet of brass, which hold the filter in front of the objective, avoiding optical aberration that could be induced by tensions in the mount (Fig. 4).

Our focal reducer had 0.5X and the vignetting induced in the field was pronounced, so we had to address this problem. We made a new, short barrel for the focal reducer, which transformed the Optec NHW reducer in about 0.7-0.8X one, and which allowed us to obtain a full disk image of the Sun.

All these actions to transform the solar instruments gave us three refractors with different specifications for distinct types of solar observation.

Camera	Atik 11000			Atik 4000		
Refractor	RefA	RefB	RefC	RefA	RefB	RefB
Aperture D	130	110	80	130	110	110
Focal length F	1950	1650	1200	1950	1650	1650
Telescope scale	15.0	15.0	15.0	15.0	15.0	15.0
tz2	1	1	2	1	1	2
reducer	1	1	1	0.7	1	1
Focal final	1950	1650	2400	1365	1650	3300
a=1/rad	57.3	57.3	57.3	57.3	57.3	57.3
rad	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174
c	206265	206265	206265	206265	206265	206265
wavelength	WL	WL	Ha	WL	WL	Ha
lambda	5700	5700	6563	5700	5700	5700
angrez (in rad)	0.93	1.10	1.75	0.93	1.10	1.10
rez in arcsec	1.10	1.30	2.06	1.10	1.30	1.30
ccd px	0.009	0.009	0.009	0.0074	0.0074	0.0074
no. of px	2672	2672	2672	2047	2047	2047
ccd chip	24.0	24.0	24.0	15.1	15.1	15.1
px/D	0.95	1.13	0.77	1.12	0.93	0.46
arcsec/px	0.43	0.43	1.00	0.48	0.69	1.37
sun [gr]	0.533	0.533	0.533	0.533	0.533	0.533
imag [mm]	18.14	15.35	22.32	12.70	15.35	30.70
fov [gr]	0.71	0.84	0.57	0.64	0.53	0.26
fov/sun	1.33	1.57	1.08	1.19	0.99	0.49

Fig. 3 – CCD cameras and refractors comparison parameters.

Fig. 4 – Mounting mode of the ERF filter.

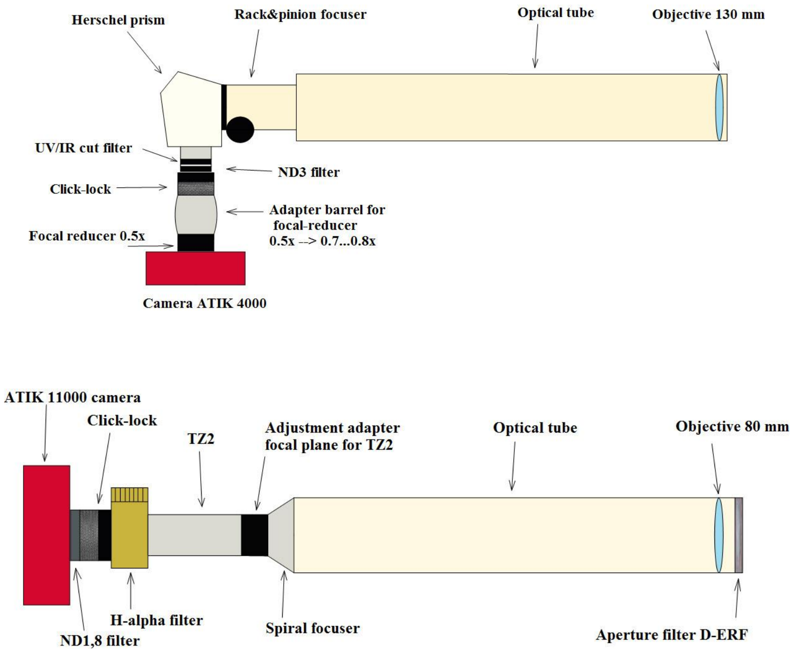


Fig. 5 – Optical diagram for Ref A (top). Optical diagram for Ref C (bottom).

Ref A became a photospheric instrument (white light) and it's optical diagram is shown in Fig. 5 top. Focal reducer with the new adapter was mounted after the Herschel prism and a ND3 filter was required to further reduce the most intense solar radiation coming from the refractor with greater aperture (Fig. 5 top).

Ref C was designated for observations of chromosphere (H-alpha) and its optical diagram is shown in the Fig. 5 (bottom). A supplementary ND1.8 filter was used to avoid CCD sensor saturation of the images. The Neutral Density (ND) filters have no effect on the spectral response, since the total energy of the Suns radiation is uniformly reduced with wavelength. The index in the denomination of the filters is the power of reduction the intensity of light:

$$\frac{I}{I_0} = 10^{-d} \quad (1)$$

where I is the input intensity and Io is the output intensity.

The refractor Ref B is on standby and it will be soon upgraded to be used in observations of the solar active regions or filaments, in different scientific programs.

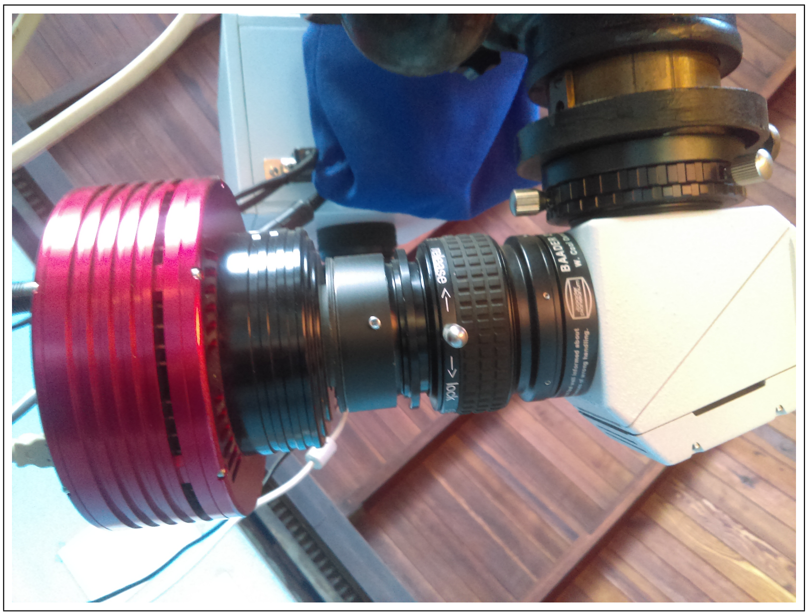


Fig. 6 – Images of the new configurations of the instruments: Ref A (top) and Ref C (bottom).

2.2. REF C INSTALLATION

A technical problem was the installation of Ref C (80/1200 mm) on the same mount with the other two refractors (fig. 7). Fixing this refractor on the mount was solved by manufacturing two rings with collimation screws and a mounting plate which hold the Ref C on the mounting rings of Ref B. We had collimate the Ref C with the Ref A and used it in dual observations, white light and Halpha in the same time.

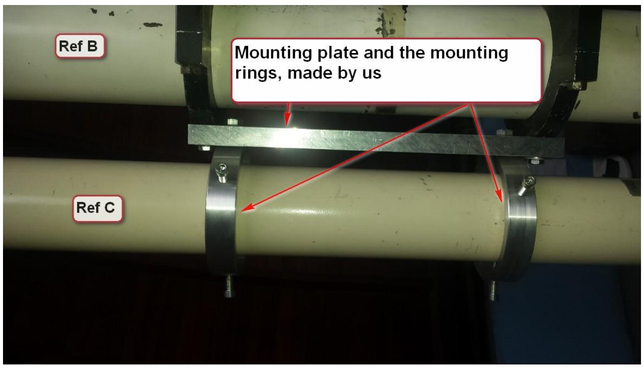
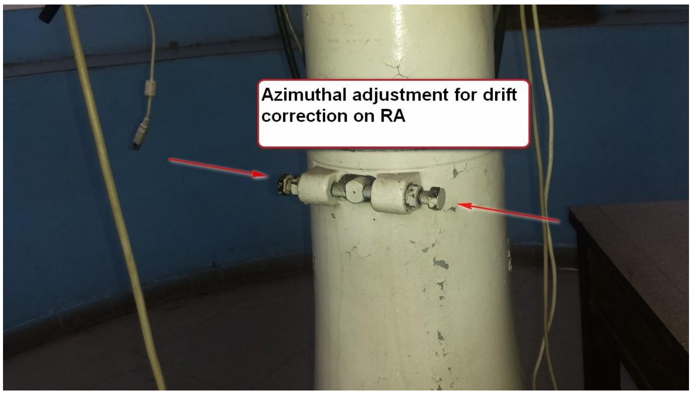


Fig. 7 – Installation of Ref C on the equatorial mount and on the mounting rings of Ref B.

2.3. POLAR ALIGNMENT

The polar alignment of the mount was performed using the classical method of drift (Johnston, 2000). The mount was made in the 1956s and has no polar finder, or any other kind of system for the correct alignment. We used a very sensitive and fast CCD planetary camera, namely ZWO ASI 174, that shows a medium magnitude star in real time.

On the Right Ascension we followed the drift of a near meridian stars and adjusted the screws to move the axis in order to compensate the drift. We followed two stars near the celestial equator – one in the east and one in the south – and we adjusted the screws according to the drift we could see on the screen.



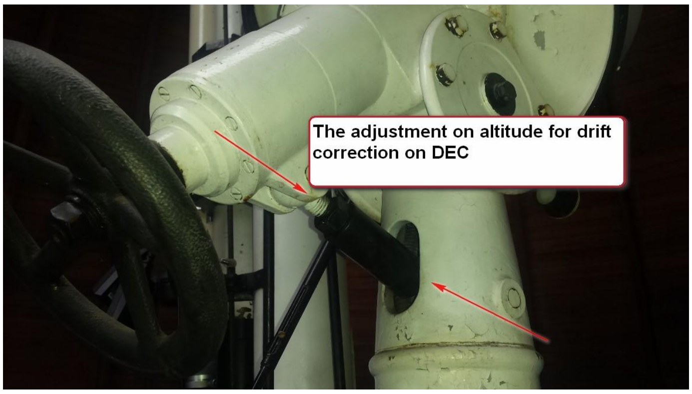


Fig. 8 – Right ascension (top) and declination adjustment (bottom).

After the polar alignment the drift of the mount is small but we observe that the Right Ascension compensation movement is slight in advance than the celestial rotation of the Sun. The controller has no adjusting knob outside the box, it is based on a fixed quartz clock and a custom frequency divisor. Further solution for the mount upgrade will be considered when a project for the instrument robotisation will be envisage.

2.4. HALPHA THERMAL INSULATED BOX

This point is a work in progress, but very close to be done. We build an isolated box around the Halpha Solar Spectrum filter with an intelligent WiFi controlled heater, powered by a 12V power supply and a UPS with extended backup to protect the power line from blackouts at all times (Fig. 9). We used a FLIR Thermal image camera to measure the temperatures inside and outside the insulated box and the results are displayed in Fig. 10. This subject will be detailed on another paper.

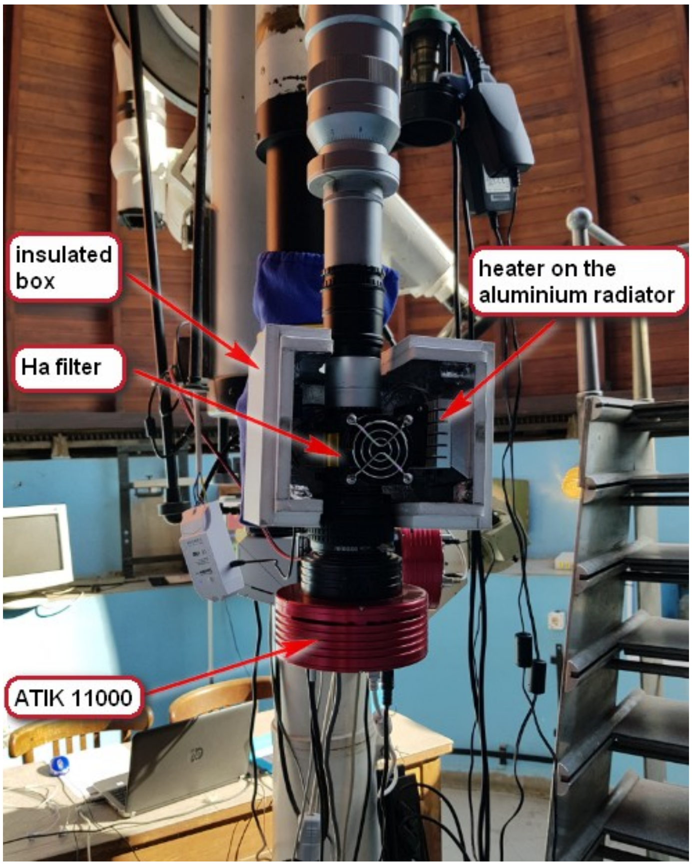


Fig. 9 – Thermal insulated box.

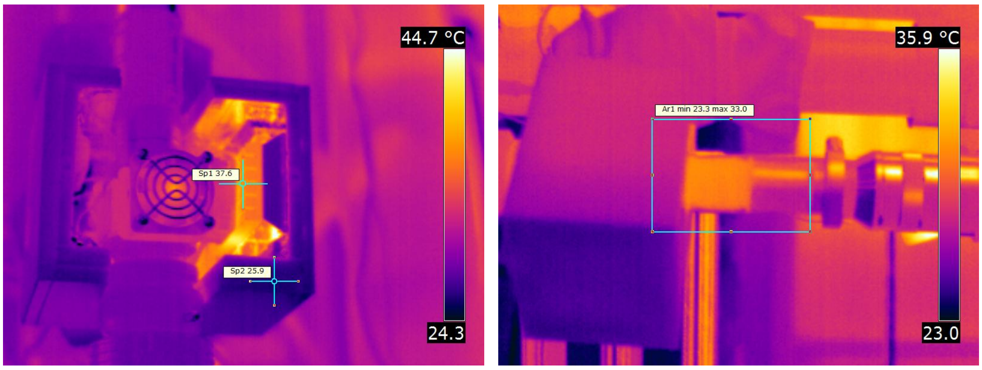


Fig. 10 – left: box open; right: box closed (FLIR camera images).

3. CONCLUSIONS

The main goals of the work was attained successfully. Our work contributed to the restart of the solar patrol observations at the Bucharest Observatory after a 20 years gap.

The ongoing Solar Patrol Program with synoptic observations are used in the Space Weather projects. Our daily white light and Halpha solar observations (selection) are published on the site http://solar1.astro.ro, in fits and jpeg format. The level0 fits files are archived and a selection of level1 data are available on the web site Observations section.

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