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LUCKY IMAGING AT VIDOJEVICA

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Abstract. We use a Lucky Imaging technique to obtain images with much improved angular resolution. We present the first results from a short observational campaign on the 1.4 m telescope "Milanković" at Vidojevica and quantify the performance of our system when astronomical seeing is 1.5 arcseconds or more. Also, we are investigating the limits of our equipment and possible application to other observational programmes.

1. INTRODUCTION

As early as from 2011 researchers of the Astronomical Observatory in Belgrade who study visual double stars have been trying to get the necessary equipment for speckle interferometric technique of observing these objects and/or lucky imaging. Here we present lucky imaging technique which efficiently uses a high number of images in order to freeze the influence caused by atmospheric turbulences. This technique improves the image resolution under the limits imposed by atmospheric seeing.

A fast CCD camera Andor iXon 897 Ultra was obtained in 2017 and it was tested immediately at the 60 cm telescope "Nedeljković" (Pavlović et al. 2018). Due to problems with opening the dome inside which the 60 cm telescope was situated, this CCD camera was transferred to the left port of the 1.4 m telescope "Milanković". Telescope "Milanković" optical configuration is Ritchey-Crétien with "bent" Cassegrain focus which provides users with two available ports where instruments can be mounted. After a short time at the left port of this telescope a focal reducer and a new Andor iKon-L CCD camera were mounted, whereas the Andor iXon 897 Ultra CCD camera was moved to the right port without focal reducer. The left port has a focal reducer which reduces the focal length of the telescope from 11.2 m to 7.1 m. This would be an ideal configuration: at the left port there is a good camera with a large field of view, whereas at the right one an ultrafast camera. For the lucky imaging technique it is necessary to use concurrently two CCD cameras, one capable of obtaining frames of short exposures, of the order of a few milliseconds, and another one which has a wide field of view used in orientation determination, i.e. position angle. Due to its alt-azimuth mount, telescope "Milanković" has derotators for the field of view on both ports and those derotators are not synchronized. This produces a problem in determining the position angle of the components of double stars. To solve this, it was necessary to provide another CCD camera and selector instrument in order to mount both cameras at the same telescope port. Finally, the equipment for lucky

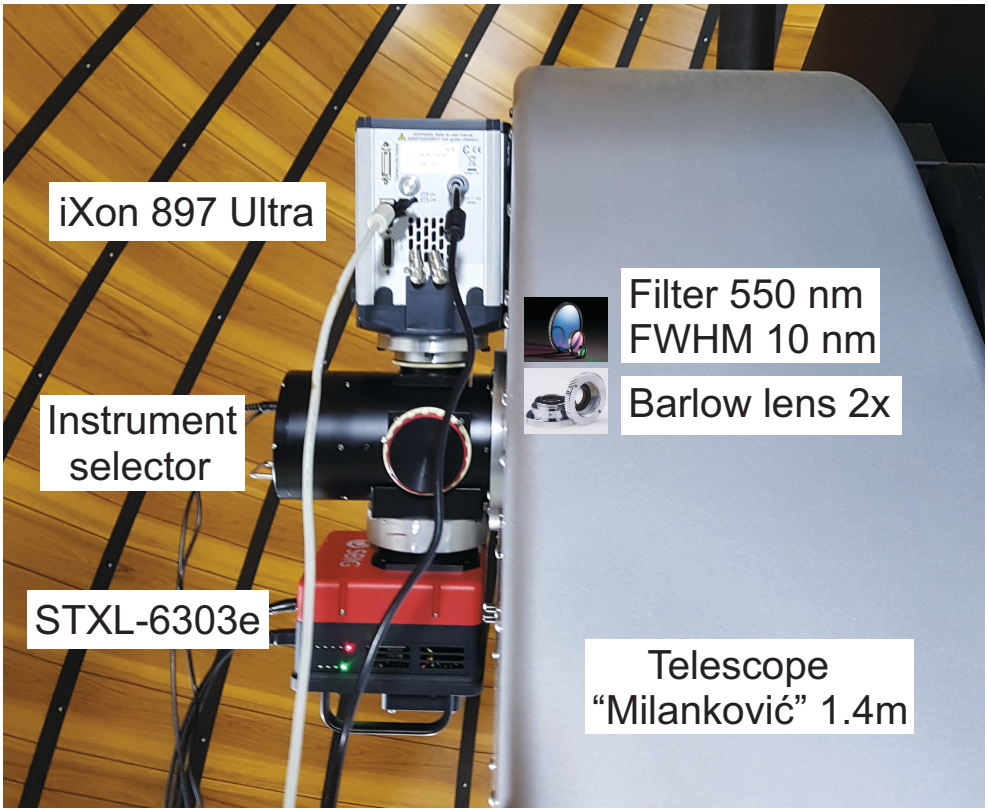

Figure 1: The equipment for lucky imaging attached to telescope “Milanković” at AS Vidojevica.

imaging was completed in early 2020, and in July first observations of double and multiple stars were performed using this technique.

2. LUCKY IMAGING ON “MILANKOVIĆ”

As already mentioned, our equipment for lucky imaging mounted at the right port of “Milanković” telescope consists of two CCD cameras Andor iXon 897 Ultra and SBIG STXL-6303e and an Optec Perseus 4-port Instrument Selector (Figure 1). The properties of these two cameras are given in Table 1. The selector instrument makes it possible to divert a light beam from either camera to the other one. Within the instrument selector and in front of the iXon 897 Ultra camera there are two more components: a single filter with central wavelength at 550 nm and full width-half maximum of 10 nm, and a Barlow lens with 2× magnification.

For the purpose of calibrating his optical system for lucky imaging Kohl (2013) observed binaries with precisely determined orbits. Afterwards he used the orbital elements in order to recalculate the separation and the position angle for the observational epoch. By comparing these quantities with those obtained from the observations he determined the pixel scale and the orientation of the camera. For the

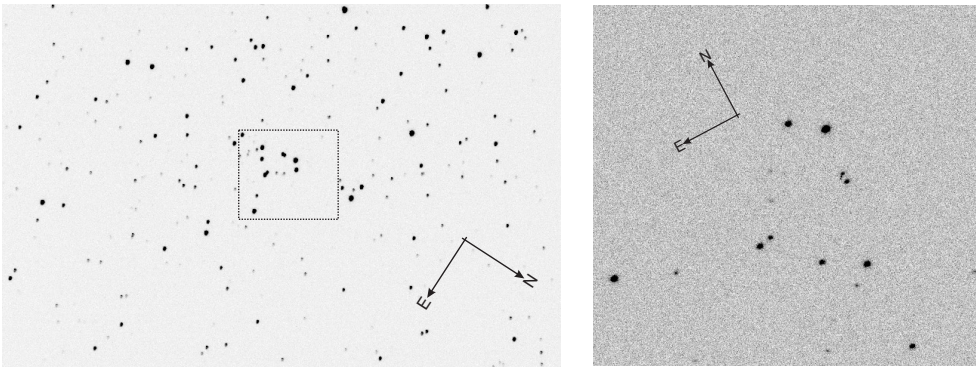

Figure 2: Open cluster M52 recorded by CCD camera SBIG STXL-6303e (left) and Andor iXon 897 Ultra (right). The rectangle on the left panel indicates the part of the sky shown in the right panel.

purpose of determining these parameters we use an alternative approach. In order to have a sufficient number of stars in the field of view of Andor iXon 897 Ultra we start the observation night or session by taking frames of a star cluster. Then we obtain another frame of the same cluster with the other camera. Using a plate solver engine, Astrometry.net[1] or PinPoint[2], we directly obtain the pixel scale, and then the connection between the northwards directions for both cameras. In this way we can determine the position angle during the calibration of frames of double stars. An example of such frames is presented in Figure 2.

During the night of August 13th, 2020, we took 200 frames with the exposition of 0.1 seconds of binary system WDS 22202+2931 = BU 1216, for which there exist orbital elements[3]. In this way we obtained images with high signal-to-noise ratio after processing. From all exposures an average bias and dark frame was subtracted, but flat fielding was not performed because we had a problem to take flat-fields that night. The left panel of Figure 3 shows the result that was obtained by just stacking all short exposures without further image processing whereas the right panel shows the result obtained by lucky imaging i.e. using only 20 % of the best frames according to their FWHM of the PSFs. In the right panel it is seen that the binary components are clearly resolved, whereas in the left panel they are blurred. The parameters for this binary, separation and position angle, determined by using lucky imaging are: $\rho = (0.918 \pm 0.014)$ arcseconds, $\theta = (276.57 \pm 0.57)^\circ$. The ephemerides for the observational epoch 2020.61875 are: $\rho = 0.916$ arcseconds and $\theta = 276.2^\circ$ in a fairly good agreement with our measurements. The seeing for that night was about 1.9 arcseconds, whereas we measured a double star the separation of which is twice as small. Because of this we hope that we shall be able to resolve even closer pairs when we have a better seeing.

[1]https://astrometry.net
[2]http://pinpoint.dc3.com
[3]http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/orb6

Table 1: CCD cameras used for lucky imaging at AS Vidojevica and its properties. Both cameras are attached at the right port of telescope "Milanković". More details about the telescope can be found on the website http://vidojevica.aob.rs/index.php?option=com_content&view=article&id=40:the-1-4m-telescope&catid=22:teleskopi&Itemid=249

CCD camera	iXon 897 Ultra	SBIG STXL-6303e
Active pixels	512×512	3072×2047
Sensor size (mm)	8.2×8.2	27.7×18.5
Pixel size (μm)	16×16	9×9
Read noise	$< 1e^-$	$15e^-$
Maximum cooling ($^\circ C$)	-100	-40
Pixel scale ($''$/pixel)	0.1488	0.1649
Field of view (arcmin)	1.3×1.3	8.2×5.5
Illumination	back	front

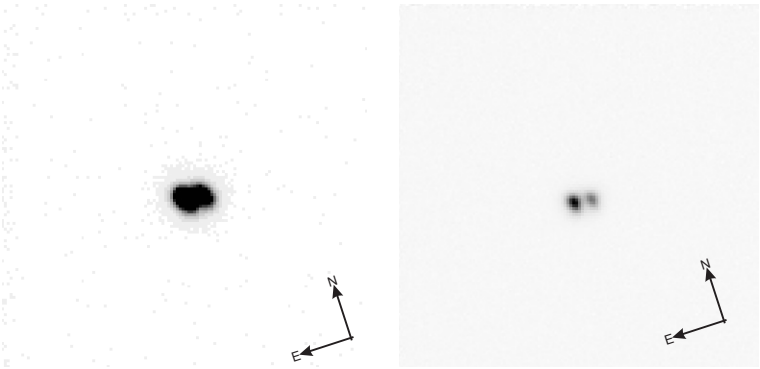

Figure 3: The binary WDS 22202+2931 = BU 1216.

3. CONCLUSIONS

Here we show that using lucky imaging at 1.4 m telescope "Milanković" at AS Vidojevica, with the existing equipment, we can resolve double stars for which the separation is at least twice as small as the seeing value. There is a room for improvement, instead of Barlow lens 2× to use another one with a higher magnification, for instance 3× or even 5×. There is another possibility, in the next period to substitute the existing filter with another one which would have a larger transparency width and to estimate if this will result in an improvement.

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