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THE DWARF PROJECT: VIDOJEVICA

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Abstract. The DWARF project is an important international project for observing eclipsing binary stars and searching for third companion which orbit around both stars. Recently, a group of researchers at the Astronomical Observatory of Belgrade joined this project using the 60 cm telescope at the Astronomical Station Vidojevica for observations. All the equipment and the human potential involved with this project from Serbia will be described in this paper.

1. INTRODUCTION

DWARF is an international project aimed at detection of circumbinary extrasolar planets using the timing of the minima of low-mass eclipsing binaries. There are 37 institutes/observatories from 18 countries involved in this project. It was initiated on the IAU conference in 2011, in Slovakia, and realized by Dr. Theodor Pribulla and his colleagues from the Slovakia Observatory. More details about the project can be found in Pribulla et al. (2012) and see also Pribulla in these proceedings.

There are several methods to detect circumbinary planets: (1) precise radial-velocity measurements, (2) photometric detection of transits of the planet across the disks of the components of the inner binary, and (3) timing of the inner binary eclipses. The timing technique proved to be the most effective in detecting circumbinary planets and it will be the principal technique used in the DWARF project (see Lee et al. 2009 for more details on this technique).

Relatively bright binary stars are chosen for observation (R band magnitude between 10 and 17) in order to be observable by small and middle class telescopes, that is, with telescopes ranging from 20 to 200 centimeters in diameter. The program stars in this project can be sorted into three groups: (1) systems with K or/and M dwarf components, (2) systems with hot sub-dwarf (sdO or sdB) and K or M dwarf components and, (3) post-common envelope systems with a white dwarf component.

A group of researchers, working on the project "Stellar Physics" at the Astronomical Observatory of Belgrade, joined this project in 2012. We use the 60 cm telescope located at the Astronomical Station Vidojevica for observations. The observatory and the instruments used for observation will be described in more detail in the first section. The preliminary observing results will be shown in the second section. Some final remarks and the conclusion will be given in the last section.

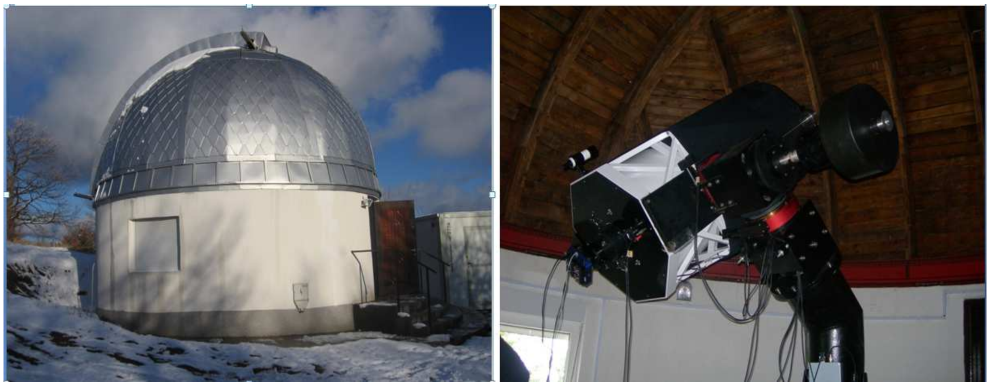

Figure 1: The telescope-dome and the 60 cm telescope at the Astronomical Station Vidojevica

2. OBSERVATORY AND INSTRUMENTS

Astronomical Station Vidojevica is the observational site of the Astronomical Observatory of Belgrade. It is located on the mountain Vidojevica in South Serbia near town Prokuplje. It was founded in 2003 but the first observations were made only in June 2010. Since than, the site was tested for different astro-climate conditions showing that the site has a relatively good seeing (1.2 arcsec in median) and around 100 cloudless nights per year on average (Jovanović et al. 2012).

So far, we have set up only one telescope on the ASV. It is an equatorial mount, Cassagrein system pursued from Astro System Austria company [1]. Mirrors are made in LOMO with 60 cm and 20 cm in diameter for the primary and secondary ones respectively. The telescope was calibrated and tested for different basic characteristics (Vince & Jurković 2011). Figure 1. shows the telescope's pavilion and the 60 cm telescope. We plan to build a new, 1.5 m-class, telescope in a very close future.

For observational purposes, the Astronomical Observatory of Belgrade provided several instruments: portable spectrograph, several CCD cameras, two filter sets (BESSEL and Strömgren) and other auxiliary equipment for different observational projects. The Alta Apogee U42 CCD camera is the most used camera for both, photometry and astrometry. It is a back-illuminated high sensitive CCD with 2048 x 2048 resolution and 13 micron pixel size. It is thoroughly tested for different parameters in Vince (2012). This camera is used for the observation in this project.

The telescope is controlled by the "Autoslew" software. It works under 32-bit Windows system and it is fully compatible with the ASCOM platform enabling communication with other ASCOM-compatible drivers and softwares. The CCD camera and the filter-wheel are controlled by the MaxIm DL imaging software. Recently, the telescope's dome was automatized and synchronized with the slewing of the telescope. At this stage the telescope is ready for the automatization which was the general idea for this telescope.

[1] See `http://www.astrosysteme.at`

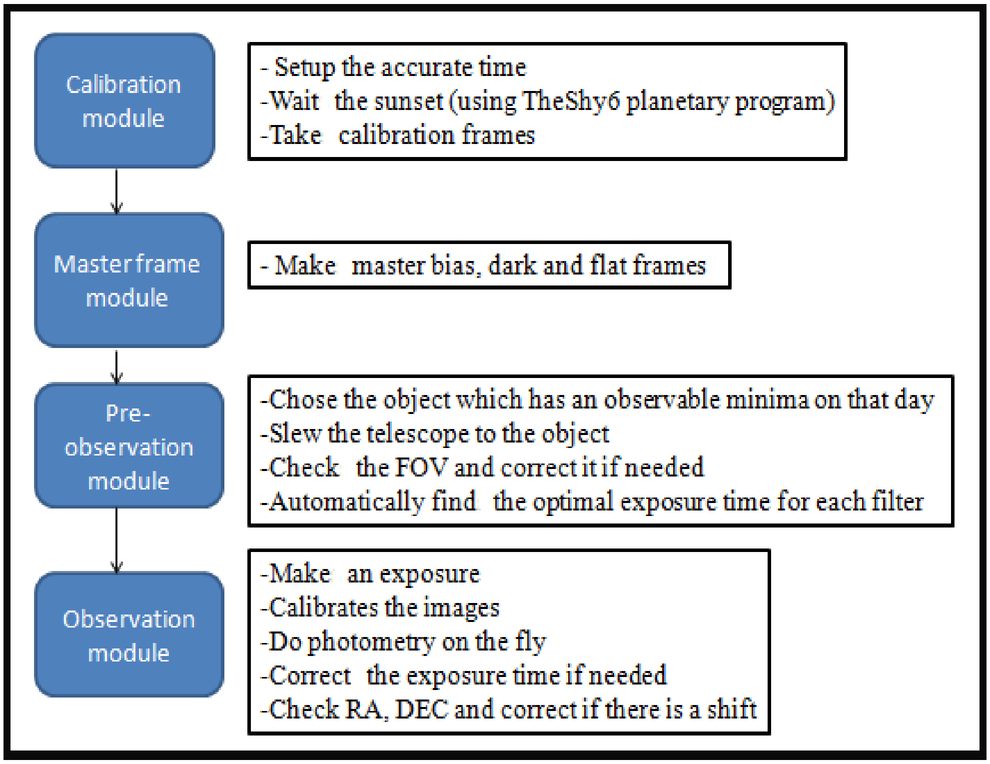

Figure 2: Schema showing the automatization procedure for the observation on the 60cm telescope

3. OBSERVATION AND PRELIMINARY RESULTS

The observation for the DWARF project is fully automatized in Visual Basic Scripting language (VBS). The algorithm for the automatization is schematically shown in Figure 2. Basically, the whole procedure consists of four linear modules as it is shown on the left side and shortly described on the right side of the figure.

In the first module, the calibration images are taken automatically. These are: a) 5 flat-fields in all four BESSEL filters in use (B, V, R, I) with 5 second exposure time which is short enough to take sufficiently large number of flats with high signal to noise ratio and long enough to avoid shutter effect, b) 10 dark flats, that is darks with 5 seconds exposure time for direct correction of the flat frames for the zero level and the thermal noise, c) 10 biases, d) 10 long dark frames for scalable dark correction for the later use.

In the second module, master images are made by combination (averaging or medianing) of the corresponding calibration images. Hot pixel mask is directly obtained from the long exposure dark frames where these pixels rich very high values relative to the average value from the whole frame.

The 'brain' of the algorithm is the third module where the binary system is chosen for observation. This step depends on the ability to observe a particular binary system

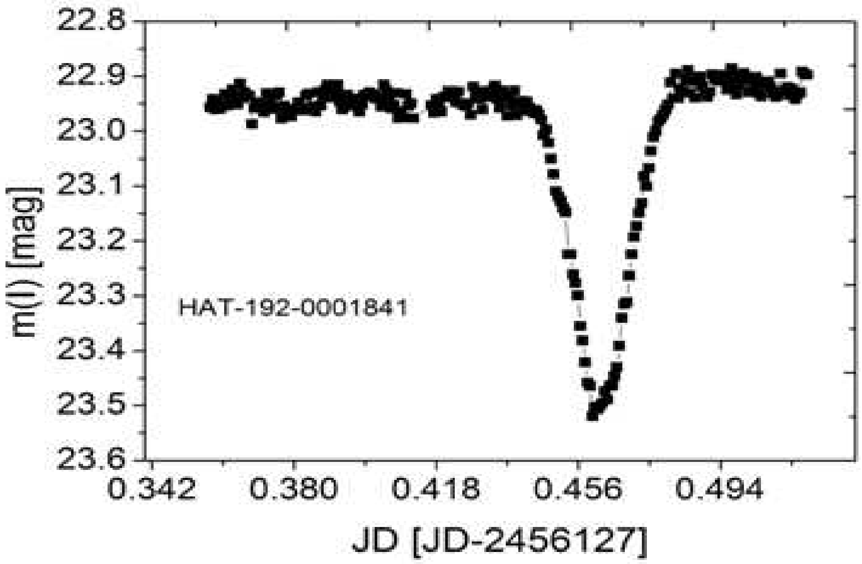

Figure 3: The light-curve of the HAT-192 binary system as an example of the direct output of the VBS script

on that day such as: duration of the period, the relative position of the Moon, the time remained to the sunrise etc.

In the fourth module, the photometry of the binary system is measured on the fly, that is, images are taken and corrected for bias, dark and flat which is followed by the aperture photometry. To ensure that the photometry is measured in the same aperture, the position of the telescope is constantly checked and corrected if the tracking error is larger then the aperture's half-width maximum.

Figure 3. shows an example of the output given by the script. It is the eclipsing binary system HAT-192-0001841 consisting of K and M dwarfs. It is relatively bright object (V band magnitude in the maximum is 14) with short period of 0.31 day. Since we deal with dwarf system, it is observed in the I photometric band. The photometric uncertainty is around 0.02 magnitude.

Although the observation is automatized in a such a way to measure the photometry on the fly, the final results are measured in IRAF data reduction package. This is required by the DWARF project due to unification and homogenization of the observations. However, this step is also accelerated and simplified by writing IRAF scripts which call different IRAF tasks for the aperture photometry[2]. Where the field is crowded with stars, the PSF photometry is performed[3]. To date, we have observed and analyzed three binary systems: HAT-192-0001841, HS 2231+2441, and NSVS 14256825.

[2]See `http://iraf.noao.edu/iraf/docs/apuser.ps.Z`
[3]See `http://iraf.noao.edu/iraf/docs/daorefman.ps.Z`

4. FINAL REMARKS

According to our experience so far, there are several things that deserve attention in order to perform high-quality observations for this project:

i.) The shutter delay, that is, the delay that occurs between the instant of issuing the command to start an exposure and the instant at which the shutter actually opens. Of course, it is important to take this effect into account since we are measuring the variation of the light-curve minima of the binary systems. Fortunately, this effect is very close to zero for this camera but can be much larger for some cameras (like in the example of our Alta Apogee E47 CCD camera where this delay is 0.43. seconds). It would be important for all members of the DWARF project to correct observations for this effect.

ii.) The shutter effect, that is, the uneven exposure of the detector to the light due to the finite time needed to open and close the shutter. Our CCD camera has an IRIS shutter (blades are opened from center to the edge) which means that the central region of the detector is the most exposed to the light. Short exposures are frequently used for making flat images and they very often suffer from this effect. Calibration of images for flat-field with this flats can be quite catastrophic in some cases.

iii.) Non-linearity of the CCD camera. This parameter is the most important to know for accurate photometry.

iv.) The fringing, that is, the pattern very often present in the I band (even in R band in some cases). It is caused by interference of the light in the thin emulsion layer of the CCD detector. There are useful information on the Internet how to make correction for this effect.

To conclude, having these remarks on mind, we can perform quite accurate photometry with the 60 cm telescope at the ASV and positively contribute to the DWARF project. Since 1980's, when the observations in Belgrade were terminated due to light pollution, Serbia is for the first time active again in observational projects. These activities will be certainly improved with the new 1.5 m-class telescope that is being purchased.

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