Journal of Physics: Conference Series

PAPER • OPEN ACCESS

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To cite this article: M. Yusuf *et al* 2019 *J. Phys.: Conf. Ser.* **1127** 012045

IOP Conf. Series: Journal of Physics: Conf. Series 1127 (2019) 012045 doi:10.1088/1742-6596/1127/1/012045

Bosscha Robotic Telescope (BRT) - a 0.35 meter telescope on Bosscha Observatory

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Abstract. We introduce the second generation of the Bosscha Robotic Telescope (BRT), a remotely and automatically operated 0.35-meter telescope. This paper will describe the BRT technical properties, system, and the data from early observations. We have been working on the robotic automation of the telescope system in order to be ready for the national observatory along with international telescope networks. The use of the telescope includes monitoring observation of variable stars, exoplanet, near earth asteroid; and observational for education.

1. Introduction

Robotic telescope is a telescope that can operate without human interaction during the night time observation. Recent advances in a robotic telescope made it possible to do an observation in a very remote location that offer very dark sky and optimum condition in order to obtain high quality data. Bosscha Robotic Telescope (BRT) is included as one of the preparation steps for the national observatory that will be located at a very remote area in Timor Island (East Nusa Tenggara), Indonesia.

BRT (figure 1) is a 0.35-meter robotic telescope located at the Bosscha Observatory on Lembang. This telescope is the second generation of our robotic telescope with more capable mounting system, bigger telescope and a better camera as advancements from the previous generation [1]. The first generation of BRT has relocated to Nusa Cendana University, East Nusa Tenggara. This system is planned to be applied to a 0.5 meter telescope in Timor.

2. System

2.1. Optical Tube Assembly

BRT is a telescope system with f/7.2 Corrected Dall-Kirkham (CDK) design from PlaneWave Instruments[1] with a 0.35-meter diameter primary mirror. It has an ellipsoidal primary mirror with spherical secondary mirror, and a combination of two additional corrector lens to produce a 52mm diameter circle of coma-free flat field with no off-axis astigmatism. Table 1 and figure 2 show the detail specification and the spot diagram of the telescope.

The telescope has a motorized focuser capable of 18 kg lifting within a 30 mm (30000 microns) range with a 1 micron step. It is also equipped with a dew heater, capable to maintain the

[1] http://planewave.com/products-page/telescopes/14-inch-cdk-optical-tube-assembly/

temperature of the telescope at a desire value to prevent a dew build up. The telescope is equipped with a self-made rotator and spacer in order to get a fine adjustment of CCD camera position angle.Figure 3 shows our custom rotator and spacer made at our workshop.

Table 1. Optical tube assembly specification.

Optical Design	Corrected Dall-Kirkham (CDK)
Aperture	356mm
Focal Length	2563mm
Focal ratio	F/7.2
Central Obstruction	23.5% by surface area; 48.5% by diameter
Optical Performance	3.1 micron RMS at 13mm off-axis
	6.0 micron RMS at 35mm off-axis
Optimal Field of View	70mm Image Circle

Figure 1. BRT Telescope.

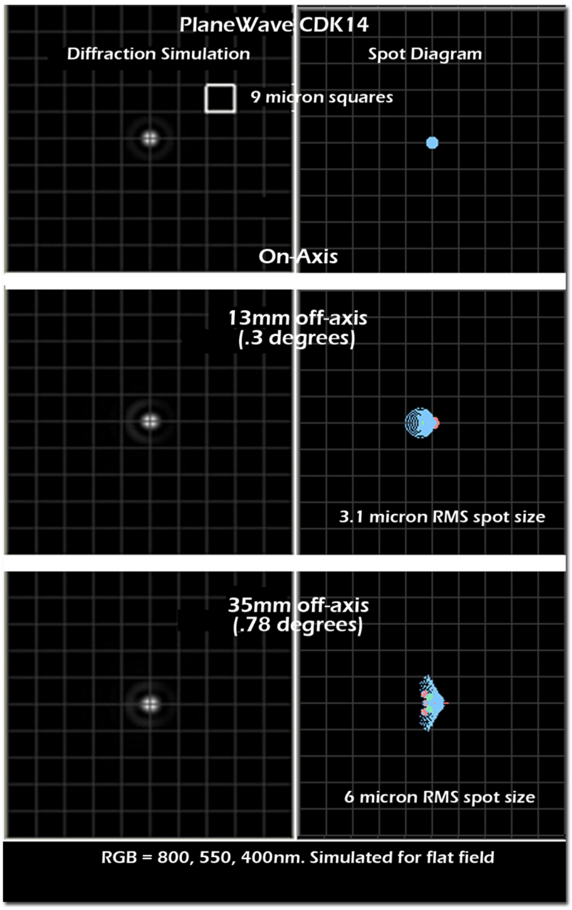

Figure 2. Telescope Spot Diagram.

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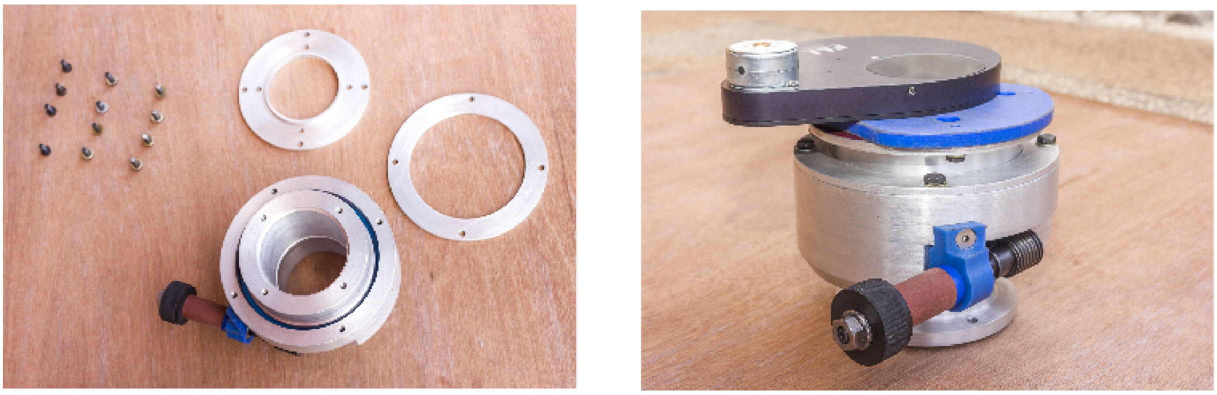

Figure 3. Custom rotator and spacer.

2.2. Mount
The telescope mount is an Astrophysics 1600 GTO[2] with a German-Equatorial design. This design requires a pier-flip when tracking a target across the observer's meridian from east to west, that requires about 1 minute delay in data acquisition. The mount has an RMS pointing accuracy of $\sigma = 4$ arcmin around the mean pointing position, and < 0.3 arc seconds periodic error tracking. The error most probably due to flexure in the telescope and a small errors in the polar alignment. The pointing will be automatically corrected by the software and we eliminate the tracking error with an external guiding scope. The mount also has a relatively fast slew with a 5 degrees/s speed.

2.3. Science Camera
We use FLI Proline 11002 Monochrome camera features a Kodak Interline KAI-1102M sensor. The camera is equipped with an integral five-position filter wheel with a 2-inch diameter *BVRI* filter. The camera is capable to maintain -55°C below the ambient temperature as we usually operate the camera at -30°C. The CCD specification are listed in table 2.

Table 2. CCD camera specification.

Detector sensor	4008×2672
Pixel sise	9 µm
CCD field of view	48.38 arcmin $\times$ 32.26 arcmin
Full well depth	60000 electrons
Dark current	$<$ 0.005 electrons/pixel/sec at -30°
Typical system noise	9 electrons at 1 MHz; 16 electrons at 12 MHz

2.4. Control System
Not like the previous generation, to cut the development time and resources, we decided to use the ready-made software ACP (Astronomers Control Program) to control the instruments and equipments. ACP is a product of DC-3 Dreams[3] that takes advantages of ASCOM standards environment to interface a range of astronomy equipments.

[2] http://www.astro-physics.com/index.htm?products/mounts/1600gto/1600gto
[3] http://acp.dc3.com

Observations have been carried out either by writing a plan then submit it to a scheduler, or by a direct command from console in a real time. The scheduler accepted inputs as a list of observing request and set of constrains to perform the observation automatically. The scheduler also capable of interrupting the run to allow quick response of transient events (e.g. GRB and supernova follow-ups) and will respond to changes in observing condition. It is also qualified to dispatch requests that can be perform in the current condition, and will retry failed observation automatically. [2].

The focusing is also done automatically by searching the best Full Width at Half Maximum (FWHM) of a selected 7-8 magnitude star. The typical focusing process is about 3 minutes, including the slewing time. We have a predefined focus offset to skip focusing through each filter. The focusing is performed in the beginning of each night or if the statistical value of FWHM changed by 50%.

The flat field, dark, and bias images are taken regularly at dusk and dawn time. The flats are taken using a sky flats where the telescope picks a position in the sky on the solar circle near the zenith, offset in the anti-solar direction by 15 degrees. This should be "close enough" for most uses, including precision photometry [3].

3. Science Programs and Current Usage

3.1. Exoplanet

We used BRT to observe the transiting exoplanet WASP-74b, one of the brightest system accessible to the southern hemisphere telescopes. It is a 0.95 M_{Jup} planet with a moderately bloated radius of 1.5 R_{Jup} in a 2-d orbit around a slightly evolved F9 star [4]. We were able to observe delta magnitude of $dV = 0.010 \pm 0.001$mag. Figure 4 shows the transit light curve of WASP-74b on June 27, 2016.

3.2. Variable Stars

This telescope is able to make observation of variable stars monitoring with two or three target per night depending on time resolution. In our monitoring project we choose a variable stars that follows: short variability period, relatively bright, and have a modest delta magnitude [5].

3.3. Astrometry of Near Earth Asteroid

We are also able to observe and do astrometry on Near Earth Asteroid (NEA) up to 18.4 magnitude (figure 5). The telescope is able to track a fast moving object by modifying the tracking speed of both axis, RA and DEC. Table 3 shows the example of astrometry observation of NEA with 3-sigma uncertainty from minor planet center[4].

3.4. Education

BRT also functions as a valuable teaching and educational resource for undergraduate student at astronomy research division of Institute of Technology Bandung. The system control has made it possible to operate telescope from anywhere so it opens wide opportunities for collaborative observation with other institution. Figure 6 is an example of astrophotography from BRT. With the advancement of operating system that has been developed, we hope to encourage future citizen scientists and amateur astronomers, groups which historically have analyzed a lot of astronomical data and made numerous discoveries.

[4] http://www.minorplanetcenter.net/

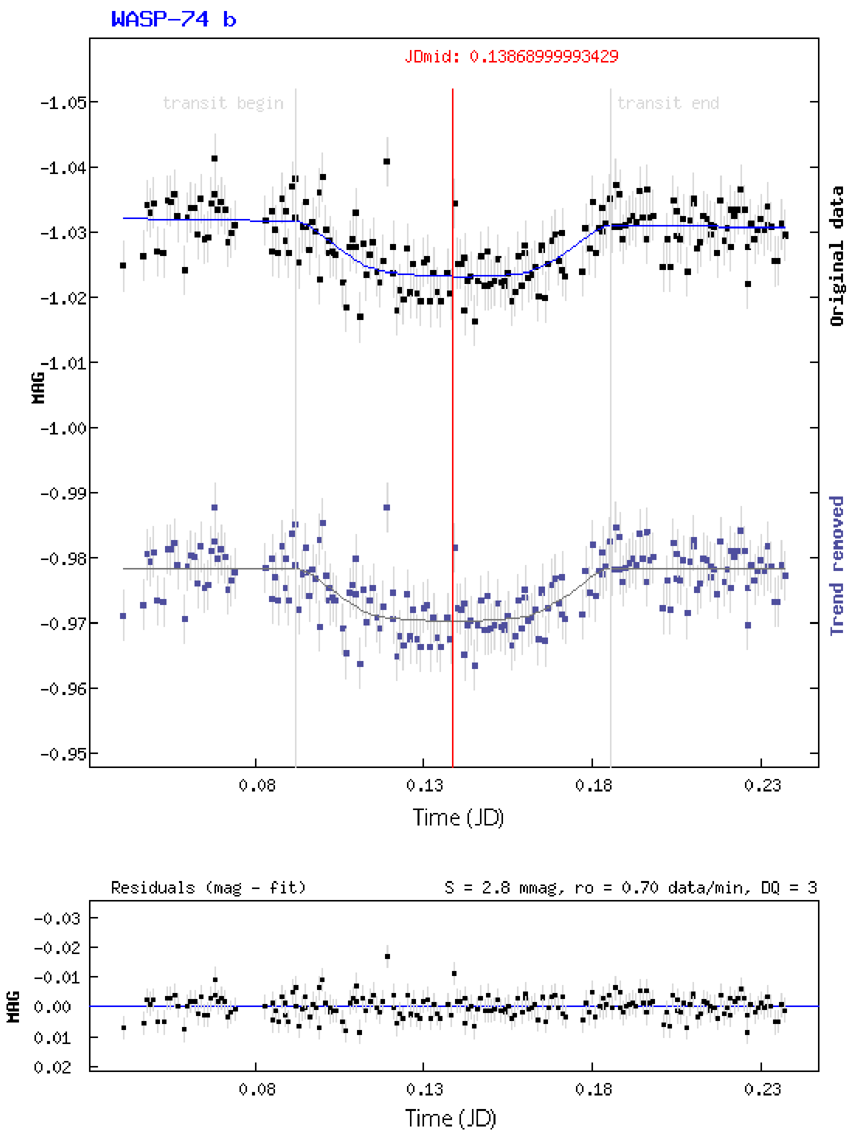

Figure 4. Transit light curve of WASP-74b.

4. Summary

In this paper, we presented current hardware and software of BRT. BRT is a fully operated 0.35-meter telescope installed at Bosscha Observatory, that can be controlled remotely from anywhere. The use of the telescope includes monitoring observation of a variable stars, exoplanet, near earth asteroid; and observational for education. We are planning to do a long term monitoring of variable stars and near earth asteroid.

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Table 3. Example observation of NEA.

Object	Mag (V)	Time (UT)	RA predicted (d m s)	DEC predicted (d m s)	Sky Motion ("/min)	RA observed (d m s)	DEC observed (d m s)
1998 GL10	17.8	2015 03 24 20:15:44	11 51 16.9	-05 51 13	1.33	11 51 16.9	-05 51 12
2015 MU59	18.4	2015 08 29 19:59:45	23 54 01.7	-07 34 16	1.23	23 24 01.7	-07 34 16
2016 KB1	18.4	2016 06 26 21:48:33	00 54 28.5	-22 17 32	7.17	00 54 28.8	-22 17 28

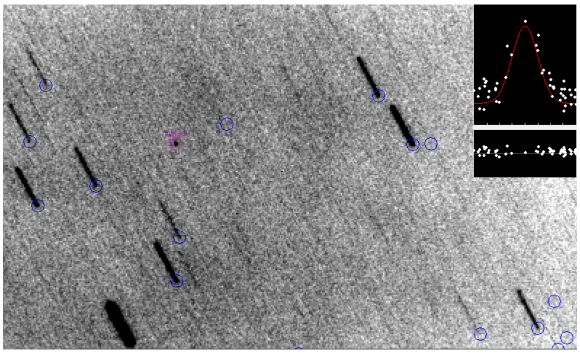

Figure 5. Near Earth Asteroid 2015 MU59 (purple circle) with 18.4 magnitude and 1.23 arcsec/min motion. Reference stars that were used for the astrometric data reduction are circled blue.

Figure 6. A *BVR* composite color image of M 20 taken with BRT.

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