AIRA T40 – FIRST LIGHT

R.M. GHERASE, M. POPESCU, A.B. SONKA,
PETRE PARASCHIV

Astronomical Institute of Romanian Academy
Str. Cutitul de Argint 5, 040557 Bucharest, Romania
Email: radu.gherase@gmail.com

Abstract. We report the installation of the Ritchey-Chrétien - 0.36m robotic telescope in the Astrolabe "roll-off roof" building belonging to the Astronomical Institute of the Romanian Academy. The calibration procedure performed in order to set up the telescope is shown. The test observations show a limiting magnitude of $\approx$ 18.6 (mostly due to the sky light pollution of Bucharest) and a seeing in the order of 2.0–3.5 arc seconds. The available instruments are a CCD camera SBIG STL 11000 M with a field of view of 44 x 30 arc minutes and an Alpy 600 spectrograph. The CCD camera has a standard UBVRI filter wheel.
The astrometric observations allowed to confirm the discovery of 2017 RV1 (*M.P.E.C. 2017-R57*). The telescope was used to obtain photometric data for the near-Earth asteroids (326683) 2002 WP and 2016 LX48. These were reported to Minor Planet Bulletin (Sonka *et al.*, 2017). Preliminary observations of (3122) Florence were performed with the Alpy 600 spectrograph. It allows covering the spectral interval 0.4–0.80 microns with a resolution of R$\approx$600.

Key words: astronomy – observatory – telescope – instrumentation – remote control.

1. INTRODUCTION

The *Astronomical Institute of the Romanian Academy* (AIRA) is one of the main institutes in Romania dedicated to research in astronomy and astrophysics. The mission of AIRA is the fundamental scientific research in the fields of astronomy (fundamental astronomy, astrophysics and cosmology). The institute is responsible for providing astronomical knowledge with cultural, social and economic impact. The research fields are: celestial mechanics, astrophysics of small bodies in the Solar System, solar physics and heliosphere, stellar astrophysics and exoplanets, extragalactic astronomy, cosmology, history, education and outreach of astronomy*.

The Bucharest Observatory holds three instruments for the night-sky observations: 1) the Cassegrain Telescope with a primary mirror diameter of 500 mm and a focal length of 7500 mm mounted in 1964; 2) the Prin-Merz double Astrograph with a lens diameter of 380 mm and a focal length of 6000 mm; and 3) and the Great Meridian Circle (190/2350 mm). However, only the Cassegrain Telescope is still in

*http://aira.astro.ro

use (Sonka *et al.*, 2014, 2015, 2016). The main subject covered by this telescope is the astrometry and the photometry of the small bodies of the Solar System. In order to have a fast follow up of transient phenomena as well complementary observations of the data acquired with larger telescopes it is required to have a robotic telescope remotely controlled with a high-quality optics and differential ratings capabilities.

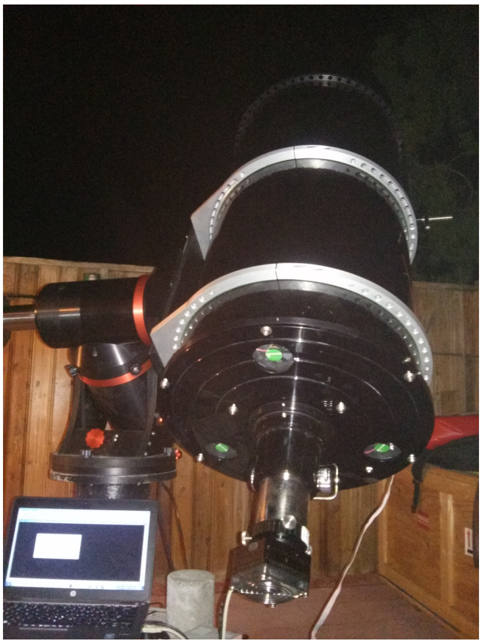

Fig. 1 – T40 telescope installed in the Astrolabe building.

In this context we started the installation of the T40 a Ritchey-Chrétien type reflector with 0.36 meter primary mirror and a f/8 focal ratio. This telescope was produced by the Optical Guidance Systems †. Our tests were performed at the Bucharest Observatory site, in the Astrolabe building. The geographical coordinates are 44^{o}24'42.7"N +26^{o}05'39.4"E. This location is associated by *Minor Planet Center* (MPC) with the code 073 - Bucharest.

The building was modified in order to install the telescope: the roof was made mobile, similar to other roll off roof observatories. The roof assembly is put in motion by an electric motor. The requirements for a proper installation include: a 220 Volt power supply and a broadband internet connection. The computer and the mount are powered via an *uninterruptible power supply* (UPS), to protect them from power

† http://opticalguidancesystems.com/products-and-services/technology/ogs-optics/

surges or power outages.

The telescope tube is mounted on a German type equatorial mount produced by Astrosysteme Austria, model ASA DDM85 ‡. It is placed on a robust concrete pillar. This is one of the top performing mounts for this class of telescopes. It has direct-drive motors and encoders assuring no periodic tracking error. The Autoslew software is used for tuning and controlling the mount movements. The mounted telescope is shown in Fig. 1.

The instruments available for this telescope, as of August 2017, include a *Charge Couple Device* (CCD) camera and the low resolution spectrograph Alpy 600. The image acquisition camera was produced by the Santa Barbara Instruments Group SBIG STL11000M. It has a 9 micron square pixel which for this setup is equivalent to 0.656 arc-seconds per pixel spatial resolution. The total field of view covers 43.8 x 29.2 arc-minutes. The SBIG CCD camera has an integrated filter wheel which facilitates the use of photometric filters of the Johnson-Cousins UBVRI standard. These filters cover the 0.35–0.9 microns spectral range wavelength. A screen capture from the *astrometry.net* software for a 90 seconds exposure using V filter of M13 globular cluster observed with T40 is shown in Fig. 2.

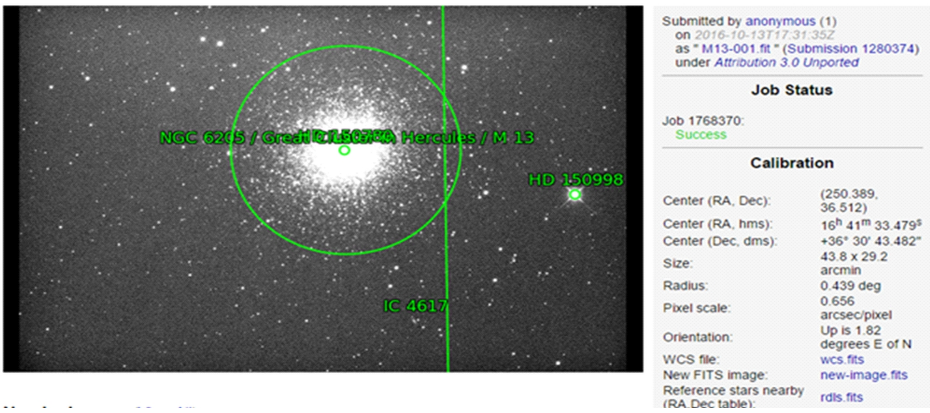

Fig. 2 – Screen capture from the astrometry.net software. A 90 seconds exposure made with T40 setup for the globular cluster M13 is shown. The V filter was used.

The Alpy 600 spectrograph produced by Shelyak Instruments is available for the low-resolution spectroscopy. It is equipped both with a guiding module and a calibration module. This instrument allows a resolving power of R 600 and covers 0.4–0.8 microns spectral interval. Currently, this instrument was tested on a small telescope and requires additional mechanical pieces for interfacing with the T40 telescope.

‡`http://www.astrosysteme.com/shop/asa-direct-drive-ddm85-standard-24v/`

2. SETTING UP THE EQUIPMENT

The mount was leveled and polar aligned: its axis was oriented to the North-South direction with a precision greater than 10 arc-minutes. The control software allows for an estimation of polar alignment accuracy. After attaching the telescope to the mount, it is necessary to mechanically balance the whole system, on both Right Ascension and Declination axes. This is firstly done by gross mechanical balance check, and then the fine balance is made using the Autoslew control software procedures, which accurately compare the impulse and travel of the telescope tube on both axes, in both directions. The telescope balance must be checked and refined each time if there is an instrumentation change.

The focus was made with the internal robotic focuser, which adjusts it by moving the secondary mirror. There is also an external focuser at the back of the telescope, to which the camera is attached, but we used it only for achieving rough focus during tests.

In order to have a precise pointing to given coordinates, it is necessary to synchronize the mounts coordinates to a known star position, so that the software knows where the mount is pointed (the encoder positions are relative to a fixed reference, not absolute). After this important calibration step, the software roughly knows where the mount is pointed. As no optical-mechanical system is perfect, for high precision pointing it is necessary to further correct these slight imperfections by using a list around 20 to 40 fixed targets (stars) distributed all over the sky. After all these steps are completed, the software is able to create a pointing model for compensation and to position the mount with a precision of a few arc-seconds on the chosen target.

The mount tracks very well its targets: we were able to acquire unguided frames with 10 minute exposure length without any trace of tracking error. However, for longer exposure times it is recommended to increase the number of calibration stars and to use the ASA Sequence software Multipoint Local Precision Tracking option. Though, this improvement was not necessary for current scientific targets. The mount allows a differential tracking (very useful for asteroid and comet tracking), with speeds of up to 15 times the sidereal motion possible on both axes. We successfully tested differential tracking and observed near-Earth objects with differential speeds of 60 arc-seconds per minute.

Overall control of the whole system (Telescope, Mount, CCD Camera and Filter Wheel, Focuser) is exclusively computerized, using serial (USB) connections for communication the control computer is in the same room with the telescope. For this purpose we use the Maxim DL software [§], which has all the necessary functions for telescope and camera control, imaging and image processing capabilities (*e.g.* Fig. 3).

[§] `http://diffractionlimited.com/product/maxim-dl/`

The control computer can be accessed remotely by using an internet connection. During several nights we observed from the office at the Institute (approximately 200 meters away from the telescope building), as well as from home (several kilometers away), using personal computers as the terminal. The connection was stable, the only limitation being the necessity for parallel weather monitoring to avoid the Observatory exposure to sudden dangerous meteorological conditions. We are currently working on building a weather station for automated signaling of potentially dangerous meteorological conditions while observing.

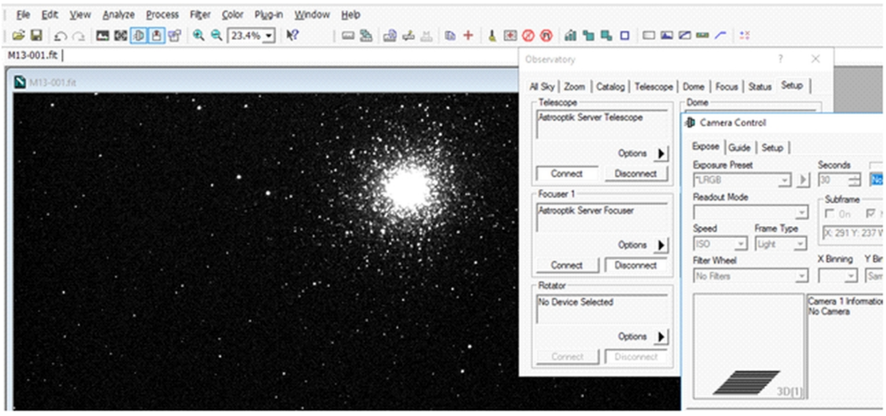

Fig. 3 – The telescope control software: Maxim DL.

The quality of astronomical observations is strictly dependent on sky quality (light pollution, number of nights with clear sky per year, humidity, the amount of dust in the atmosphere). The measured limiting magnitude with the above equipment for this observing site in Bucharest is around 18.6 (for a signal to noise ratio of around 3). The average seeing calculated using FWHM value of star images near zenith is within the 2–3.5 arc-seconds range (depending on the night).

3. FIRST SCIENTIFIC RESULTS

By using this setup we obtained both astrometric and photometric data for near-Earth asteroids. Among these we highlight the observations of 2016 LX48 a Potentially Hazardous Asteroid (a near-Earth object which may present a potential danger for Earth in the long term, due to cosmic hazard) on a cometary orbit discovered in 2016. The light-curve of this object showing a rotation period of 5.67 hours with amplitude of 0.43 was reported to Minor Planet bulletin (Sonka *et al.*, 2017). The photometric errors for this object, obtained when the object had V magnitude of 16.5 $\pm$ 0.5 were $\approx$0.1 mag. In this case no additional filter was used.

Overall, we reported astrometry measurements to the Minor Planet Center positions for objects with an undetermined orbit. Within the reported information, with outline the confirmation of the newly discovered object 2017 RV1. Our observations were part of Minor Planet Electronic Circular *M.P.E.C. 2017-R57*, announcing the discovery of this object. The quality of astrometric data is measured by the observed-computed (O-C) differences, once the orbit was sufficiently accurately computed. All performed observations have O-Cs with a sigma σ=0.5 arc seconds.

We reported photometric data (Fig. 4) for two near-Earth asteroids: (326683) 2002 WP, 2016 LX48 and (Sonka *et al.*, 2017). The goal of photometric observations is to determine their shape and structure.

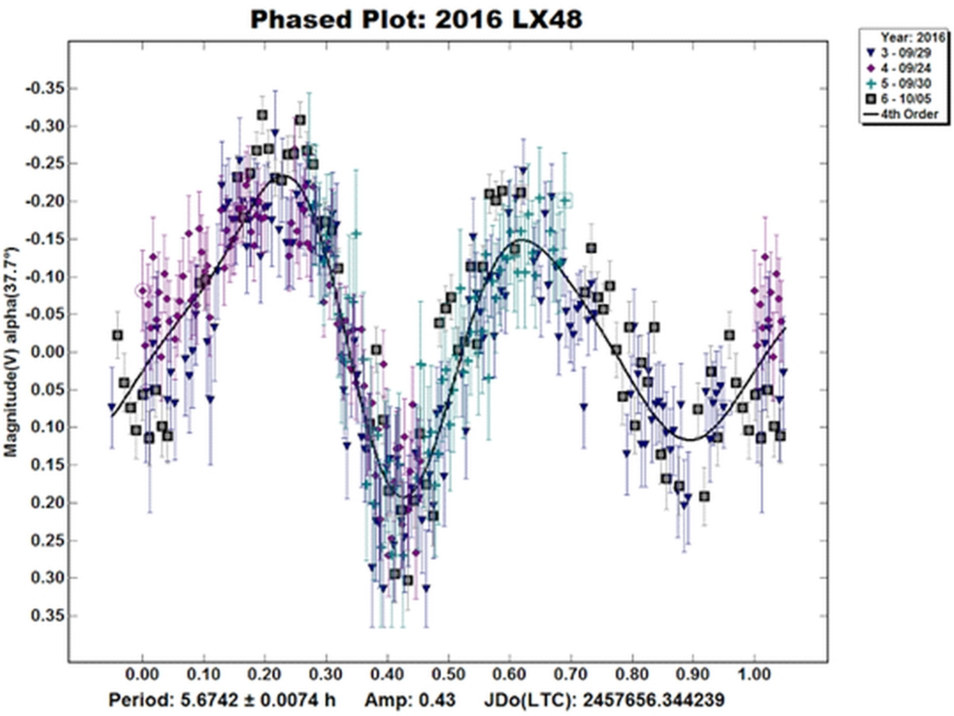

Fig. 4 – The light-curve of asteroid 2016 LX48 - source:[1]. The figure shows the photometric accuracy for an object at an estimated V magnitude of 17.

The first spectral observations were performed with Alpy 600 spectrograph using a similar smaller 20 cm f/8 Ritchey-Chrétien telescope (Gherase *et al.*, 2015), before mounting it on the T40 telescope. Thus, we determined that the asteroid (3122) Florence belongs to the Q-type class, with a spectrum similar to ordinary chondrite meteorites with low-metal content (Popescu *et al.*, 2012). The observed spectrum is shown in Fig. 5.

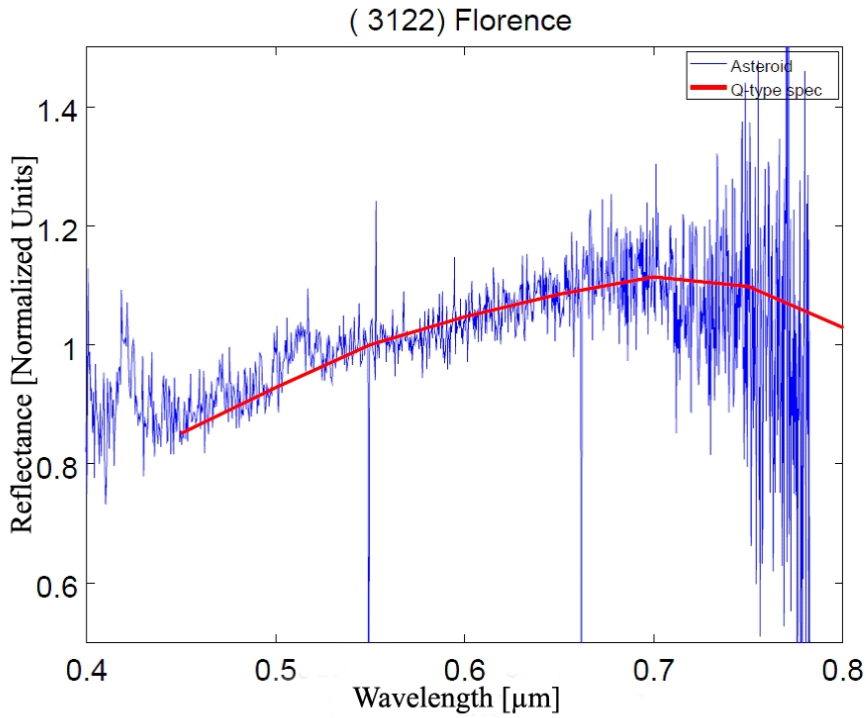

Fig. 5 – Spectral data obtained with Alpy 600 for the asteroid (3122) Florence.

4. CONCLUSIONS

We report the installation of the R.C.-0.36 m robotic telescope in the Astrolabe “roll-off roof” building belonging to Astronomical Institute of the Romanian Academy. The setup is fully functional and allows remote observations. The pointing precision is in the order of arc seconds. The limiting magnitude for imaging is $\approx$ 18.6, while the seeing may vary in 2-3.5 arc seconds range.

There are two instruments available for acquiring scientific data with this telescope: 1) the SBIG STL11000M CCD camera equipped with a UBVRI Johnson filter wheel; and 2) Alpy 600 spectrograph for acquiring low resolution spectra. First scientific results were obtained for several near-Earth asteroids including 2017 RV1 - discovery confirmation, 2016 LX48 - lightcurve and rotation period determination, and (3122) Florence – spectral characterization.

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