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The new 50-cm multi-purpose telescope of the Russian-Cuban observatory

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Abstract. Since 2017 the Institute of Astronomy of the Russian Academy of Sciences (Russia) and Institute of Geophysics and Astronomy (Cuba) have been implementing a joint international project with the aim of building a distributed global optical telescope network. The first 20 cm aperture robotic telescope of the the Russian-Cuban network has been operating since 2021 in Havana. It has a 3.5×3.5 degree field of view and a FLI PL16803 4K CCD camera with a set of UBVRI photometric filters. Construction of the second 50 cm telescope near Kislovodsk (Russia) has been underway since 2023 and it will be finished at the end of 2024, its scientific operation will start in early 2025. By 2030, the plan is to build the third 1 m telescope at Valle de Picadura (Cuba). The main parameters and scientific equipment of the new 50 cm telescope are described and its role in the Russian-Cuban distributed global telescope network is discussed.

Key words: telescopes – wide field telescopes – astronomical observations

1. Introduction

Since 2017 the Institute of Astronomy of the Russian Academy of Sciences (INASAN, Russia) and Institute of Geophysics and Astronomy (IGA, Cuba) have been developing a joint international project with the aim of building a distributed multi-task network of optical telescopes RCO (Russian-Cuban Observatory) (Bisikalo et al. (2018)).

At the beginning of 2021, the first telescope was installed at IGA in Havana (Bisikalo et al. (2022)). In 2023, the second optical telescope of a 50 cm aperture began being built in Russia.

According to the current plan, the third custom 1 m wide-field telescope based on INASAN's experience to build a 1 m modern telescope with a 9k detector (Ibrahimov et al. (2020); Shugarov et al. (2020); Ibrahimov (2019)) having spectroscopic, astrometric and photometric capabilities will be installed in 2030 at Villa de Picadura located 80 km east of Havana.

2. RCO network

The time difference of 8 hours (120 degrees) between Cuba and Russia (Kislovodsk) allows for continuous observations of up to 16 hours, which makes the RCO an efficient tool for many observational tasks requiring a long continuous observation series of the studied objects (see Fig. 1). The location of the second telescope in Russia significantly boosts the functionality of the Russian-Cuban network both in terms of global coverage and observation modes.

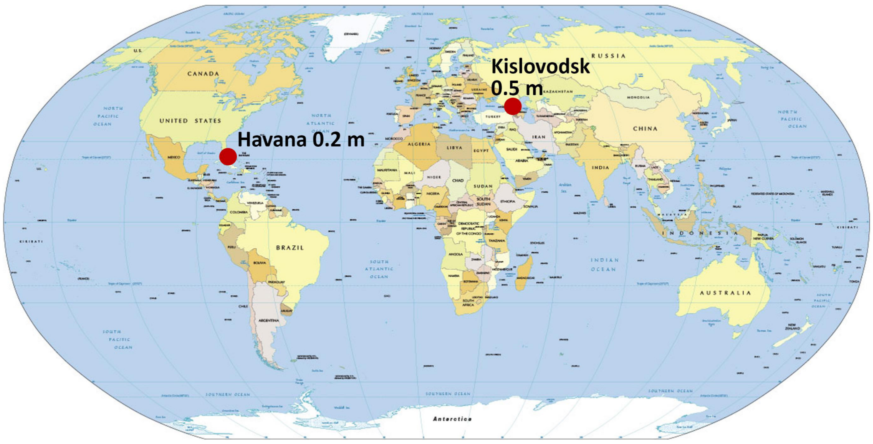

Figure 1. Russian-Cuban network of optical telescopes (RCO).

Among scientific goals, we can reference the detection and tracking of newly discovered asteroids (Ibrahimov et al. (2021)), photometric studies of variable stars (Savanov et al. (2024, 2023); Naroenkov et al. (2022a,b)) and the study of optical transient events, e.g. sources of gamma-ray bursts and tidal disruption events.

At least two types of telescopes should be included in the network – wide-field survey telescopes and middle-aperture follow-up telescopes equipped with cameras and spectrographs.

The first telescope of the Russian-Cuban network is a multipurpose photometric robotic telescope, which has a 20 cm aperture, 3 degree field of view and a set of UBVRI filters. The most interesting new objects, discovered by the 20 cm wide field telescope, will be studied in more detail with larger telescopes both in spectroscopic and photometric modes.

For this purpose, in the frame of the stage 2 of the RCO network development, the second 50 cm telescope with two main scientific instruments for spectroscopy and photometry is under construction.

For the second RCO observation station, the Kislovodsk observatory in the North Caucasus at the altitude of 2070 m was chosen. The observatory already has all key infrastructure and is easily accessible from the closest city of Kislovodsk.

This site has relatively good astronomical seeing for the central part of Russia. According to (Kornilov et al. (2016a)), the median moonless night-sky brightness is 22.1, 21.1, 20.3 and 19.0 mag per square arcsec for the B, V, R and I spectral bands, respectively. The annual amount of clear night astronomical time is, on average, 1320 h, i.e. 45% of the possible amount at the latitude of the observatory (Kornilov et al. (2016b)).

3. 50 cm telescope for the second RCO station

The second RCO observation station close to Kislovodsk will be equipped with:

- Astrosib RC500 0.5 m aperture telescope;
- custom-made focal unit with a switchable diagonal mirror for fast (about 15 s) switching between two scientific instruments;
- FLI Kepler 4040 FSI camera with Johnson-Cousins-Bessel UBVRI filters;
- suspended BACHES spectrograph with a ZWO ASI294 MM camera and active optics;
- ASA DDM100 direct drive mount;
- Astrosib ASD-4.5 dome.

The new 50 cm telescope RC500 for the second RCO observation station is produced by ASTROSIB Ltd, Russia (see Fig. 2). It has a 0.5 m aperture Ritchey-Chretien optical system with a 508 mm primary mirror housed in a carbon-fiber truss design optical tube assembly and a two-lens field corrector. The equivalent focal ratio is F/8 and focal length is 4000 mm. The telescope is equipped with a motorized focuser and motorized primary and secondary mirrors covers.

The telescope is mounted on an ASA DDM100 equatorial mount equipped with direct drive motors and absolute encoders. A well-proven Astrosib ASD-4.5 all-sky dome (4.5 m) was chosen and will be mounted on an original hyperboloid 5.4 m high pier designed by INASAN (see Fig. 3).

The RCO observation station close to Kislovodsk will operate in a fully robotic mode with remote access by INASAN and IGA staff. For remote and

Figure 2. RC500 0.5 m aperture telescope for the second RCO station near Kislovodsk (Russia).

autonomous operations, the observation site has a set of equipment: weather stations, lightning detector, GPS/GLONASS receiver, all-sky camera and surveillance cameras. The observatory is controlled by a set of special software created by INASAN, which allows the control of all devices to perform scientific observations, data storage and data processing remotely.

4. Custom focal unit and scientific instruments

The second RCO station telescope most complicated part is its custom designed fully automated focal unit, which allows remote observations in both photomet-

Figure 3. 4.5 m Astrosib ASD-4.5 all-sky dome installed on a 5.4 m high pier at the INASAN observatory close to Kislovodsk (Russia).

ric and spectroscopic modes. The RC500 focal unit optical scheme, mechanical design and fabrication were done by INASAN. The majority of the focal unit components are off-the-shelf, which reduces cost and makes it easy to reproduce it for another telescope.

The RC500 custom-made focal unit main functions are:

– electromechanical switching between photometric and spectral modes of operation;

- electromechanical switching to calibrate spectrograph with calibration lamp;
- to alight two scientific instruments' focuses to avoid the telescope refocusing during switching between instruments;
- a possibility of installing an additional focal extender for the spectrograph;
- telescope guide camera and spectrograph slit viewing and guiding cameras;
- tip-tilp corrector for the spectrograph;
- high rigidity, mechanical stability of the entire structure and reliable fasteners;
- light tightness design;
- the ability to rotate and fix the entire assembly and its elements around the optical axis of the telescope, for accurate orientation of the spectrograph.

The main components of the custom-made focal unit are presented in Fig.4, 5 and the optical scheme is shown in Fig.6.

The 50 cm telescope has two main scientific instruments – a photometric imaging camera and medium resolution spectrograph, which are quickly interchangeable by the telescope's motorized folding mirror within 15 seconds. It allows for a very flexible observational program every night. Both photometric and spectroscopic modes of operation are available at any time without the need to modify the telescope's setup.

The main instrument for spectroscopic research is the Basic Echelle Spektrograph (BACHES). It is a compact, lightweight and inexpensive medium resolution (R=20000) Echelle spectrograph manufactured by Baader Planetarium GmbH, well suited for remote autonomous operation at a robotic observatory.

BACHES main parameters are:

- average spectral resolution: R$\sim$20000 with a slit of 25$\times$130 μm;
- spectral range: 3920-8000 Å continuously (depending on detector size);
- spectrograph efficiency: $\sim$27% at 5040 Å, total efficiency $\sim$11-13%;
- limiting magnitude: $\sim 10^m$ visual (SNR=20, 30 min. exposure);
- detector: a low noise and extra high sensitivity cooled back-illuminated sCMOS camera ZWO ASI294MM, Sony IMX492, sensor size 19.1$\times$13 mm;
- fiber feed calibration module: a Thorium-Argon hollow cathode lamp and Tungsten flat-field lamp.

BACHES allows the acquisition of spectra of an observed object as well as calibration spectra. To couple the spectrograph with the telescope, a simple

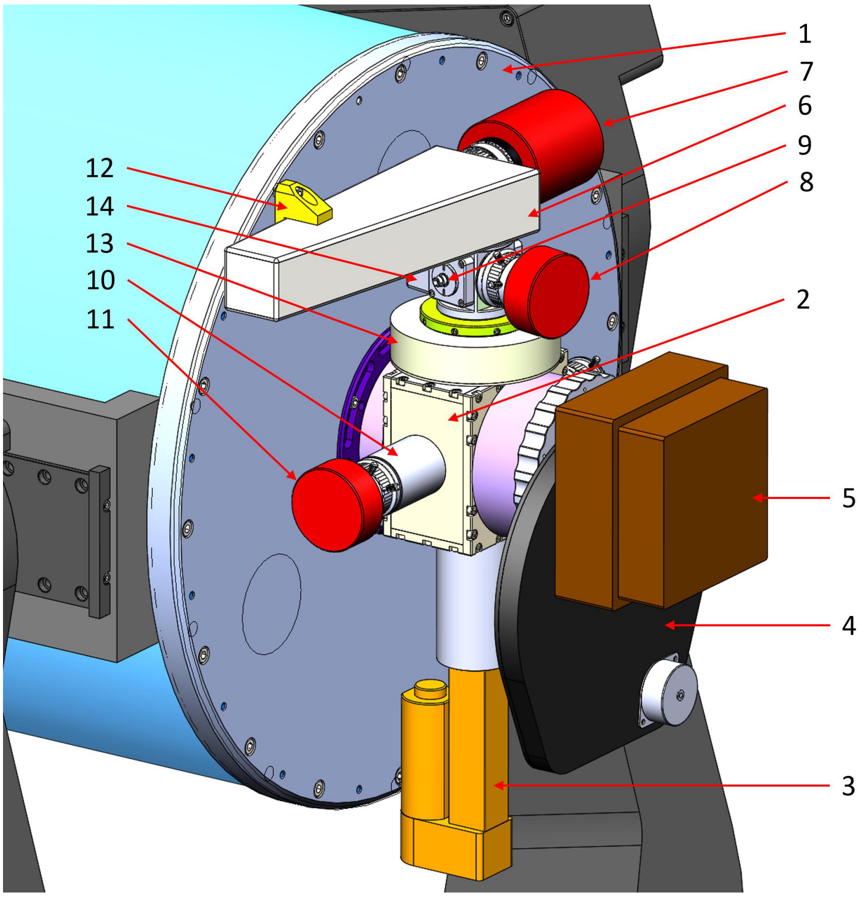

Figure 4. Custom focal unit main components: 1. Rear flange of the telescope; 2. Instrument selector; 3. Linear actuator, electromechanical driver of the diagonal mirror; 4. Filter wheel; 5. FLI Kepler 4040 camera; 6. BACHES spectrograph; 7. Spectrograph detector; 8. Spectrograph slit viewing and guiding camera; 9. Fiber-optic light input from the calibration module; 10. Off-axis guide camera focuser; 11. Off-axis guiding camera; 12. Additional mounting bracket for the spectrograph; 13. Active optics module for the spectrograph. 14. Driver of the diagonal mirror of the spectrograph calibration module.

achromatic telescope's focal extender Edmund Optics 62495 F/8 to F/10 is used. To allow for long spectroscopic observations with an exposure of up to 0.5 hours and more with minimum loss of light, BACHES is equipped with a tip-tilt active optics Starlight SXV-AO-USB module with a ZWO ASI178MM slit viewing and guiding camera. With a 0.5 m telescope, BACHES is capable of obtaining spectra of 10 mag targets with a SNR=20 for 30 minute exposures.

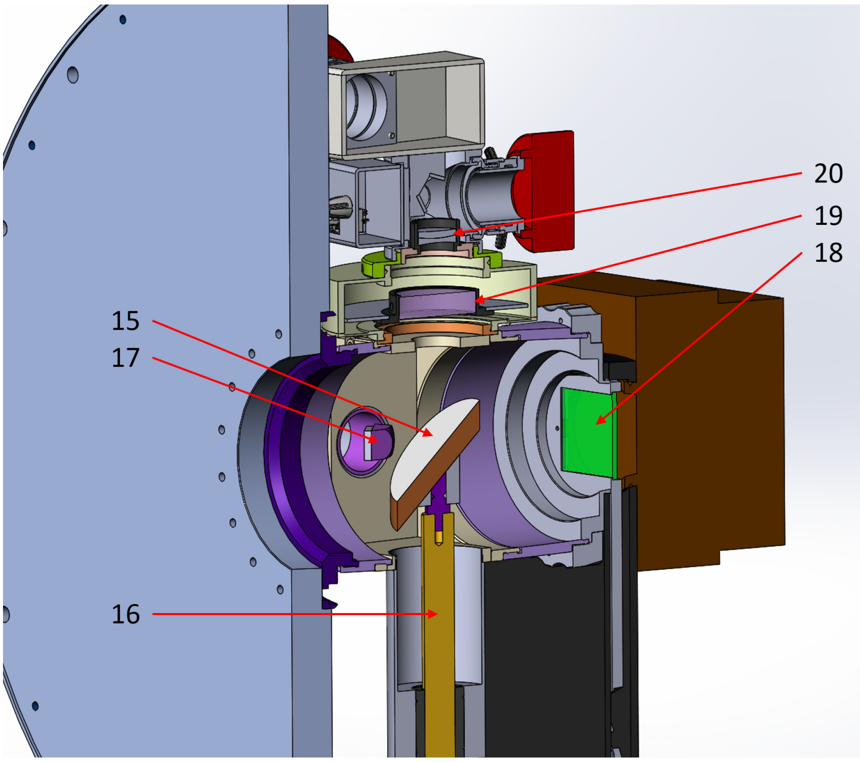

Figure 5. Custom focal unit main internal components: 15. Instrument selector diagonal mirror; 16. Linear actuator of the diagonal mirror, the position for spectral observations is shown; 17. Diagonal mirror of the side off-axis guider; 18. Scientific filter installed in the filter wheel; 19. Active optics module tip-tilt plate; 20. Focal extender for the spectrograph.

BACHES has been successfully used on the 1 m telescope at another INASAN observatory for several years. In 2024 it will be relocated to the new 0.5 m RCO telescope.

The second main 50 cm telescope scientific instrument is the sCMOS camera FLI Kepler 4040. The camera's main parameters are:

– sensor: GPIXEL GSENSE4040;

– format: 4096×4096 pixels;

– pixel size: 9 μm;

– full well capacity: 70000 e-;

– shutter type: rolling and mechanical;

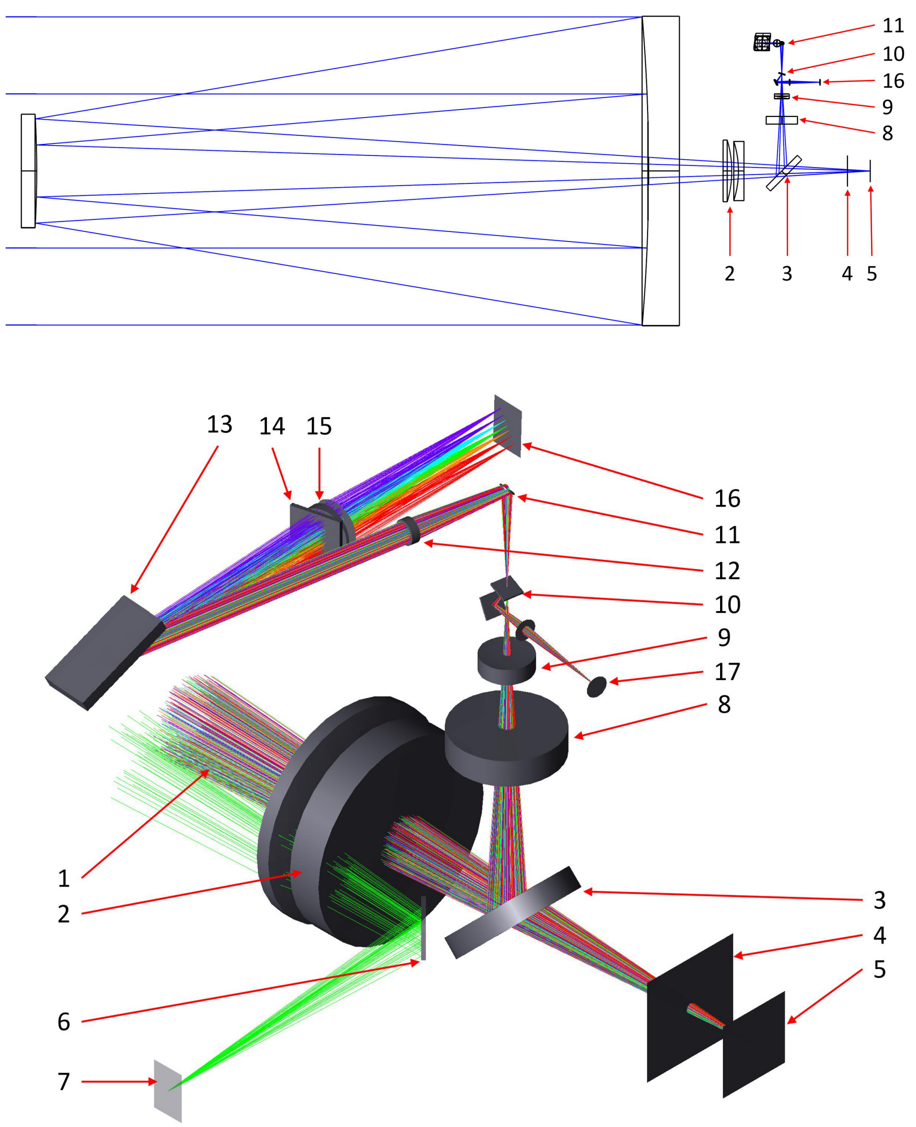

Figure 6. RC500 0.5 m aperture telescope and its focal plane instruments optical schemes: 1. Light from the telescope; 2. Telescope field corrector; 3. Diagonal switching mirror; 4. UBVRI filters; 5. Scientific FLI Kepler 4040 camera; 6. Main off-axis guide pick-off mirror; 7. Telescope off-axis guiding camera; 8. The tip-tilt plate of active optics module; 9. Focal extender; 10. Spectrograph entrance slit with a slit viewing mirror; 11. Spectrograph internal fold mirror; 12. Spectrograph collimator; 13. Spectrograph Echelle; 14. Spectrograph cross-disperser; 15. Spectrograph objective; 16. Spectrograph detector; 17. Spectrograph slit viewing and guiding camera.

– typical system noise: 3.7 e-;

– typical dark current: < 0.5 e-/pixel/sec at -30°C;

– typical non-linearity: < 1%.

The telescope focal unit has an off-axis guiding camera ZWO ASI178M with a Baader focuser 2458125. The camera is equipped with a FLI CFW5-7 filter wheel with 7 slots for photometric filters. In the first step, 5 filters of the standard Johnson-Cousins-Bessel system UBVRI will be installed. The sixth slot of the filter wheel will be used for broad-band imaging (integral light) to achieve maximum sensitivity of the telescope. In particular, this mode is efficient to search for new objects such as asteroids, comets and space debris. The seventh slot of the filter wheel will be reserved for future scientific observation programs.

5. Summary

The first 20 cm telescope of the Russian-Cuban RCO network has already been built in Havana (Cuba) and has been operating since 2021. The construction of the second 50 cm telescope close to Kislovodsk (Russia) is currently close to completion. Both telescopes are designed to operate in a fully robotic mode. It will allow Cuban and Russian astronomers to conduct scientific research remotely, both in photometric and spectroscopic modes.

It is expected to build the third 1 m telescope at Valle de Picadura (Cuba) before 2030, which will significantly improve the Russian-Cuban network functionality both in terms of global coverage and observation modes, including spectroscopic observations and more precise photometric observations.

Other telescopes worldwide, based on existing agreements, can be used for follow-up observations of the most interesting objects: INASAN's 2 m telescope at the Terskol observatory and INASAN's 1 m telescope, 0.5 m telescope of the Ussuri Department of the IAA RAS, several 0.5-1.5 m telescopes of the astronomical institutes of the Academy of Sciences of the Republic of Uzbekistan and the Republic of Tajikistan. All these observation sites together allow observations along an arc of 214 deg (or 14.3 h) in the northern hemisphere, which enables planning almost round-the-clock monitoring programs and alert observations from the above-mentioned observation sites.

International cooperation with other countries is highly welcomed for further expansion of the scientific potential of the optical telescope network.

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