# 1st Report of the Advisory Group of the Herouni Mirror Radio Optical Telescope (ROT-54/2.6)

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## Introduction

The Herouni Mirror Radio Optical Telescope (ROT-54/2.6) is a 54m radio dish built into the mountain Aragats (Armenia) and is combined with a 2.6m optical telescope mounted on the secondary support structure aligned with the radio optical axis. The telescope's coordinates are Lat. 40.3508609°, Lon. 44.2417924°, and Altitude 1711m. The large 54m spherical dish is illuminated by a movable secondary mirror arm resulting in an effective antenna diameter of 32m.
The antenna was built in the early 1980s and commissioned in 1987. Observations were carried out until 1995, when first modernization works were realized that continued until the 2001. Basic funding to further maintain the Aragats Scientific Center was available from 2001 to 2010 and concepts for the further operation were studied within the framework of student projects like Bachelor, Master and PhD theses.
Since 2012, there is effectively no funding for the observatory and no further maintenance to the structure could be provided. The basic infrastructure is still in a good shape and the observatory could be reactivated given that a few fundamental repairs are being made and funding for the installation and development of new control computers and receiving system can be found.
In 2017 an initiative was started to perform these tasks and create the "Herouni United Space Center" (HUSC) within the framework of the Jurisdiction Armenia Foundation. To support the local staff with expertise from other scientific institutions an Advisory Group was established in 2020. The Advisory Group (AG) of Herouni Mirror Radio Telescope (ROT-54/2.6) is formed by experts of HUSC (Armenia) and other institutions, in particular of the European VLBI Network (EVN).
The AG will evaluate the status of the ROT-54/2.6 and study possible developments and instrumentation for it to be able to operate as a radio telescope for single-dish and as an element of a VLBI network, in particular as a member of the EVN. The AG will as well evaluate the ROT mission, in-house programmes, both for astronomy as well as technical research and development, and suggest enhancements in the areas of personnel, training and education, laboratories, and other technical facilities.
In this report we will summarize the activities from the first months of work in this group.

## Current Status

The AG first met on August 27, 2020 in a video meeting to get to know each other, discuss the tasks of the group, and plan the further activities. Real face to face meetings are currently not possible because of travel restrictions in many countries and institutions due to the COVID-19 pandemic. The meeting was attended by 21 participants, about equally distributed between the international and local Armenian experts. A collection of documents about the ROT-54/2.6, the HUSC project, the Advisory Group members, and the minutes of the meeting can be found on the Joint Institute for VLBI in Europe (JIVE) wiki[1].
The meeting started with an overview presentation of the current situation at the observatory by Dr. Arevik Sargsyan, followed by a discussion and questions from the international participants.

[1] http://www.jive.nl/jivewiki/doku.php?id=husc:husc_armenia

The most serious problem today is the broken lever for accurate angular positioning of the East-West axis, which prevents any movement in this direction. Its repair will be the most important task to allow any pointed observation with the antenna. The AG collected further ideas how to start working at the antenna; e.g. recording of a 24h track with the fixed antenna and a receiver to measure the sources that pass through the beam. The group will look if there are any spare receivers at stations that could be send on loan to Armenia.
The AG agreed on "Terms of Reference" for the future work. Further discussion via email and a "Mattermost" chat server are being planned.

On September 18th, 2020 our Armenian colleagues organized a short conference entitled "XXIII International Conference on Radio Telescopes and Radio Interferometers". Many members of the AG participated in this meeting. The presentations are available from the JIVE wiki too[2].
The main topic was the situation at the ROT-54/2.6. A careful inspection of the main antenna structure has been performed in early September and the results were presented at the meeting. Beside the known problems with rust and the broken lever, another crack in a welding of the secondary support arm was found. This needs to be welded again when the other tasks are being performed, like lubrication of the bearings, anti-corrosive protection, and the repair of the lever of the East-West.
In September 2020 a microstrip patch antenna was installed in the secondary focus and a 24h sky track was recorded at 4.5 GHz. The spectrum analyser recorded only a narrow bandwidth channel and therefore it might be hard to detect any astronomical source in the data. However, the potential sky region where the antenna is pointing to, crosses the Cygnus region with a few prominent sources, that should in principle be visible. It is planned to repeat the test using more bandwidth.
John Sarkissian presented an L-Band receiver that was built at CSIRO[3] as New Technology Demonstrator for the SKA, which is no longer needed. It could be given to HUSC on loan. The different geometry would require the design and construction of a new feed and due to the distance between Sydney and Armenia it would be more practical if a possible installation would be supported by European partners.
Kees van't Klooster performed a radiation pattern calculation for the ROT-54 antenna at various frequency bands (1.6 GHz, 10 GHz and 36 GHz). The beam shape and pattern agree very well with earlier measured results from the commissioning of the antenna at 10 GHz and also the very low system temperature results from P. Herouni appears to be confirmed by this study. A critical point for the future could be the pointing control of the antenna. Because of the design, with the secondary mirror at the end of a 12m long arm, the movements at the central mounting have to be very accurate (on the order of 0.2mm) to allow a precise pointing of less than an arcminute of the antenna beam.

In a meeting on October 21st, 2020 the AG updated each other on the activities during the last month. Activities in Armenia suffered from the conflict with Azerbaijan, but the group is optimistic that further tests at the antenna can be continued soon.

In December 2020 two more recordings of the sky signal around the time of the passage of the Cygnus region were conducted. The first recording was done on December 3rd and the second recording 13 days later on December 16th. Without any direct source

[2] http://www.jive.nl/jivewiki/doku.php?id=husc:xxiii_international_conference_on_radio_telescopes_and_radio_interferometers_rr2020
[3] https://www.csiro.au/

identification this data should allow to detect the time shift of the pattern between the two dates. Indeed, some remarkable structures appear time shifted between the two epochs of recording which likely originate from astronomical sources. Some uncertainties remain in the exact time stamps of the data, but a similarity of the two track is noticeable. A full report can be found on the wiki pages[4].

The AG recognizes the potential of the ROT-54 antenna as a single dish instrument and in particular as an element in the European VLBI network. The design and accuracy of the main surface promises a sensitive instrument for frequencies of 1 GHz to 43 GHz, maybe even 90 GHz. The re-activation of the observatory would require a number of tasks to be performed and below we list a few of the main works that need to be done.

### Action list

In the following we list the tasks needed to proceed with the reactivation of the ROT54 that were identified in the previous meetings. The list is not in any particular order, but some items require others to be finished, e.g. pointing control is not possible without the restauration of the axis control.

- Fixing the lever on the East-West axis should have the highest priority, as it is required for any pointed measurements.
- Lubrication of the bearings and movable parts.
- Implement anti-corrosion measures.
- Planning for re-cabling: electrical engines, power and data connections for receivers, optical fibres, sensors/encoders
- Install computers and software to control instruments, read antenna sensors, and precisely control the positioning of the antenna.
- Install astronomical receivers and backends for continuum pointing, spectroscopy and VLBI data generation.
- (VLBI) Data recording, storage, and transport
- Connect the observatory to the internet. The aim should be a connection speed of at least 2 Gbps for data transfers, remote access for support and video conferences. For real-time eVLBI observations a speed of 4-10 Gbps would be desirable.

## Additional resources

Although many of the AG members haven't had the chance to visit the observatory until today, there are a number of documents that provide a lot of details about the current situation at the observatory and the technical details, e.g. Kees van't Kloosters report from a visit in 2018[5]. It precisely documents the current status and describes the required works to re-activate the antenna well.

[4] https://www.jive.eu/jivewiki/doku.php?id=ztrack

[5] http://www.jive.eu/jivewiki/lib/exe/fetch.php?media=husc:rot_54_status_v1.pdf