Setting Up the Cosmic Ray Tracking Detector | Queensborough Community College Summer REU

Nkeiru Ubadike| July 26 2019

Introduction

Cosmic rays are energetic particles that hit earth at least once a second. Some of these cosmic rays are the most energetic particles ever recorded in nature. Various experiments show that as the energy of these particles increase, the flux of these particles decrease. Particles of energies of 10GeV hit earth at a rate of $1x10^{-4}$ m^{-2}. At 10PeV, that rate decreases to $1x10^{-7}$ (a few times per year). The source of high energy cosmic rays ($>10^{15}$ eV) is still being debated.[1] There are galactic cosmic rays (GCR) that reach these high energies and some scientists propose that they originate from the black hole in the center of our galaxy: Sagittarius A*[2]. In light of these proposals, the cosmic ray tracking detector (Figure 1) is being configured to track Sagittarius A*.

Figure 1

Tracking Detector Arrangement

The detector consists of three plastic scintillators, each connected to a photomultiplier tube, fitted into an aluminum box frame. The kinetic energy of a muon that hits the detector is converted to a photon by the scintillator. The PMT converts this to an electrical signal from which meaningful data about the particle can be obtained. This frame is mounted on an azimuth and elevation enabled rotator (Yaesu G5500).The rotator is manually controlled by a desktop controller unit (Figure 2)

Figure 2

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[1] Pierre Auger Observatory auger.org

[2] "Acceleration of petaelectronvolt protons in the Galactic Centre" H.E.S.S. collaboration:**arXiv:1603.07730**

Computer Control of Detector

First steps were to get the detector controlled by the computer. The interface between the rotator controller and the computer is the Antenna Rotator System USB (ARS-USB ; Figure 3). Connecting the ARS-USB involved wiring the DIN-8 connector of the rotator to the RCI-USB circuit board (Figure 4). In the rotator, there is a potentiometer associated with the antenna mast axis. Voltage feedback changes when rotator turns the detector. The circuit board reads the voltage present on the rotator potentiometer and thus calculates the rotator position[3]. The circuit board accepts 5V as the maximum voltage. The Yaesu G5500 output was 3.91V. This signal had to be amplified in order to avoid loss of resolution by adjusting the RCI-USB internal potentiometer. The rotator is calibrated by connecting it to a voltmeter and turning the rotator to its clockwise limit and adjusting the internal potentiometer until it reads 5V. This is done separately for the azimuth and elevation axes. Once connected, the ARS USB was connected to a PC via USB port. The computer recognizes the ARS-USB as a COM Port. Drivers for the ARS-USB were installed from a CD-ROM. ARSVCOM is the program supplied with the ARS. There were issues concerning COM port recognition. This was resolved by reassigning the COM port several times until ARSVCOM recognizes the COM Port associated with the ARS USB (It is recommended that the controller/ARS/tracking computer is not turned off or disconnected unless necessary to avoid this issue in the future.) Once these issues were resolved, computer control of the detector was established. The detector could be moved by selecting the desired azimuth or elevation angle in ARSVCOM [insert picture]
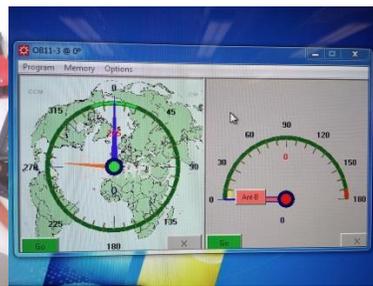
Figure 3   Figure 4   Figure 5

Automatic Control of the Detector

ARSVCOM also creates a virtual COM port which 3rd party software can access to control the rotator. Nova for Windows was selected as the tracking software. It has the ability to track 20 celestial objects including all nine planets and the most popular astronomical radio sources including Sagittarius A*. Before setting Nova to track, the detector had to be calibrated to true north. This was done by rotating the detector to its counterclockwise limit (0 degrees) and then spinning the detector to ensure that at this position it pointed
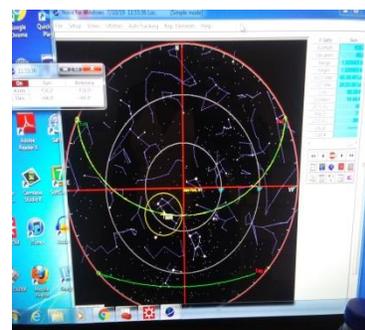
Figure 6

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[3] EA4TX ARS USB Manual

at true north. A compass was used but it was pointe   Magnetic north is 12.89 degrees west of true north. A compass was used to find true north and then the detector was spun 13 degrees clockwise of that point. With the detector calibrated to true north, the detector was set to track the sun for three days. It was observed that the detector was moving in the right direction over the course of 3 days. The detector was set to track Sagittarius A. A computerized telescope will be used to determine the detector's tracking accuracy.

Summary

Once the tracking accuracy of the detector can be confirmed, it will be used to track Sagittarius A*. Comparing flux rate data from the tracking telescope to data from the stationary detectors could reveal something interesting about our Galactic Centre.

Autotracking Instructions

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1. Open ARSVCOM. If two dials appear as pictured below, then proceed to step 5. If only the azimuth dial appears, go to step 2.
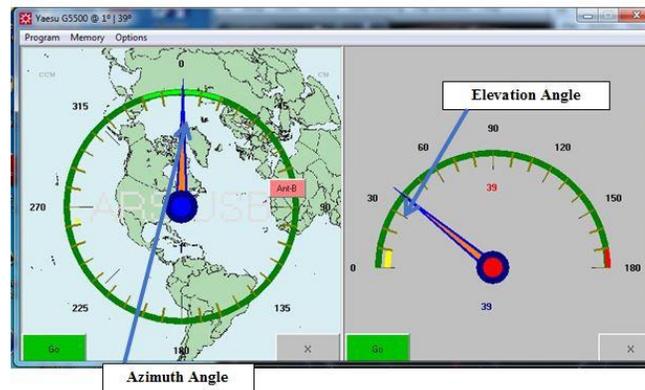
2. If only azimuth dial appears, this means the program is not recognizing the COM port assigned to the ARS- USB device. Open Device Manger and locate the ARS- USB device. The COM port number assigned to it is in brackets beside it.
3. Unplug and re-plug the ARS- USB in a different USB port. Note the new COM port number assigned to the device.
4. In ARSVCOM, select Program and then Rotor Setup. Change the COM port number to the number you noted. Click Save. The two dials should appear as pictured above. If not, repeat the process until suitable COM port is found.

5. Open Nova for Windows. The small Autotracking window (encircled below) should appear somewhere along top of screen. Sag A should be selected in the box below. To turn on autotracking, click the off button in the Autotracking window.

- Twenty celestial objects including the most popular astronomical radio sources can be tracked using Nova for Windows. To change object tracked, refer to user manual. User manual is downloaded to computer. Search "Nova for Windows User Manual". If you need to track an object not listed, try getting the software "Moon Sked" to work. The RA/Dec of desired object can be inputted in the "Noise Source Track" section.
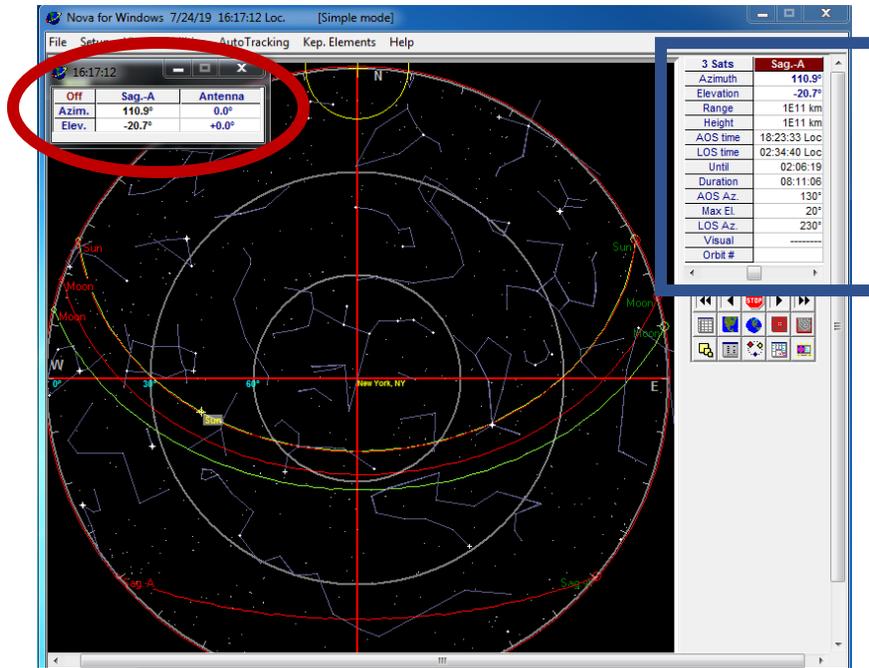
Weekly Reports

Photomultiplier Tube Fitting

Both PMTs were fitted to the scintillators with multiple layers of Tyvek paper and black tape. Longer screws had to fitted to accommodate one of the thicker wrapped PMTs.

DAQ board connection

DAQ board and oscilloscope connected and data is being collected. Scintillators were probed with a flashlight, there were no major jumps in frequency while doing this, suggesting there are no severe light leaks.

Meade Telescope

Telescope remote received. Set it to track Moon for a day. Seems to be working fine. Will use it to verify tracking once detector set up.

Scintillator Wrapping

Both scintillators wrapped in tyvek, light tight paper and light tight pvc.

Scintillator Wrapping

Large light leaks were found so scintillator was wrapped in Tyvek paper, light tight paper and light tight film. Hole cut in middle for PMT.

Detector Adjustments

PMT tube was recessed back to avoid scintillator bowing.

Before   After

Detector Adjustment

The actual detector elevation position was found to be 90 degrees off what was reported by the controller. The detector was unscrewed and rotated 90 degrees counterclockwise.

Successful Sun Tracking

After the adjustment and a day of tracking, it was determined that the detector sucessfuly tracks the sun. In the morning, the tracker faced east and moved westward. The elevation angle reached its highest point in the south around noon.

Determining Sagittarius A* Movement

To know what successful tracking looks like for Sagittarius A*, I did some research into how it moves across our sky. During the summer, it will be up at night. Current acquisition of signal time (AOS) i.e time it rises above horizon is around 19:30. In 6 months from now it will be up during the day. Its RA/DEC value is RA 17h 45m 40s | Dec -29° 0′ 28″ which puts it close to the border of the constellation Scorpio. Sag A* stays close to the horizon from our latitude (i.e does not rise high in the sky) as seen in the picture below. The elevation angles of the detector are not suspected to reach above 30 degrees. At AOS, the azimuth angles should be around 90 degrees (east). At loss of signal time (LOS), the detector should be around 270 degrees (west).
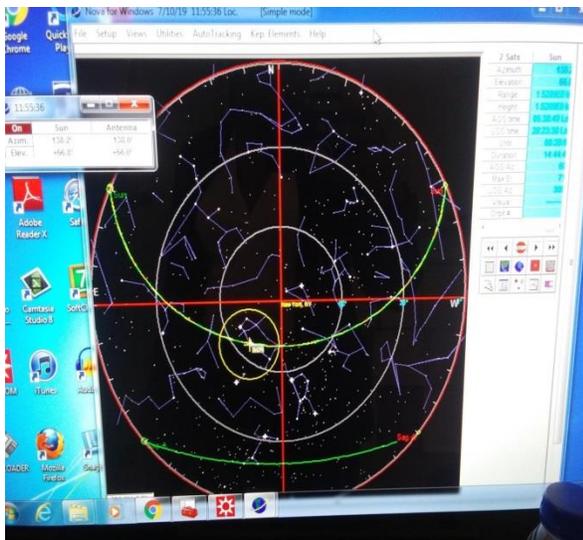
The path Sag A* is shown in green. It does not rise above 30 degrees elevation.

Coordinate System and Calibration

The detector was turned so that when it was at 0 degrees, it faced true north (12.89 degrees east of magnetic north as per compass). The picture below shows the cardinal points. North is at the top of the picture.

Nova Software

The software seems to work best using the Yaesu GS-232A interface. The software read the number given by ARS-USB verbatim. When I set it to track the sun, the azimuth and elevation given by software was verified to be correct but elevation wise, the detector did not seem to point in the right direction. It turns out the detector was placed 90 degrees "off" where it is supposed to be. It is yet to be determined as to whether I can account for that with code/software or whether the detector itself has to be adjusted.

Paper Discussions

On the Galactic Center being the main source of galactic cosmic rays as evidenced by recent cosmic ray and gamma ray observations

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Abstract. We revisit the idea that the Galactic Center (GC) is the dominant source of galactic cosmic rays (GCRs), based on a series of new observational evidence. A unified model is proposed to explain the new phenomena of GCRs

It has proposed an interesting model for how GCR are produced by the black hole which also incorporates gamma rays and the Fermi bubbles in GC. It also states the anisotropy of the GC scenario of origin of GCRs is still an open question. I thought this could be something the detector could be used to investigate once set up.

Coordinate System and Calibration

Discussed how the rotator knew it was pointing at the various cardinal points and elevation. In particular, the question was asked how the rotator knew 0 (azimuth) degrees was North. It was determined that 0/360 degree (Azimuth) must always be North and the rotator must move clockwise from north to hit east (90), south (180) and west (270).
There is a magnetic north and a true north which corresponds to the north pole and north celestial pole.

Next steps are to find and orient the rotator to true north using a compass and the local magnetic declination value for QCC of 12.89 degrees west(azimuth). Also, Nova must be calibrated with the ARS-USB. So far, calibration instructions outlined in the manual have failed to work for this particular set up.

Discussion on Assigned Papers

Paper 1

Paper 2

The paper concluded that a possible source of petaelectronvolt cosmic rays was the black hole in the centre that coincides with Sagittarius A. The paper stated that Sag A produced these cosmic rays 10^6 - 10^7 years ago but it was not clear how we could still be receiving those rays now.

Software

Software issues concerning calibration and COM Port assignment were resolved. ARSVCOM now starts up and controls the rotator without issue.

Rotator Connection

The Yaesu G-5500 rotator was connected to the ARS-USB via a DIN 8 connector.
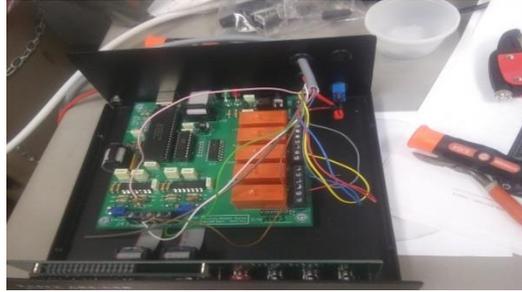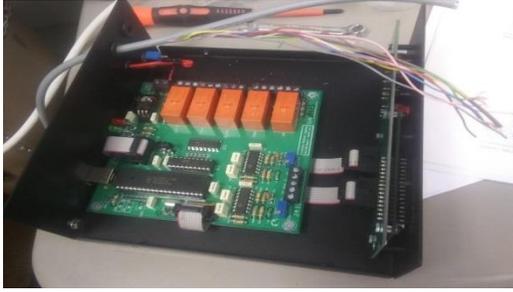
A potentiometer engaged with the antenna mast axis in the rotator acts as the elevation and azimuth position detector. The voltage feedback changes as the rotator moves. At the CCW limit, 0V was provided. The max voltage is provided at the CW limit. Before calibrating the rotator provided a max voltage of 3V and 2.81V for the azimuth and elevation position detector respectively to the ARS- USB unit. This was amplified to the required 5V for both azimuth and elevation.

Initial Computer Control via ARSVCOM

There was initial trouble installing the ARSVCOM program provided with the ARS-USB. This was solved by logging in as an administrator. With this program, you can select a particular azimuth or elevation coordinate and the detector will be pointed there. It does not provide tracking.
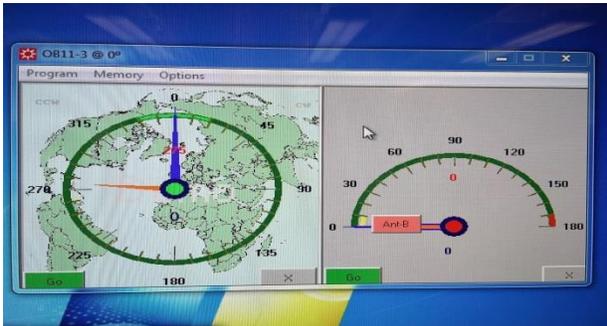
The Search for Astronomical Tracking Software.

Significant time was spent searching for suitable software. There were several potential candidates. PstRotator program could only provide satellite, moon and sun tracking. MoonSked could track astronomical noise sources such as Sagittarius A. However, due to some unknown reason, it could not control the elevation coordinate on the rotator. Nova was ultimately chosen. It successfully controls the azimuth and elevation on the rotator and can track satellites and numerous astronomical objects including Sagittarius A.