Progress Report On Continuum Survey Via KAT-7

Ermias A Kassaye

April, 2015

Overview Of The research

The candidate, Ermias K., studied Active Galactic Nuclei (AGN) observed by the KAT-7 telescope that are likely to be good calibrator sources. For the research, 48 potential calibrators were identified from various surveys or catalogues such as NVSS, SUMSS, etc. Majority of the selected sources ($\sim 90\%$) reside over the southern hemisphere. The sources belong to different AGN groups: about 46% are quasars, $\sim 50\%$ are faint galaxies and two sources are BL Lac objects. The classification based on their spectra indices: $\sim 41\%$ and $\sim 43\%$ have flat and steep spectra indices respectively. Moreover, inverted spectra ($\sim 8\%$) and Giga Hertz Spectrum ($\sim 8\%$) sources are identified in the sample.

Using the sources, the research has achieved the following:

- The position accuracy of the KAT-7 telescope was determined. According to the result, the KAT-7 could measure the position (right ascension and declination) of a source at an accuracy ~ 5 arcsec.

- It was checked whether the KAT-7 is on the same flux density scale with other radio data by using standard flux-density calibrator sources (i.e. 3C147, 3C286, and 3C48). The result showed that the KAT-7 is consistent with other other radio data at the level of $\sim 2\%$.

- There is always a systematic error during the process of transferring (bootstrapping) flux-density from the flux-density calibrator to the target source. The systematic error was estimated using the well-studied source (3C123), which has been shown to have a very constant flux density over time. The analysis showed that there is a $\sim 5\%$ systematic error during flux-density bootstrapping.

- Since some of the sources were observed at different days between Oct 2012 and Feb 2013, their flux-density variability with time were statistically analysed. The result is a preliminary indicator whether we would use the sources as flux-density calibrators for future surveys.

The current research uses the above results as an input for improving calibration and source extraction. The initial phase of the research are focusing on extracting sources located within the KAT-7 field of view ($\sim 0.8°$). In this case, each potential calibrator would serve as a phase center. To implement this, we initially utilize PKS J1939-6342 for the development of a data reduction pipeline.

After successfully implementing the pipeline to this source, we use it for the other sources in the list. Accordingly, the project goal will be :

- preparing a catalogue to be used as a sky model for calibration as well as utilizing it during the commissioning phase of the MeerKAT.
- getting a clear picture of the intrinsic and extrinsic variability of the sources.
- examining the number of sources as a function of the flux density to identify AGN and starburst galaxies.

  We can also deal with other issues that will come unexpectedly through the research process.

Summary of Progress

So far the research candidate has been reading different publications supporting the research and writing scripts that will be compatible with the softwares (meqtrees, CASA, ...). For this purpose, Pyxis was created by O.M Smirnov to simplify and facilitate the data reduction process. Hence, the candidate has been learning about the Pyxis as well as Meqtrees to effectively utilize them for the aforementioned objectives of the research.

The general steps followed by the candidate to extract of the sources.

- PKS J1939-6342 was selected as a tester for the development of the pipeline. The fact that its stable flux density and compact structure, as confirmed by various radio telescopes and interferometers, made the source to be our first choice for the purpose. Moreover, since it is southern hemisphere source, we could have 8 measurement sets (MS) during the observation periods. This helps us investigating the problem with each MS during the process of developing the pipeline.

- After having the position of the source from SUMSS catalogue and its flux density at 1.83 GHz from the candidate's previous research work, the sky model was prepared.
- After performing self calibration in meqtrees, we obtained the map representing the model minus the source. From this map, we could able to identify the sources using the source extractor software (pybdsm) within the KAT-7 FOV.

The pipeline has been constructed to firstly calibrate each MS and then concatenate them to yield one measurement set. By subtracting the sky model from the calibrated concatenated MS, we extract the source in the FOV. Using the corrected residual map, we implement pybdsm to extract the sources at threshold pixel of 5 and threshold island of 3. By doing so, 5 sources have been identified ranging from 25.5 mJy to 66.8 mJy.

Cross Validation

After extracting the sources, we cross-check their positions with their corresponding catalogue positions. This will serve as a means to distinguish whether the detected sources are real or fake. Secondly, we predict the flux densities of the sources at our observing frequency and compare them with the value obtained from our source extraction analysis.

We can estimate the flux density, S_{kat}, of a source at the KAT-7 observing frequency, ν_{kat}, using:

$$S_{kat} = S_{cat}\left(\frac{\nu_{cat}}{\nu_{kat}}\right)^{\alpha}, \tag{1}$$

where S_{cat}, ν_{cat} and α are flux density of a source obtained from the catalogue, the frequency of the survey in which the source was observed, and spectral index, respectively.

Since the spectral indices of the extracted sources are not available in the catalogues, we fairly use $\alpha \sim$ -0.7. This is due to the fact that α = -0.7 is a typical indicator of the non-thermal radio sources (i.e., detailed explanation is also available in the candidate Msc. thesis, pg 15-20).

We also need to compare the theoretical RMS with that of the images using:

$$\Delta S = \frac{2K_B T_{sys}}{\eta A\sqrt{\Delta\nu\Delta t n(n-1)}}, \tag{2}$$

where Δt is the total integration time. The other values in the above equation are listed in Table 1 shown below.

Table 1: The key parameters of the KAT-7.

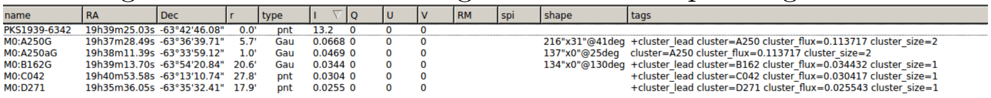
Parameters	values
Number of antennae (n)	7
Dish diameter (D/m)	12
Dish Area (A/m^2)	110
Aperture efficiency (η_a)	0.66
Central frequency (ν/GHz)	1.83
Bandwidth ($\Delta\nu$/GHz)	0.25
Wavelength (λ/cm)	16.41
Minimum baseline ($b_{\mathtt{min}}$/m)	26
Maximum baseline ($b_{\mathtt{max}}$/m)	185
System temperature (T_{sys}/K)	$\leq$ 35 across the entire frequency band (∽30 average) for all elevation angles
Synthesised resolution ($\theta_{\mathtt{res}}$)	$\sim 4'$
Primary beam (θ_{pb})	$\sim 54'$
Sky coverage (deg)	-80 to 50 (Dec) and 0 to 360 (RA)

Plan for the next 6 months

- Apply the pipeline for other calibrator sources in the list.
- Analyse the result and prepare the catalogue
- Write a draft paper for publication

Your recommendation is priceless for the success of the project. So, I kindly request you to send me your comments and suggestion after reading the progress report.

Figure 1: The sources along with the corresponding values.



name	RA	Dec	r	type	I	Q	U	V	RM	spi	shape	tags
PKS1939-6342	19h39m25.03s	-63°42'46.08"	0.0'	pnt	13.2	0	0	0				
M0:A250G	19h37m28.49s	-63°36'39.71"	5.7'	Gau	0.0668	0	0	0			216"x31"@41deg	+cluster_lead cluster=A250 cluster_flux=0.113717 cluster_size=2
M0:A250aG	19h38m11.39s	-63°33'59.12"	1.0'	Gau	0.0469	0	0	0			137"x0"@25deg	cluster=A250 cluster_flux=0.113717 cluster_size=2
M0:B162G	19h39m13.70s	-63°54'20.84"	20.6'	Gau	0.0344	0	0	0			134"x0"@130deg	+cluster_lead cluster=B162 cluster_flux=0.034432 cluster_size=1
M0:C042	19h40m53.58s	-63°13'10.74"	27.8'	pnt	0.0304	0	0	0				+cluster_lead cluster=C042 cluster_flux=0.030417 cluster_size=1
M0:D271	19h35m36.05s	-63°35'32.41"	17.9'	pnt	0.0255	0	0	0				+cluster_lead cluster=D271 cluster_flux=0.025543 cluster_size=1

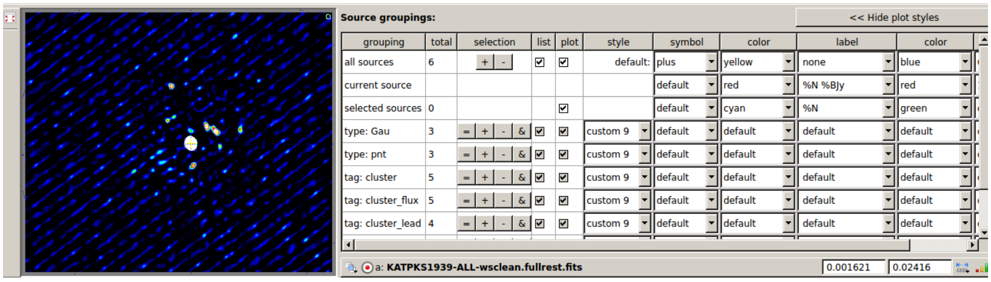


Figure 2: The initial feature of the pipeline for the source extraction.