A MeerKAT Pulsar Survey of Fermi Unidentified Sources

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Introduction

The survey is a part of the Large Survey Proposal **TRAPUM** (TRAnsients and PUlsars with MeerKAT). **Fermi LAT** has provided an amazing roadmap to assist with pulsar searches. We are conducting a survey using the **MeerKAT telescope** to find **new radio pulsars** associated with **gamma-ray sources**. In this poster, we will focus on the **preparation** for this survey. The main goals in this survey is to help uncover the population of energetic from our galaxy.

Telescope and catalogue

MeerKAT is a **64-dish radio interferometer** in the Northern Cape, South Africa. The Fermi Large Area Telescope Fourth Source Catalogue **(4FGL) [1]** contains a total of 5064 gamma-ray sources, 239 are pulsars and 1336 are unidentified sources.

MeerKAT parameters

Number of antennas	**64**
Dish diameter (m)	**13.5**
L-band (MHz)	**856-1712**
UHF (MHz)	**544-1088**
Gain (K/Jy)	**2.75**
Trec (K)	**18**
Number of beams	**480**
Coherent beam size (')	**~20 (L), ~25 (UHF)**

Source selection

We selected **79 sources** for the first phase of our survey. These were chosen based on 1) **probably of being a pulsar** from gamma-ray properties, 2) **source visibility**, and 3) **gamma-ray localisation** allowing for a single radio pointing. We do the cross-matched (**Figure 1**) with the **PSC list** to avoid duplicating effects. **NE2001 [2]** electron density model was used to evaluate **maximum dispersion measure (DM)** along the line of sight.

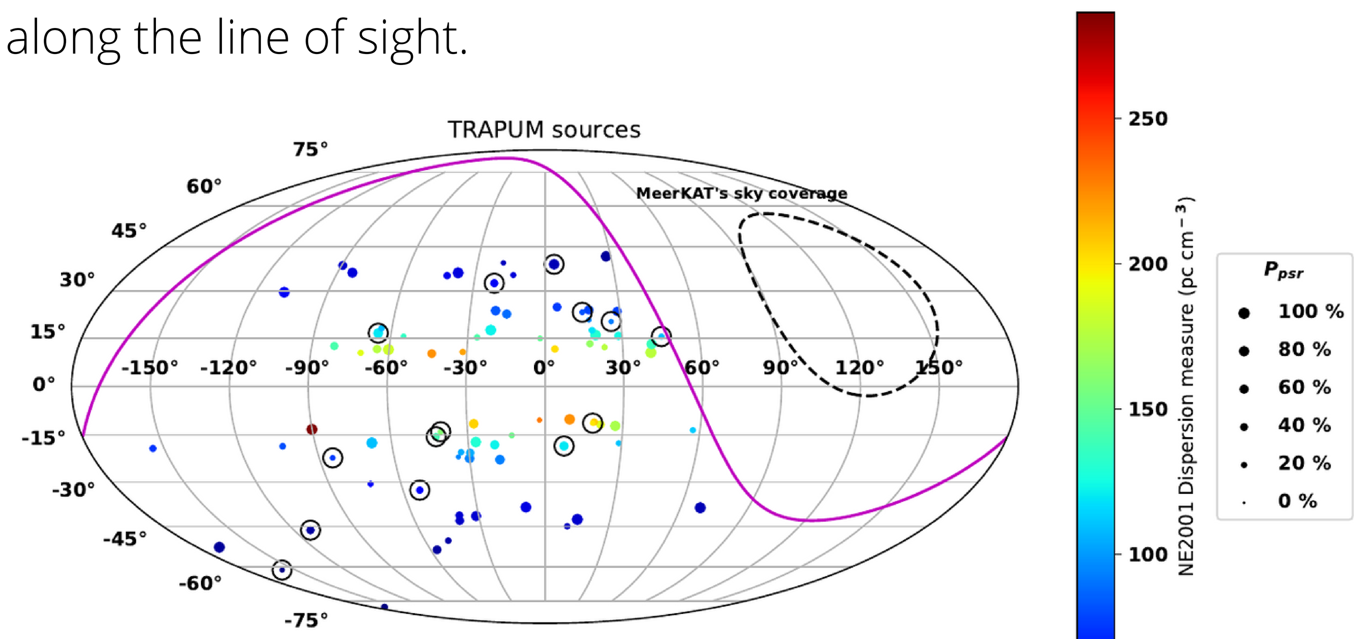

Figure 1 Targeted sources in Galactic coordinates. The data colour bar represents the maximum DM along the line of sight. Sources circled with a black circle represent the ones that have not been observed by the PSC. The purple line is 20°declination. The black line is MeerKAT's sky coverage and the dot size indicates the pulsar probability.

Integration time

In order to find the optimal integration time for MeerKAT telescope, we use the information from four previous surveys (**Parkes [3]**, **GBT [4]**, **Arecibo [5]** and **Effelsberg [6]**) to find the required time for MeerKAT to match their sensitivity (**Figure 2**).We conclude that **10 minutes** would be optimal to improve by an order of magnitude as previous work.

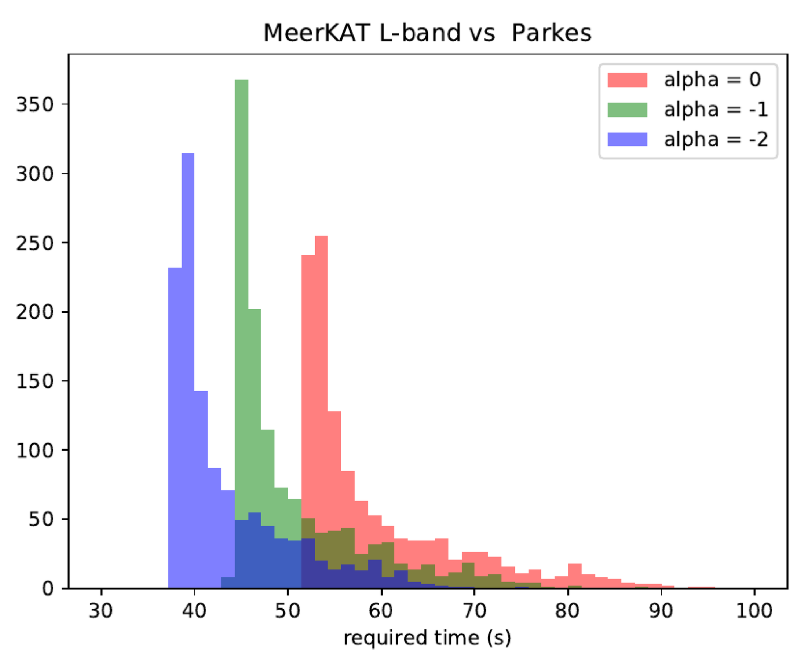

Figure 2 An example of histogram of required times for MeerKAT's L-bands to reach the same sensitivity as a similart survey at Parkes (1390MHz), assuming a spectral index of 0, −1 and −2.

De-dispersion plan

At this step, we design a processing strategy (**Figure 3**) using **PRESTO [7]**. The set up is to reach DM from **0 to 300 pc/cc** with steps of **0.05 pc/cc**, a sampling time of 57 µs, 2048 channels and 480 coherent beams with overlap at 70 % power.

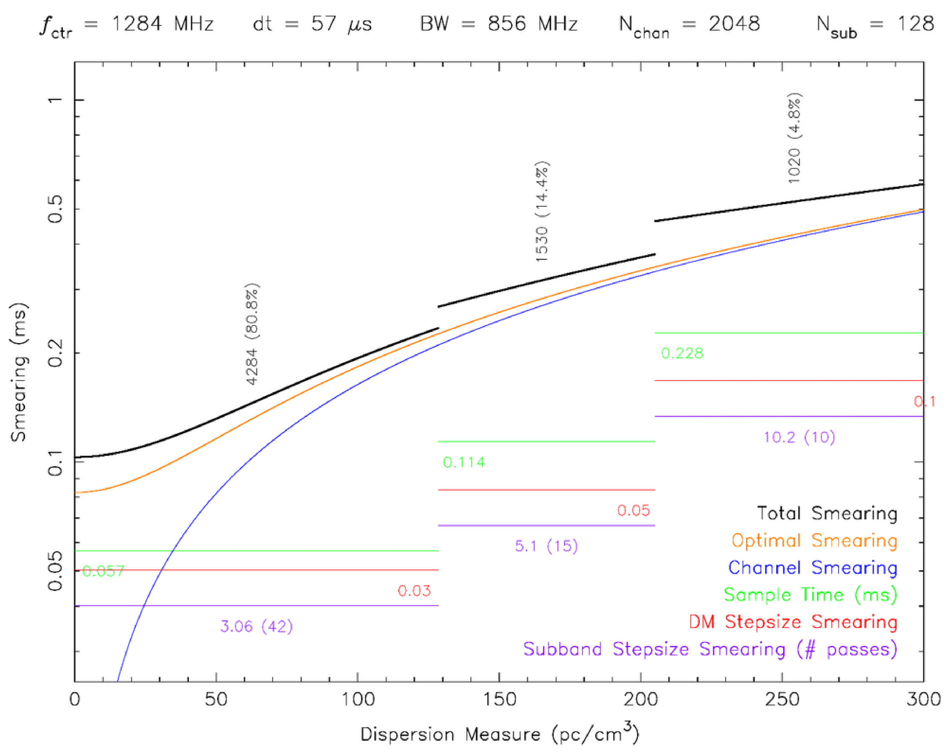

Figure 3 De-dispersion plan from PRESTO's ddplan.Key setup parameters are indicated at the top.

Acceleration search

Acceleration search [8] is a technique to find pulsars in **binary systems** using Doppler-shifted kernel matching for periodicity search in the Fourier space. For the planning, we plot the relationship between acceleration (a), Fourier shifted bin (z) and orbital period with orbital parameters for four common types of pulsar systems (**Figure 4**).

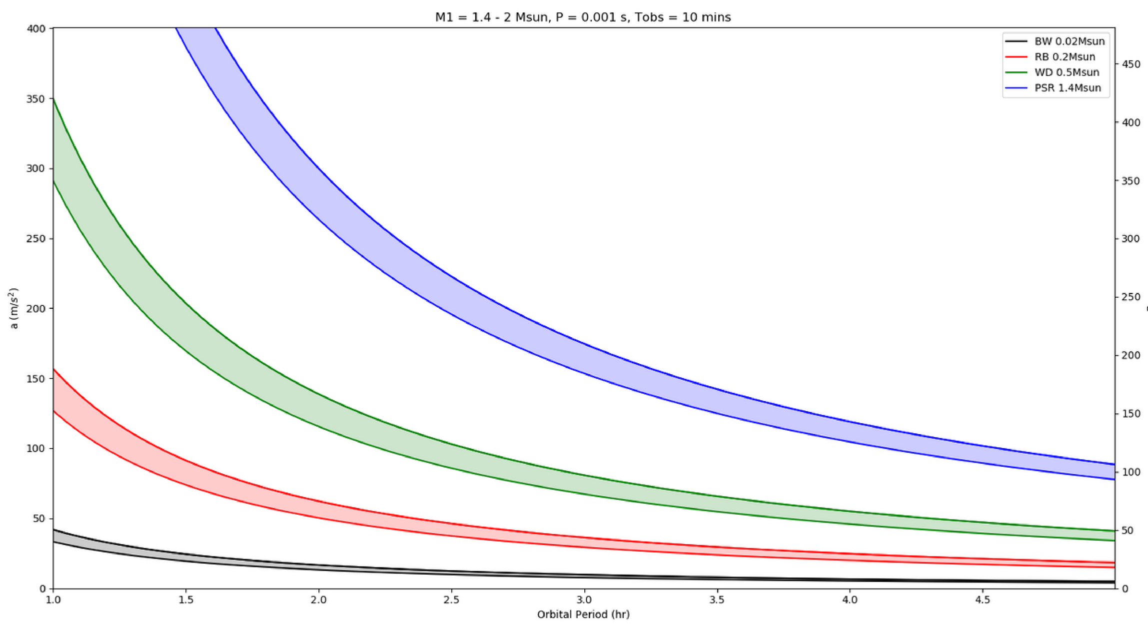

Figure 4 The plot between the orbital period and acceleration/z for pulsar binary system with distinct companions: Black widow (BW), Redback (RB), white dwarf (WD) and pulsar (PSR). The colour region represents the epulsar mass from 1.4 to 2 solar mass. Finally, we assume that the pulsar is a millisecond pulsar with an observing time of 10 minutes.

Result and Localisation

We discovered **eight new pulsar** candidates. Those have been confirmed as a pulsar by several telescopes. In order to find the position, we use a beam tilling script and a localisation script from Weiwei Chen and Tiaan Bezuidenhout, respectively. Lastly, we use the gamma-ray detection of known pulsar from Lars Nieder with the scripts for localisation (**Figure 5**).

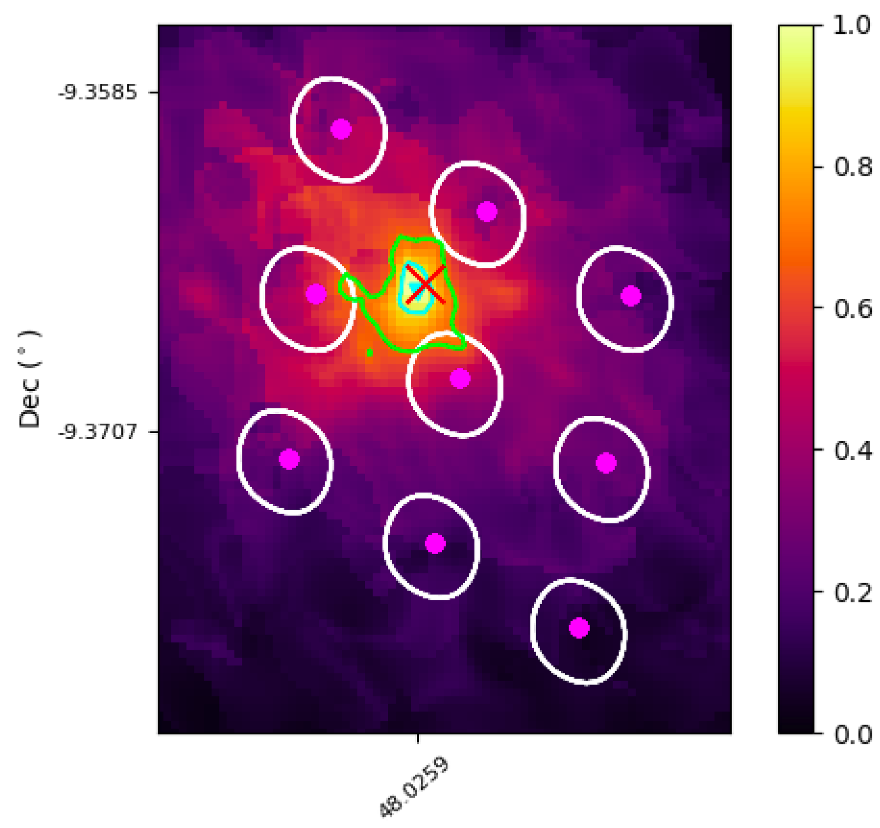

Figure 5 Localisation map for J0312.1−0921. The colour map depicts the localisation probability, with the pink dot marking the centre of eachbeam while the white contour is the beam shape at 70 % power point. Green and cyan contour represent 68 and 90 percent probability, respectively. The red cross is the location from the gamma-ray detection of J0312.1−0921.

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[3] Camilo F., et al., 2015, The Astrophysical Journal, 810, 85
[4] Ransom S. M., et al., 2010, The Astrophysical Journal, 727, L16
[5] Cromartie H. T., et al., 2016, The Astrophysical Journal, 819, 34
[6] Barr E. D., et al., 2012, Monthly Notices of the Royal Astronomical Society, 429, 1633
[7] Ransom S., 2011, PRESTO: PulsaR Exploration and Search TOolkit (ascl:1107.017)
[8] Andersen B. C., Ransom S. M., 2018, The Astrophysical Journal, 863, L13