A survey of the Galactic plane for dispersed radio pulses with the Australian Square Kilometre Array Pathfinder

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ABSTRACT
We report the results from a survey of the Galactic plane for dispersed single pulses using the Australian SKA Pathfinder (ASKAP). We searched for rare bright dispersed radio pulses comprising 160 pointings covering 4800 deg2 of the Galactic plane within |b| < 7◦, each pointing with an exposure time of 10 hours. We detected one fast radio burst, FRB 180430, and single pulses from 11 pulsars. No rotating radio transients were detected. We detected FRB 180430 in the Galactic plane in the anticentre direction with a fluence of 216 ± 5 Jy ms a dispersion measure (DM) of 264.1 pc cm−3. We estimate the extragalactic DM of the object to be less than 86.7 pc cm−3 depending on the electron density model. One model suggests that this FRB may be a giant pulse within our galaxy; we discuss how this may not correctly represent the line-of-sight DM. Based on the single detection of FRB 180430 in 3.47×104 deg2 h we derive a FRB event rate in the Galactic plane at the 20 Jy ms threshold to be in the range 2–140 per sky per day at 95% confidence. Despite the necessarily large uncertainties from this single detection, this is consistent with the current ASKAP all-sky detection rate.

Key words: surveys – intergalactic medium – pulsars: general – ISM: structure

1 INTRODUCTION
Single pulse radio transients such as fast radio bursts (FRBs; Lorimer et al. 2007), pulsar giant pulses (Staelin & Reifenstein 1968) and rotating radio transients (RRATs; McLaughlin et al. 2006) are isolated dispersed bursts of radio emission occurring on an extremely short timescale of nanoseconds to milliseconds. FRBs and single pulses of RRATs are distinguished by the dispersion measurement (DM) of these pulses. The DM of FRB are higher than the Milky Way DM contribution in that direction while the DM of pulsars and RRATs are lower than the Galactic contribution. Most RRATs have been observed with recurring outbursts but no FRB, except FRB 121102, has been observed to repeat.

The nature of FRBs remain largely unknown due to lack of definitive observational data. The DM of FRBs and RRATs indicate a different distance scale for the two populations. However, the sporadic burst rate and pulse properties of transient radio neutron stars such as RRATs (Keane & McLaughlin 2011 & McLaughlin et al. 2009) and magnetars (Pen & Connor 2015) display a similarity to the sporadic bursts of the repeating FRB 121102 (Spitler et al. 2014; Gajjar et al. 2018).

The Galactic plane is an interesting region to search for FRBs and single pulses from RRATs. The population of RRATs is observed to have a Galactic distribution1, with 69 out of the total 113 in low/intermediate Galactic latitudes. For FRBs, 11 low/intermediate latitude (|b| < 15°) FRBs have been detected from a total of 66 (Petroff et al. 2016)2. The paucity of FRBs detected in the Galactic plane is because the large majority of these FRB searches having been performed simultaneously with pulsar searches which focus on lower Galactic latitudes.

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1 http://astro.phys.wvu.edu/rratalog/
2 http://frbcat.org/
The search for FRBs in the southern Galactic plane has benefited from several large scale radio survey projects: the Parkes Multibeam Pulsar Survey (PMPS; Manchester et al. 2001), the High Time Resolution Universe South (HTRU-S; Keith et al. 2010), the upgrade to the Molongo Observatory Synthesis Telescope (UTMOST; Bailes et al. 2017), and the SURvey for Pulsars and Extragalactic Radio Bursts (SUPERB; Bhandari et al. 2018). These radio transient and pulsar surveys by Parkes (PMPS, HTRU-S, SUPERB) have provided 30 minutes to 1 hour pointings of the Galactic plane. These surveys have good sensitivity but have a relatively lower integration time per pointing due to the limited field of view (FoV) of these telescopes. With a telescope that has much larger FoV, it is possible to cover more sky simultaneously and provide longer integration time per pointing with the same amount of observation time. Thus increase the probability of detecting more of these bright dispersed single pulses, rarer RRAT outbursts and repetition.

The Australian SKA Pathfinder (ASKAP; Johnston et al. 2008; Schinckel et al. 2012) is a new wide-field radio telescope designed for large surveys. ASKAP has 36 12-metre antenna dishes which are equipped with an approximate 30 deg$^2$ FoV phased array feed receivers (PAF; Hay & O’Sullivan 2008). Each single ASKAP antenna has an measured System Equivalent Flux Density of approximately 2000 Jy, which is less sensitive than the Parkes radio telescope by a factor of 50, but the 30 deg$^2$ field of view at 1.4 GHz provided by the PAF is 40 times wider than Parkes. This enables a survey with low sensitivity but large simultaneous coverage.

The Commensal Real-time ASKAP Fast Transients survey (CRAFT; Macquart et al. 2010), has developed high time resolution (~1 ms) capabilities on ASKAP with the goal of localising dispersed radio pulses. 22 bright FRBs (fluences > 20 Jy ms) have been reported from surveys at Galactic latitude 50° (Bannister et al. 2017; Shannon et al. 2018; Macquart et al. 2018) and two at a Galactic latitude of 20° (Macquart et al. 2018).

In the past works, the discovery rates of FRBs at low Galactic latitudes is lower compared to high latitudes (Burke-Spolaor & Bannister 2014, Petroff et al. 2014 and Keane & Petroff 2015). Several factors have been proposed to explain this absence by Petroff et al. (2014): dispersion and scattering by the interstellar medium (ISM); relatively high sky temperature and scintillation. There is also some evidence that suggest at least one low Galactic latitude FRB may be RRATs due to the additional Hα and Hβ observations for FRB 010621 (Bannister & Madsen 2014). This implies a possible population of giant pulses from distant pulsars that were not previously detected similar to FRBs. However, recent FRB discoveries such as Caleb et al. (2017) have shown less dependence on Galactic latitude in detectability.

To search for low burst rate (> 1 Hrs$^{-1}$) RRATs and constrain the low-latitude FRB event rate, we conducted a millisecond timescale Galactic plane survey for pulsars and radio transients with the longest observation time per pointing, aimed at 10-hours total observation time of the entire Galactic plane observable from ASKAP.

### 2 SURVEY OVERVIEW

#### 2.1 Receiver Configuration and Survey Data Reduction Pipeline

The PAF consists of 36 dual polarization beams sensitive to radio frequencies between 0.7 and 1.8 GHz. Beam weights are calibrated with a maximum signal-to-noise (S/N) algorithm and observing the sun as the reference source (Hotan et al. 2014; McConnell et al. 2016). The signal received by the PAF from each element is digitized and channelized to 336 1-MHz frequency channels. For the observations in this survey the band was centred at 1297 MHz.

The CRAFT data pipeline is described in detail by Clarke et al. (2014). For the survey presented in this work, the voltages from the beamformer are squared and averaged over an integration time of 1.265 ms. The data is then transmitted to a processing computer and saved in SIGPROC format filterbanks (Lorimer 2011).

The data are then searched offline with the Fast Real-time Engine for Dedispersing Amplitudes (FREDDA; Bannister et al. in prep.), a GPU based FRB detection pipeline implementing the Fast Dispersion Measure Transform algorithm (FDMT; Zackay & Ofek 2017). There is a detailed description of the software in Bannister et al. (2017).

In this survey we use FREDDA to search for candidates within the dedispersion range is 0–3763 pc cm$^{-3}$. To focus our search on possible FRB candidates which have a relative narrower pulse profile and reduce the misidentification of known radio frequency interference (RFI), we applied a width boxcar threshold of < 11 time samples (approximately 13.915 ms) and a S/N > 7.5 detection limit to reduce false candidate events. Due to the significant number of pulsars in the Galactic plane, we performed a pulsar identification using the beam position and the DM of the candidates. We searched for pulsars and RRATs within a 1.5 beam radius (approximately 0.68 degrees) and 10 percent DM threshold based on DM and position information from the latest version of the pulsar catalogue psrcat$^3$ database (Manchester et al. 2005). The pulsar and RRAT candidates that match one of the following criteria were selected:

(i) The object has been detected more than 5 times in all observations during this survey.

(ii) The object has been detected less than 5 times but has an average significance of 9.5σ or higher during this survey.

Identified single pulses and unidentified single pulses are written to separate files for further RFI check and pulse validation. For strong candidates (S/N > 9.5), five second cutouts were automatically generated to display the spectra of the filterbank for fast visual validation check of RFI. We then visually inspected the cutout images for false detections. We also show a visualization of this pipeline in Figure 1.

The amplitude of candidate spectra is converted to physical units with an assumed system equivalent flux density (SEFD) measurement ($S_{sys} = 2000$ Jy). We assume off-pulse noise in the observation data to be gaussian noise.

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$^3$ http://www.atnf.csiro.au/research/pulsar/psrcat/
2.2 Survey Parameter Space

We conduct a search for bright single pulses along the Galactic plane in this survey using 8 ASKAP antennas as 8 separate single dish telescopes. With the extended 240 deg$^2$ FoV of 8 ASKAP antennas this is an ideal survey for capturing random rare bright radio bursts such as FRBs and pulsar giant pulses. This survey has a significantly poorer sensitivity compared with other single dish telescopes such as Parkes but surpasses the integration time per pointing of most other Galactic plane surveys while only using a much shorter observing period as shown in Figure 2. We highlight the light green region as the previously undetected time domain for burst repetition that we probed with this survey. Also, the single dish sensitivity of ASKAP is sufficient for detecting previously detected FRBs, and we expect to search for the population of bright FRBs as displayed in Shannon et al. (2018) at higher Galactic latitudes.

In Figure 2, we plot 40 RRATs with known burst rates and flux measurements to compare the current population of RRATs to the sensitivity and observation time of this previous Galactic plane surveys. We also display the single pulse distribution of the RRAT J1819-1458 based on the work of single pulse energetics in Burke-Spolaor et al. (2012). This limit indicates that this survey will not likely detect the fainter frequent Galactic radio single pulses from these known RRATs. It should be noted that there are RRATs with lower flux densities than J1819-1458 but without a known burst rate we do not estimate the detectability of these RRATs in this plot. To confine our estimates, we calculate an estimate detection rate with a simulated population of RRATs in Section 2.4.

2.3 Survey Strategy and Observations

This survey operates ASKAP in ‘fly’s-eye’ mode, pointing each dish in a different direction to extend the total FoV during observing. The FoV in ‘fly’s-eye’ observing mode is the beam pattern using a single ASKAP dish, but it is multiplied by the number of dishes we deploy for observing.

For the CRAFT survey, we have adopted a beam pattern configuration as shown by Supplementary Figure 2 in Shannon et al. (2018). Eight ASKAP antennas were operated in fly’s-eye mode during this survey, giving a maximum simultaneous coverage of 36 × 8 0.9° circular beams on the sky.

Our survey is designed to observe within the Galactic latitude range |b| < 7°, we display the observable region in Figure 3. Each ASKAP antenna has a roll axis for the prime reflector to correct apparent rotation of the sky. 160 pointings for the survey were planned by meshing the PAF beam pattern footprint. We align the antenna footprint into...
Figure 4. An example of footprint patterns of observed pointings meshed on sky along the galactic plane, we use a random colour scheme to distinguish the footprints.

Table 1. Survey Observation Specifications

| Region | $|b| < 7^\circ$, $170^\circ < l < 180^\circ$, $-180^\circ < l < 75^\circ$ |
|--------|-----------------------------------------------------|
| $\tau_{obs,pointing}$ (s) | 36 000 |
| SEFD (Jy) | ~2000 |
| Total pointings | 160 |
| $\tau_{obs,total}$ (s) | 5 760 000 |
| $N_{beams}$ per pointing | 36 |
| FWHM 1.32 GHz | 0.9° |
| Bandwidth (MHz) | 336 |
| $\tau_{samp}$ (ms) | 1.265 |
| $\Delta\nu_{chan}$ (MHz) | 1 |
| Centre Frequency (GHz) | 1.297 |
| $N_{chans}$ | 336 |

three parallel strips of observation footprints perpendicular to the Galactic pole at respectively $b = 0^\circ, \pm 4.67^\circ$ as shown in Figure 4. This meshes the footprints together perfectly for maximum survey efficiency.

Observations for this survey were carried out between 2018 March 29th and 2018 May 30th. Each pointing region was to be observed with a total time of 10 hrs, this sums to a total observation time of 66.7 antenna days.

We show the technical specifications for the observation in Table 1. Observation time for some pointings did not reach full target time due to commissioning work during the observation period. In this paper, we present results obtained from a total observation time of 63.1 antenna days.

2.4 RRAT Population Model

In order to get a prediction of the number of RRATs detectable by our survey, we use the population model as described in Agarwal et al. (in prep). Using PsrPopPy2\(^4\) (Bates et al. 2014) we create a simple population model without any time evolution. In brief, we start with a uniform distributions in spin period, $P$, Galactic scale height, $z$, Galactocentric radius, $R$, and log-uniform in pseudo-luminosity, $L$, and burst rate, $\dot{\chi}$. For each RRAT, the single pulse amplitude distribution is taken to be log-normal with mean sampled from the luminosity distribution and standard deviation set to ten percent of the mean. The population is then passed through four model surveys: the Parkes multibeam survey (Manchester et al. 2001; Keane et al. 2011), two higher latitude surveys (Jacoby et al. 2009; Edwards et al. 2001), and the HTRU intermediate latitude survey (Keith et al. 2010). The distributions of the detected population compared with observed distributions form the observed RRATs. The underlying population is then modified using correction factors in a similar manner to that described in Lorimer et al. (2006). We reach the optimal underlying population when the reduced $\chi^2$ between the distributions of the model detected population and observed population are of order unity. We draw 54 RRATs (as detected by the above mentioned four surveys) using the optimal underlying distributions for the physical parameters and run a model CRAFTs survey to get the number of potentially detectable RRATs. To produce the distribution of the number of RRATs detectable by the CRAFT survey, we run a 1000 iterations of the following simulation, shown in Figure 5.

3 RESULTS

3.1 Pulsar and RRAT detections

A total of 11 pulsars were detected through single pulse detection in this survey as shown in Table 2. We did not detect any RRATs listed in psrcat or the rratatalog. The period and flux density values recorded in psrcat are also displayed

\(^4\) https://github.com/devanshkv/PsrPopPy2
Table 2. List of confirmed pulsar detections during the survey

| Pulsar        | Number of Detections | Average S/N | DM (pc cm$^{-3}$) | Boxcar Width$^a$ (samples) | Flux 1.4GHz $^b$ (mJy) | Pulse Width$^b$ (ms) |
|---------------|----------------------|-------------|-------------------|----------------------------|------------------------|----------------------|
| B0525+21      | 11                   | 11.0        | 52.51             | 7.00                       | 9.00                   | 214.2                |
| B0531+21      | 746                  | 13.8        | 56.56             | 0.39                       | 14.00                  | 4.7                  |
| B0833–45      | 195013               | 14.2        | 67.40             | 1.17                       | 1100.00                | 4.5                  |
| B0835–41      | 808                  | 10.5        | 147.1             | 3.15                       | 16.00                  | 18.0                 |
| B1641–45      | 72394                | 12.2        | 477.7             | 7.27                       | 296.40                 |                      |
| B1727–47      | 42                   | 11.5        | 122.4             | 2.98                       | 12.00                  | 32.0                 |
| B1749–28      | 26                   | 9.40        | 49.70             | 4.15                       | 18.00                  | 15.0                 |
| B1933+16      | 32                   | 9.94        | 159.0             | 4.19                       | 42.00                  | 17.7                 |
| B2020+28      | 129                  | 10.3        | 24.69             | 1.11                       | 38.00                  | 15.8                 |
| J1047–6709    | 2                    | 9.97        | 115.9             | 1.00                       | 4.00                   | 21.0                 |
| J1107–5907    | 11                   | 13.6        | 40.75             | 5.45                       | 0.18                   | 170.0                |

$^a$ The boxcar width is in units of 1.2 ms samples.

$^b$ Literature results provided from psrcat for comparison. We note that the mean flux density from literature is the flux averaged and our instrument is only sensitive to the brightest pulses. Therefore our detections are biased to high fluence pulses. Among these pulsars, J1107–5907 is a known intermittent pulsar previously studied using ASKAP (Hobbs et al. 2016).

3.2 Detection of FRB 180430

We collected a total of 25079 unidentified candidates in 1514 antenna-hours. We then inspected the candidates in a time-DM plot to identify most false positive RFI events. For the remaining candidates, we checked the spectra created by the pipeline to verify the candidates and remove RFI events. After RFI removal and visual verification, we were able to find FRB 180430. We show the information for FRB 180430 and detection details in Tables 3 and 4, we also include the Galactic DM contribution and excess DM from both NE2001 (Cordes & Lazio 2001) and YMW16 (Yao et al. 2017) models for comparison.

We searched all other candidates from observations of the same pointing in a total of 10.9 hours. We did not find any other candidates with the same dispersion measure above a S/N ratio of 7.5. No single pulse of the same DM was detected in this pointing region during the whole survey period. A Periodicity search of the filterbank containing FRB 180430 did not find any periodic signal during the observation at the given DM in a total observation time of 1675.85 seconds. We also acquired 2.5 hours of occasional follow-up time between June 5th 2018 and December 23rd 2018 with Parkes and did not find any repetition from FRB 180430 at a fluence limit of $\sim 0.1$ Jy ms.

We performed a multi-beam localisation, flux measurement and dispersion measurement of FRB 180430 by combining the detection from all 4 beams. The details of the localisation technique is explained in Bannister et al. (2017). We are able to constrain the position of FRB 180430 within a region of $6' \times 6'$ at 90% confidence and $2' \times 2'$ at 50% confidence.

4 DISCUSSION

4.1 RRAT Non-Detections

We previously show in our population model that we may detect 0-4 RRATs. In this survey, we did not detect any RRATs in our single pulse pipeline. It should be noted that the average pulse width of known RRAT pulses is 18.3 ms with a wide range from $\sim 3$ ms to $\sim 65$ ms, the average width exceeds the $\sim 13$ ms width threshold of our current detection pipeline (see Section 2.1) which may also affects the detection. The average width of RRATs at 1400MHz as recorded in the rratalog is 18.28 ms, with no clear correlation of

Table 3. Properties of FRB 180430

| Observation Results |
|---------------------|
| Date                | 2018 Apr 30 |
| Time of Arrival     | 10:00:35.70(TAI) |
| Dispersion Measure (DM) | 264.1(5) pc cm$^{-3}$ |
| Right Ascension$^a$ (J2000) | 06h51m(6) |
| Declination$^a$ (J2000) | 09°57′(6) |
| Galactic Longitude  | 221.76° |
| Galactic Latitude   | 4.61° |
| Width               | 1 sample$^b$ |
| Fluence             | 177(4) Jy ms |

| Milky Way DM Estimates |
|------------------------|
| DM$_{MW,NE2001}$       | 165.44 pc cm$^{-3}$ |
| DM$_{MW,YMW16}$        | 294.16 pc cm$^{-3}$ |

$^a$ The 1-$\sigma$ uncertainty of the last digit is given in the parentheses

$^b$ The time of one sample in the CRAFT filterbank is 1.2 ms

Table 4. The observation details of the ASKAP PAF for the detection of FRB 180430.

| Beam | S/N | DM (pc cm$^{-3}$) | R.A. (deg) |Declination (deg) |
|------|-----|-------------------|------------|------------------|
| 16   | 17.34 | 263.4 | 103.380932 | 10.434731 |
| 17   | 28.20 | 263.4 | 102.970281 | 9.630296  |
| 21   | 25.25 | 263.4 | 102.467378 | 10.381924 |
| 22   | 14.28 | 263.4 | 102.058956 | 9.576174  |
width and fluence. This implies that we may not detect some single pulses due to the limited width threshold applied for candidate selection.

Based on the zero RRAT single pulses in a total observation of $34692.4 \text{ deg}^2 \text{ h}$, the non-detection of RRATs provides a 95 per cent Poisson uncertainties upper limit of $< 8.64 \times 10^{-5} \text{ deg}^{-2} \text{ h}^{-1}$ within width $< 12.7 \text{ ns}$ and above a flux threshold of 20 Jy (Gehrels 1986). This limit is heavily affected by the pipeline’s candidate selection parameters, and we expect to perform a more complete longer width and lower DM search with improved software.

4.2 The localisation of FRB 180430

FRB 180430 has a relatively large DM (264.1(5) pc cm$^{-3}$) compared to two nearby pulsars recorded in within a 10 degree radius which all have a DM of $\sim 100 \text{ pc cm}^{-3}$ this makes it very hard to estimate the DM contribution of the Milky Way in this direction. The distance of these pulsars based on their dispersion measurement are $\sim 2 \text{ kpc}$. Both pulsars have much lower dispersion than FRB 180430 and there is a lack of pulsars at higher dispersion measures in this direction. There is a disagreement on the Galactic DM contribution of FRB 180430 from the two main Galactic electron density models. It is not significantly higher than the estimate DM from the models as shown in Table 3.

This is the second FRB, the other being FRB 010621, that has a disputable DM estimate, we try and explain which model is more feasible. The measurement from NE2001 indicates an excess DM of 98.7 pc cm$^{-3}$, suggesting an extragalactic object. The YMW16 model provides a higher DM which exceeds the DM of FRB 180430, indicating a Galactic object. However the YMW Milky Way model arbitrarily extends the disk beyond $\sim 19 \text{ kpc}$ in the anticenter direction due to the lack of pulsars in that direction beyond 15 kpc (Yao et al. 2017). This may result in an overestimated Galactic DM from the YMW16 model. In this case, we suggest the lower Galactic DM by NE2001 would be more correct.

We consider a 12 pc cm$^{-3}$ contribution from the Milky Way halo (DM$_{\text{Halo}}$) following Mahony et al. (2018), using the excess DM of pulsars detected on the near side of the Large Magellanic Cloud (Manchester et al. 2005). The halo contribution is uncertain and may be higher with additional DM at further distances giving DM$_{\text{Halo}} = 30 \text{ pc cm}^{-3}$ (Mahony et al. 2018; Dolag et al. 2015), we use the former lower estimate to determine maximum redshift.

Figure 6. Example single pulse detections of each pulsar.
The DM of radio single pulses usually provides an estimate for the distance of these phenomena. In this case, after subtracting the NE2001 model and halo DM contribution, the estimated maximum excess extragalactic DM is 86.7 pc cm$^{-3}$. This gives an estimate a maximum host galaxy redshift (zero host DM contribution) of $z = 0.072$ (Inoue 2004). However, we note that there is a large scatter effect in such low dispersion measurements for estimating the redshift (McQuinn 2014).

We could not find any counterpart object such as a X-ray/radio pulsar, supernova remnant or host galaxy in SIMBAD (Wenger et al. 2000), the High Energy Astrophysics Science Archive Research Center (HEASARC)$^5$ and the NASA/IPAC Extragalactic Database (NED)$^6$ using the current $6'\times 6'$ localisation information of FRB 180430. The lack of host galaxies in the search results is expected due to the Galactic plane is not often observed in galaxy surveys.

$^5$ https://heasarc.gsfc.nasa.gov/
$^6$ https://ned.ipac.caltech.edu/
4.3 Is FRB 180430 a RRAT?

The low excess DM of FRB 180430 and disagreement with the YMW16 model does not allow us to exclude the possibility of this FRB being a galactic pulsar giant pulse or RRAT outburst. The excess DM in these cases clearly cannot distinguish an FRB and a RRAT; further analysis on the repetition rate and pulse properties such as scattering would help the argument for either case (Keane 2016). We take FRB 180430 as an example case to try discuss the boundaries between FRBs and RRATs at the edge of the Milky Way.

The absence of a supernova remnant, X-ray source or radio pulsar does not favour the possibility of this radio burst originating from a Galactic pulsar. However this does not exclude the possibility of a very faint source of Galactic origin for the burst. We note that there were no X-ray observations for this field archived in HEASARC. Future observations in X-ray may be able to further reveal the nature of FRB 180430.

The narrow width and patchy non-scattering spectral properties of FRB 180430 are similar to other FRBs detected by ASKAP and is narrower compared to RRATs which are usually wider in pulse width. We searched for possible Hα and Hβ excess in the SuperCOSMOS (Parker et al. 2005) and SHAASS (Gastaud et al. 2001) but did not find any detection within the localisation region to compare with the work performed in Bannister & Madsen (2014). There is also no scattering observed in FRB 180430, which would likely suggest less ISM contribution in the total medium FRB 180430 has passed through (Lorimer et al. 2013). These facts favour towards the NE2001 model and suggest an extragalactic origin for FRB180430.

If FRB 180430 originated in the Milky Way, it could be possible that it was a giant pulse from a young pulsar in a supernova remnant (SNR) similar to PSR B0531+21 (Crab pulsar, Connor et al. 2016; Lyutikov et al. 2016) or PSR B0540–69 (Seward et al. 1984; Manchester et al. 1993; Johnston et al. 2004) in the Large Magellanic Cloud. There are observations of extremely narrow mega-Jansky level Crab giant pulses (Hanks & Eilek 2007). Based on the YMW16 Galactic model, a pulsar with the DM of FRB 180430 would be at an estimate distance of no less than 8 kpc. The crab pulsar is at a distance of 2 kpc, the observed flux of a giant pulse similar to that of the Crab pulsar at such distance would be ~ 60 Jy. This is to the same order of flux density to FRB 180430 and suggests the possibility of a pulsar giant pulse at the edge of the Galactic plane. We performed a periodicity search with 1675.85 seconds of data from this observation. We did not find any periodicity at the DM of the FRB above 3σ (approximately 0.06 Jy with an assumed duty cycle of 0.1). These giant pulses should frequently appear, if it is indeed a pulsar we expect to see repetition from this source. However in the 10 hours of observation with ASKAP and 2.5 hours follow up with Parkes, we have not yet seen any repetition from this region.

We also consider the possibility of a RRAT at such distances. Although there has been X-ray emission detected from RRATs such as J1819-1458 (Reynolds et al. 2006), there are also cases where no X-ray emission has been detected (Kaplan et al. 2009). Therefore X-ray emission may not play an important role in identifying FRB 180430 as a RRAT. Most RRATs have a pulse width of ~ 15 ms and thus are much wider than FRB 180430 and other FRBs, but J1819-1458 is also the brightest RRAT observed, which peak flux reaches 3.6 Jy at a distance of 3.6 kpc (McLaughlin et al. 2006). Should FRB 180430 be a RRAT, it would be the brightest RRAT outburst and the narrowest pulse profile observed, yet these properties fit very well to the generic appearance of the FRB population. Also FRB 180430 has yet been observed to repeat as mentioned previously, such non-repetition would not be favoured towards RRATs (Keane 2016).

In summary, despite the possibilities of RRATs and pulsar giant pulses no other giant pulse of the same DM has been detected yet from this position. The no repetition of a high fluence unscattered single pulse event suggests that FRB 180430 is an extragalactic radio burst compared to the other possibility of a young pulsar or RRAT in the Milky Way.

4.4 FRB event rate and single pulse limits

Based on the total search time and number of FRB detections, we provide an estimate comparison FRB rate from this Galactic plane survey. The Galactic plane survey consisted 160 pointings, each pointing’s PAF footprint had an effective FoV of 22.9 deg². We use this effective FoV to calculate the total exposure of the survey. The resulting event rate

\[ R = \frac{1 \text{ FRBs} \times 24 \text{ h}^{-1} \times 41253 \text{ deg}^{-2} \text{ sky}^{-1}}{34692.4 \text{ deg}^{2} \text{ h}^{-1}} \]

which translates to

\[ R = \frac{29_{-27}^{+107}}{\text{sky}^{-1}} \text{ d}^{-1} \] with 95 per cent Poisson uncertainties (Gehrels 1986) at 20 Jy ms fluence equivalent sensitivity. The event rate, albeit with large uncertainties due to one single detection, is comparable to the event rate at Galactic latitude 50° presented in Shannon et al. (2018).

5 CONCLUSION

In this paper, we present the results of a 10 hour per pointing fly’s-eye survey of the Galactic plane with ASKAP in a total observation time of 63.117 antenna-days on the Galactic plane between $|b| < 7\degree$. We then present the data analysis and results in search of fast radio bursts and other fast radio transients. The main results and conclusions of this survey are as follows:

(i) No single pulse from RRATs were detected during this survey. Non-detection of RRATs gives an upper limit of the RRAT detection rate $< 8.64 \times 10^{-3} \text{deg}^{-2} \text{ h}^{-1}$ at 20 Jy ms fluence equivalent sensitivity and width $< 12.7$ ms.

(ii) We detected single pulses from 12 known pulsars.

(iii) FRB 180430 is an anti-centre FRB candidate with an uncertain low extragalactic excess DM between zero and 98.7 pc cm⁻³, we suggest this is more likely an extragalactic source a possible host galaxy at redshift $z < 0.072$. No catalogued galaxy was found and follow up with the Parkes radio telescope did not detect any repetition.
(iv) The detection of one FRB during this survey gives a FRB detection rate of $29^{+107}_{-27}$ sky$^{-1}$ d$^{-1}$ at 20 Jy ms fluence equivalent sensitivity.

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