



A Square Kilometre Array Pulsar Census

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Most of the pulsar science case with the Square Kilometre Array (SKA) depends on long-term precision timing of a large number of pulsars, as well as their astrometric measurements using very long baseline interferometry (VLBI). However, before we can time them, or VLBI them, we must first find them. Here, we describe the considerations and strategies needed when planning an all-sky blind pulsar survey using the SKA. Based on our understanding of the pulsar population, the performance of the now-under-construction SKA elements, and practical constraints such as evading radio frequency interference, we project pulsar survey yields; this is done using two complementary methods for a number of illustrative survey designs, combining SKA-Low and SKA-Mid Bands 1 and 2 in a variety of ways. A composite survey using both SKA-Mid and SKA-Low is optimal, with Mid Band 2 focused in the plane. We find that, given its much higher effective area and survey speed, the best strategy is to use SKA-Low to cover as much sky as possible, ideally also overlapping with the areas covered by Mid. We find that an all-sky blind survey with Phase 1 of the SKA with the AA* array assembly will detect $\sim 10,000$ slow pulsars and ~ 800 millisecond pulsars (MSPs) if SKA-Mid covers the region within 5 deg of the plane, while higher latitudes will be covered with SKA-Low. For the same survey region the yield with AA4 is $\sim 20\%$ higher, but this increases considerably by broadening the range covered by SKA-Mid Bands 1 and 2. In particular one could expect a yield of ~ 1300 MSPs with AA4. The pulsar census will enable us to set new constraints on the uncertain physical properties of the entire neutron star population. This will be crucial for addressing major SKA science questions including the dense-matter equation of state, strong-field gravity tests, and gravitational wave astronomy.

1 Introduction

Pulsar science is one of the foremost drivers for the Square Kilometre Array (SKA) Observatory (Braun et al., 2015). The possibilities in pulsar science highlighted in the 2015 SKA Science Case (Kramer and Stappers, 2015) have, in the intervening decade, motivated the design of many components of the SKA, which is now under construction in South Africa and Australia. In this paper, we revise our earlier estimates (Keane et al., 2015; Levin et al., 2018) for the number of pulsars detectable by SKA using a variety of blind pulsar survey approaches. Updated estimates are timely for a number of reasons. Firstly, immediately after the publication of our 2015 estimates, SKA was ‘re-baselined’; the effect was a nominal loss of 50% and 30% in collecting area for SKA-Low and Mid, respectively. In addition to this, the design went from incompatible ‘desirements’ of diverse user groups, to a rigorously tested set of requirements determined via a systems engineering approach (Caiazzo, 2021). As a result, many additional design choices and optimisations have occurred in the last decade. Our understanding of the pulsar population has improved in many ways, driven by new discoveries and measurements performed using SKA precursor and pathfinder instruments. Here, we factor in these changes to re-estimate pulsar survey yields from SKA using a two-pronged approach, discuss underlying challenges in deriving these estimates and highlight key areas that we need to address to advance our pulsar science cases.

Below, in § 2, we describe our two population synthesis analyses, both the snapshot and evolutionary approaches. This is followed in § 3 by our analysis of the sensitivity and survey speed of both the Mid and Low arrays. As subsets of the full arrays can be combined, in what is termed a ‘sub-array’, there are a number of sensitivity and field-of-view combinations possible so our analysis is performed as a function of increasing sub-array size. With our calculated and chosen survey parameters, we present our population synthesis results and our expected survey yields when employing each of three options for composite surveys using Low, Mid Band 1 and Mid Band 2. Finally in § 5, we discuss our estimates, and the magnitude and reasons for systematic uncertainties in these. We conclude with a ‘wish list’ of activities that can already be undertaken to improve pulsar population modeling and survey yield estimates.

2 Population Synthesis

Pulsar population synthesis is an attempt to determine the intrinsic underlying population of pulsars in the Galaxy (Faucher-Giguère and Kaspi, 2006; Lorimer et al., 2006; Kiel et al., 2008; Gullón et al., 2014; Johnston and Karastergiou, 2017), along with their key properties, based on the known observed population and our understanding of observational selection effects and other biases, as well as on our theoretical understanding of neutron star astrophysics which cannot be derived from the observations alone. Population synthesis can be undertaken in a number of ways. Here, we perform the modeling using two approaches, a ‘snapshot’ approach (Lorimer et al., 2006; Bates et al., 2014) and an evolutionary method (Graber et al., 2024; Pardo-Araujo et al., 2025). Whereas the former method models the Galactic pulsar population based on currently observed properties, the latter models the evolution of pulsars based on a set of initial conditions to reach the current

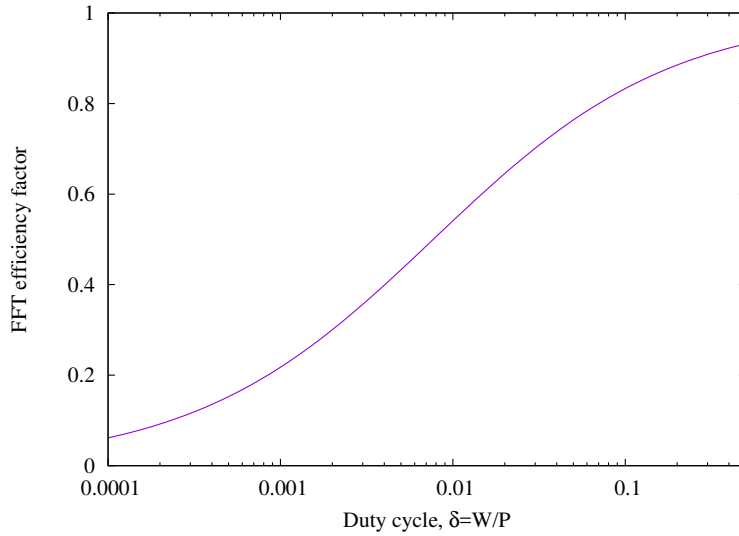


Figure 1: Shown is the FFT correction factor as a function of duty cycle, as determined by [Morello et al. \(2020\)](#); this is the response when 32 harmonics are summed. The efficiency is relative to perfectly phase-coherent signal-to-noise estimates, which the fast folding algorithm ([Morello et al., 2023](#)) more closely approaches.

population. Subsequent observational filters applied (see § 3) are, however, identical.

2.1 Snapshot

The snapshot pulsar population synthesis was undertaken using PSRPOPPY ([Bates et al., 2014](#)), which is a translated and expanded version of its predecessor PSRPOP ([Lorimer et al., 2006](#)). This population synthesis approach tries to reproduce the current observed distributions of pulsar properties, and with this achieved, the resulting population can be used to make predictions of search yields for any given survey parameters. We first updated the software¹ to correct a number of issues with inconsistent survey parameters. The most substantive change is an update to the signal-to-noise ratio calculation. Pulsars are predominantly found via Fourier-domain methods. As such, we included the duty cycle-dependent efficiency factor determined by [Morello et al. \(2020\)](#) as appropriate for incoherent searches based on Fast Fourier Transforms. Figure 1 shows this correction factor. The overall effect is to suppress narrow duty cycle pulsar signals. As the duty cycles in the long-period (hereafter ‘slow’) pulsar population are typically narrow in general, whereas those of the faster spinning millisecond pulsar population are wider, the deleterious effect is more pronounced in the slow pulsar population.

As a result of these changes, and the slight increase in pulsar detections in surveys previously considered to be complete, we re-performed the analysis of [Bates et al. \(2013\)](#) to determine the spectral index distribution that is consistent with three archival Parkes surveys. These were namely the Parkes Southern Pulsar Survey ([Manchester et al., 1996](#); [Lyne et al., 1998](#)) at 70 cm, the Parkes Multi-beam Pulsar Survey ([Manchester et al., 2001](#); [Morris et al., 2002](#); [Kramer et al., 2003](#); [Hobbs](#)

¹<https://github.com/evanocathain/PsrPopPy3>

et al., 2004; Faulkner et al., 2004; Lorimer et al., 2006; Eatough et al., 2009; Keith et al., 2009; Keane et al., 2010; Eatough et al., 2010; Knispel et al., 2013) at 20 cm, and the Methanol Multi-Beam (MMB) survey (O’Brien et al., 2008; Bates et al., 2011) at 6.5 GHz. The number of slow (total) pulsars found to date in these surveys, which is used for calibration below, are: 279 (298), 1115 (1158) and 18 (18). We choose these surveys as we consider them to be the most complete. Many surveys performed since, are still being successfully mined for new discoveries (e.g. McEwen et al. 2024; Olszanski et al. 2025). Further, we wished to re-do the analysis of Bates et al. (2013), which used these three surveys, keeping changes to a minimum. As such, we did not modify parameters such as the current-day Galactic exponential scale height, taken to be 330 pc for slow pulsars and 500 pc for millisecond pulsars, and we used the luminosity distribution from Faucher-Giguère and Kaspi (2006). These latter choices are somewhat standard in the snapshot approach (Ridley and Lorimer, 2010; Xue et al., 2023) and in an effort to make an apples-with-apples comparison to our previous estimates (Keane et al., 2015; Levin et al., 2018). However, a wider effort is ongoing to explore these and other parameters in tandem with spectral and other properties. For now, we simply note that an increased scale height, as implied by some studies (Ding, 2025), would result in a *higher* pulsar yield for SKA-Low. We also note that in the snapshot method we are sampling from period and luminosity distributions and, by definition, do not evolve our population. As such, no relation between the radio luminosity and the spin-down energy loss rate \dot{E}_{rot} is assumed or used in this method.

Following Bates et al. (2013), we modeled the spectral index distribution as a normal distribution and sampled the two-dimensional parameter space corresponding to the mean, μ , and standard deviation, σ , of this distribution. The results of this analysis that best matched the actual yields of our three pulsar surveys outlined above are shown in Figure 2. The final answer, based on 40 iterations, is $\mu = -1.45 \pm 0.05$ and $\sigma = 0.15 \pm 0.15$. This differs from the previous determination of -1.41 ± 0.06 and 1.0 ± 0.05 ; while our mean value is consistent, our distribution is much narrower. With a narrower distribution there are less pulsars both with much flatter and much steeper spectra than the mean value, meaning lower yields for both high and low frequencies, relative to intermediate frequencies in the 1 – 2 GHz range. It also differs from the *observed* spectral index distribution in the known population (Jankowski et al., 2018; Posselt et al., 2023), which is heterogeneous in terms of spectral selection effects across the various surveys wherein these pulsars were discovered. We note that, conversely, it agrees well with the observed MSP spectral distribution determined by Aggarwal and Lorimer (2022). In what follows, we adopt our newly computed values, and the assumptions mentioned above regarding the Galactic scale height and luminosity distribution, for making the snapshot yield estimates for the SKA arrays.

2.2 Evolving population

The evolutionary population synthesis framework used in the following is based on the recent works of Graber et al. (2024) and Pardo-Araujo et al. (2025), which use machine learning to infer a range of neutron star parameters. To model the spatial distribution of pulsars at birth, we sample positions in the Galactic plane using the electron density model from Yao et al. (2017), and adopt a vertical distribution following an exponential profile with a scale height of 180 pc (Gullón et al., 2014).

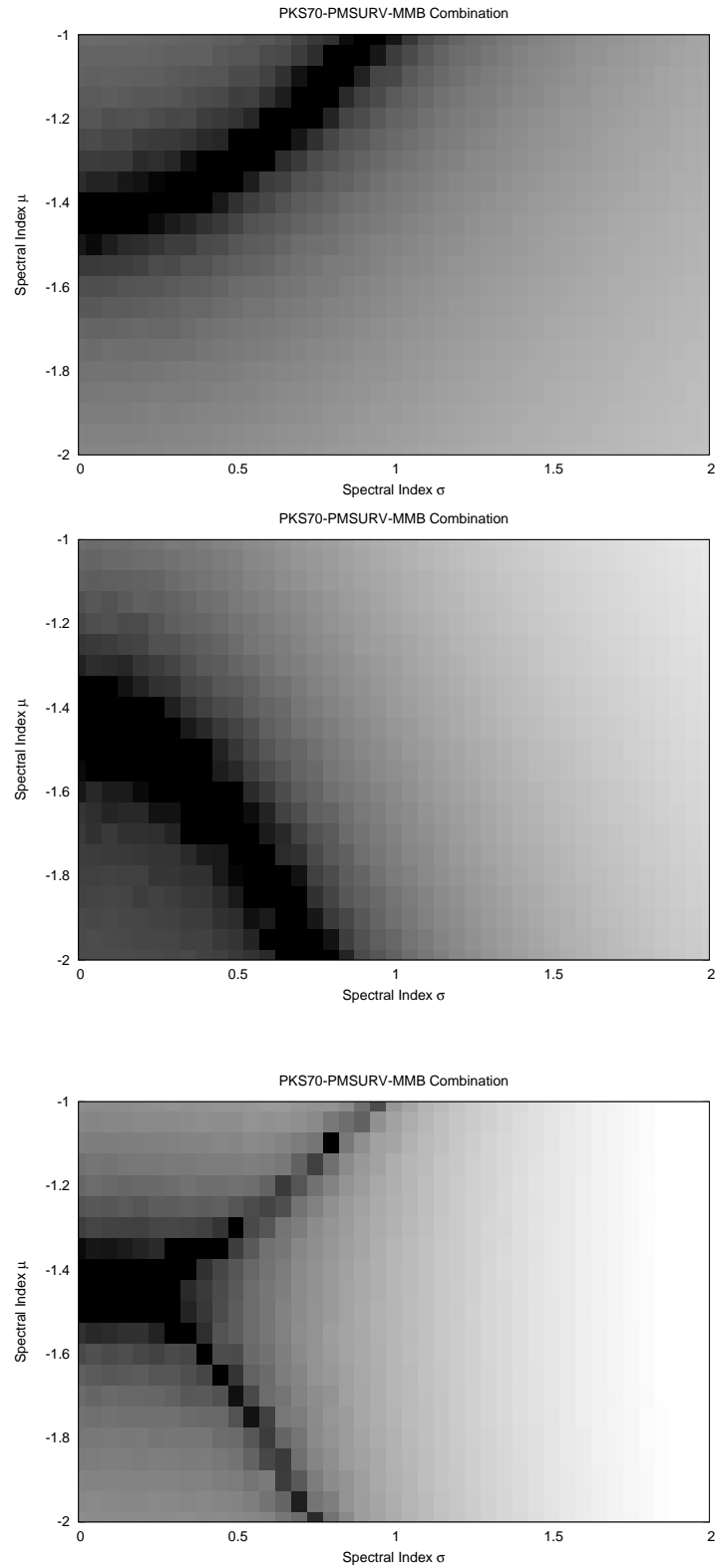


Figure 2: The top panel shows the confidence intervals, on a logarithmic colour scale, for the simulated Parkes 70 cm survey yields. The black curve can be considered as the range of spectral index parameters, where both the 20 cm and 70 cm yields match acceptably. The top left region of the parameter space produces too few pulsars, the bottom right produces too many. The middle panel shows the corresponding information for the combination of the 20 cm and 6.5 GHz surveys. Here, the bottom left produces too few pulsars, the top right too many. The bottom panel shows the ⁶logarithm of the product of the confidence intervals, demonstrating that spectral index values of $\mu = -1.45 \pm 0.05$ and $\sigma = 0.15 \pm 0.015$ match the observed detections best.

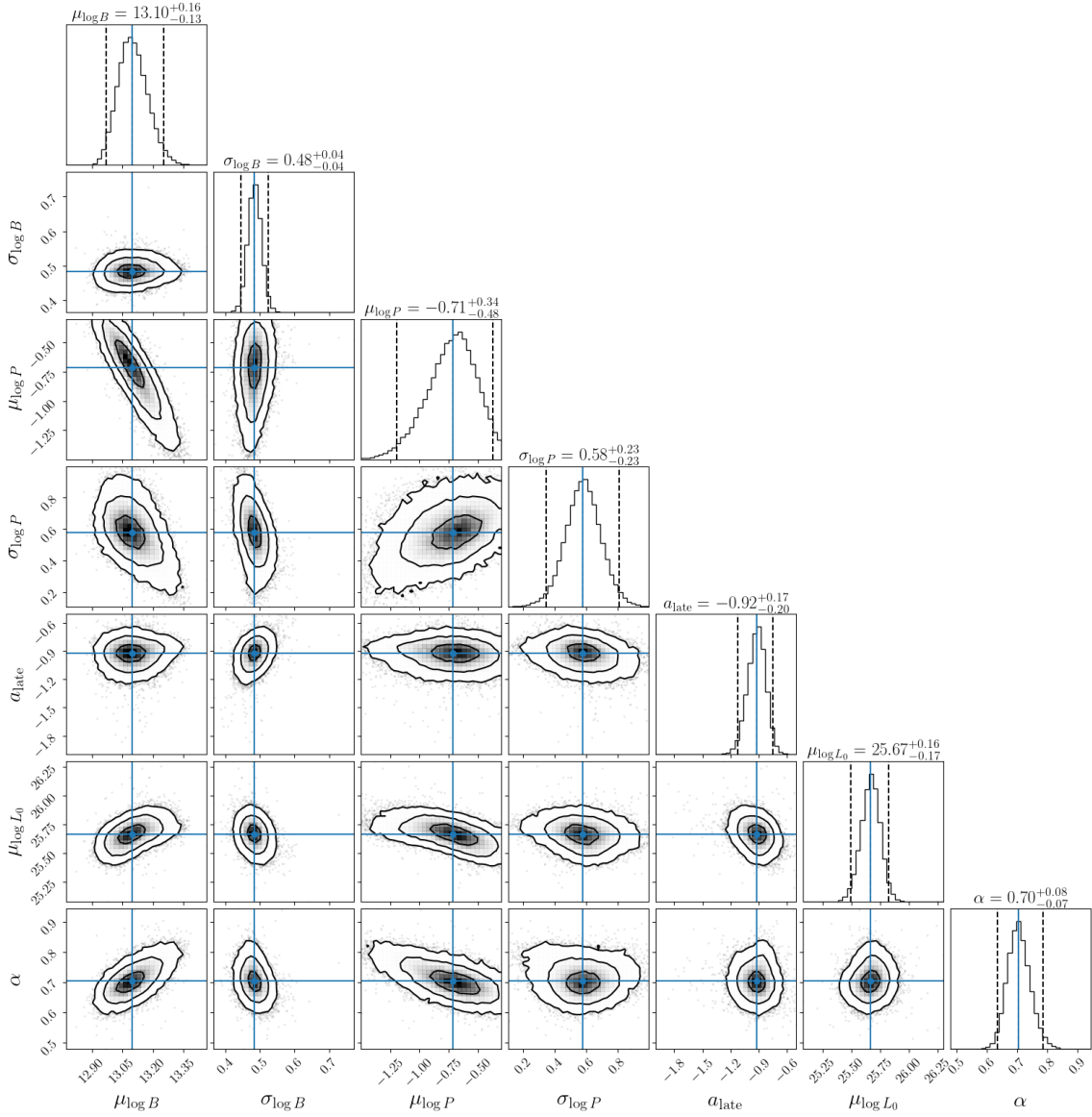


Figure 3: Corner plot with the one- and two-dimensional posterior distributions for five magneto-rotational parameters and two parameters related to the pulsars’ intrinsic luminosity. We highlight the medians in light blue and show corresponding values and 95% credible intervals above the panels. These results were obtained using the methodology outlined in [Pardo-Araujo et al. \(2025\)](#) and correspond to a converged run of a sequential simulation-based inference experiment. The key difference is that the above posteriors were obtained with a different spectral index distribution (see text for details).

Birth velocities are drawn from the Maxwellian distribution proposed by [Hobbs et al. \(2005\)](#), with a velocity dispersion of 265 km/s. Birth spin periods and dipole magnetic field strengths are sampled from log-normal distributions with means and standard deviations allowed to vary. For the magnetic field evolution, we follow [Graber et al. \(2024\)](#) and incorporate magneto-thermal simulations at early times and a power-law decay for pulsars older than ~ 1 Myr, where the power-law index is also a free parameter.

We obtain the kinetic properties of each neutron star at the current time by solving the Newtonian equations of motion in the Galactic potential, while the magneto-rotational properties are evolved using a set of coupled differential equations following Philippov et al. (2014). Intrinsic radio luminosities are modeled using the luminosity law from Pardo-Araujo et al. (2025), which scales as a power law of the rotational energy loss, introducing a further two free parameters. Beaming geometry and pulse propagation effects are also implemented as outlined in that study.

To calibrate the model, we compare synthetic populations with observed detections in three Parkes surveys: the Parkes Multibeam Pulsar Survey (1045 pulsars; Manchester et al. 2001; Lorimer et al. 2006), the Swinburne Intermediate-latitude Pulsar Survey (218 pulsars; Edwards et al. 2001; Jacoby et al. 2009), and the low- and mid-latitude High Time Resolution Universe survey (1095 pulsars; Keith et al. 2010). Note that the first count differs slightly from the value outlined in § 2.1, because we also apply a period derivative cut-off for our evolutionary population synthesis. Additionally, for a sub-population of these three surveys (see Pardo-Araujo et al. (2025) for details), we incorporate flux measurements from MeerKAT as reported by Posselt et al. (2023), providing further observational constraints. The use of surveys across a wide variety of Galactic latitudes is particularly important for the evolutionary approach to probe the properties of older sources far away from the Galactic plane.

To determine the best-fit model parameters, we represent the resulting synthetic populations as density maps in the period–period derivative plane and apply a sequential simulation-based inference algorithm (Deistler et al., 2022) to determine posterior distributions for the seven free parameters related to magneto-rotational evolution and intrinsic luminosity distribution. While results from Pardo-Araujo et al. (2025) assumed a normal spectral index distribution with $\mu = -1.8$ following Posselt et al. (2023) and $\sigma = 0$, we have repeated the inference based on the parameters deduced from Figure 2 to streamline our assumptions with those outlined in the snapshot population synthesis approach.

The resulting corner plot with one- and two-dimensional marginalised posteriors is shown in Figure 3. The inferred pulsar properties remain largely consistent with Pardo-Araujo et al. (2025) including the birth rate which ranges between $\sim 1.7 - 2.0$ neutron stars stars per century, though the updated analysis yields a smaller scaling factor in the luminosity law. This is expected, as the flatter spectral index implies intrinsically brighter sources for a given period derivative, making them more easily detectable. Using the inferred best-fit parameters summarised in Figure 3 and a birth rate of 2 neutron stars per century with stars evolved up to a maximum of 2×10^9 yrs to match the observed detection counts outlined above, we then compute a complementary set of yield estimates for the SKA arrays within the evolutionary population synthesis framework.

3 SKA Parameters

The SKA is modular by definition and is being built as such². Various checkpoints along the way are being released as completed milestones; these are called array assemblies. Array assembly 0.5

²<https://www.skao.int/en/science-users/599/scientific-timeline>

(AA0.5) is followed by AA1, AA2, AA* and AA4. Observations of the first ~ 50 pulsars have been obtained, as have the first images³, with SKA-Low AA0.5 by early 2025. Here, we will consider the pulsar yield for the latter two array assemblies—AA* and AA4. Figure 4 shows the distribution of elements for both SKA-Mid and SKA-Low between AA* and AA4. For a radio array, one can combine any number of elements depending on what is desired for the observation. Coherently combining an array of N elements results in a sensitivity, which is $N\times$ better than a single element. However, the field of view of such a tied-array beam, scales as $1/D^2$, where D is the maximum element separation. For a survey, one therefore has a choice on how to balance sensitivity (depth of survey) and field of view, and therefore survey speed (breadth of survey). Consequently, SKA pulsar survey parameters are informed by a number of factors, which we elaborate upon now; we do so separately for the Mid and Low arrays. In what follows, we will see that it is the core of the arrays that is most crucial for untargeted pulsar searches. For targeted pulsar searches, as e.g. performed on globular clusters (Bagchi et al., 2026) or the Galactic Centre (Abbate et al., 2026), as well as for pulsar timing observations (Shannon et al., 2026), this is not the case. In those scenarios, one can phase up the full array as the field of view is not a constraining factor in designing those observations. Comparing the configurations AA* and AA4 in Figure 4, it is evident that the SKA-Mid array is initially more ‘hollowed-out’ than SKA-Low as AA4 will have more dishes in the inner 1 km region. For Low, AA* and AA4 will have a comparable number of elements within the inner kilometre. We now discuss the relevant survey parameters for SKA-Mid and SKA-Low.

3.1 SKA-Mid Survey Parameters

Many of the relevant parameters for a pulsar search are fixed due to SKA design constraints (Caiazzo, 2021), but some vital parameters are configurable so that one has a choice in survey design. Some of the key fixed parameters⁴ of the Pulsar System for Searching (PSS) are shown in Table 1. We note that the PSS can perform real-time Fourier domain acceleration searches on pointings as long as 10 min, and real-time single pulse searches on pointings of up to 30 min, on 1500 (1125) tied-array Stokes I beams in AA4 (AA*). Thus, in our modelling, we choose 10 min pointings. The maximum acceleration range is $\pm 350 \text{ m s}^{-2}$ for a 500-Hz pulsar, higher for slower pulsars. In a full acceleration search one can perform 500 user-specified dispersion-measure trials, and a much larger number of non-accelerated dispersion measure trials. We note that while we expect more bandwidth to be eventually available (priv. comm. Karastergiou & de Selby), we choose to use the current widely communicated specification of 300 MHz in our calculations.

The configurable parameters are the gain employed and, correspondingly, the field of view that can be tiled out. These both depend on the choice of sub-array that is used for the search. The more elements we add into a sub-array, the higher is the gain. However, as the tied-array beam sizes scale as the inverse square of the maximum baseline, there will be a minimum beam size with which the entire primary field of view can still be covered — it is in this ‘sweet spot’ that surveys are best performed.

³<https://www.skao.int/en/news/621/ska-low-first-glimpse-universe>

⁴We note that the Pulsar System for Timing (PST) also has some searching capabilities but is limited to 16 tied-array beams; in this case voltage beams are available. The PST might therefore be preferable for deep offline targeted searches of pre-identified targets.

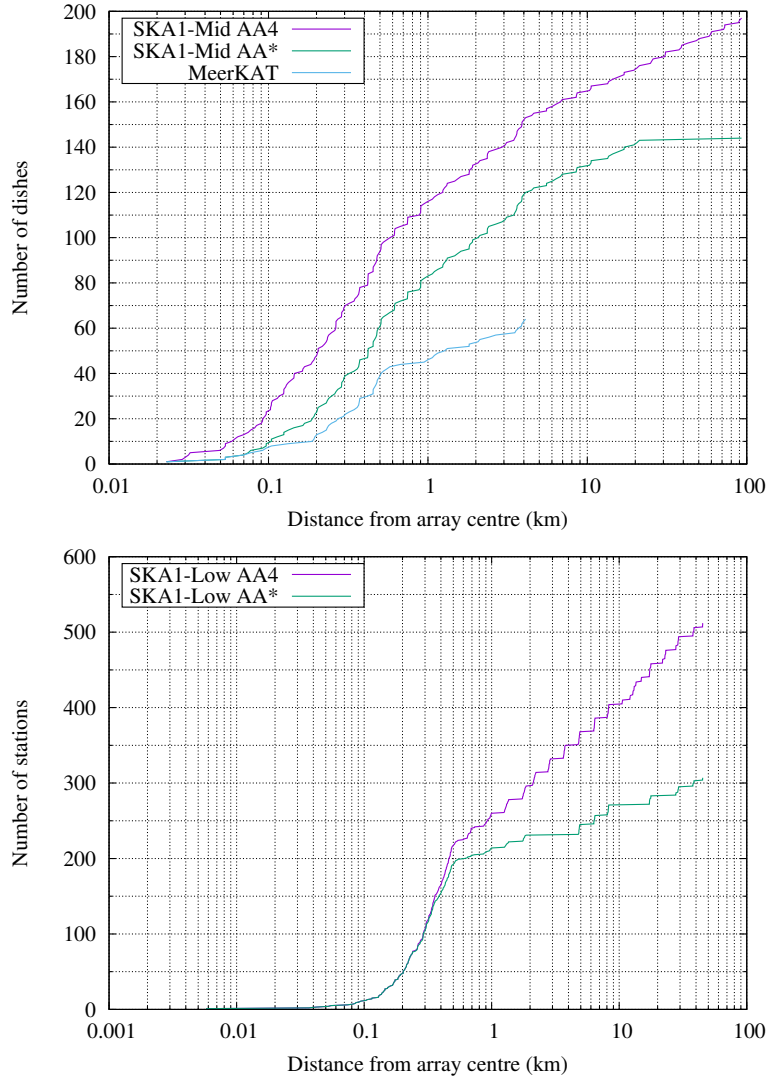


Figure 4: Shown are the cumulative number of elements for the SKA-Mid and SKA-Low arrays as a function of distance from the array centres; dishes for SKA-Mid in the top panel and stations for SKA-Low in the bottom panel. Both figures show the comparison between AA* (purple) and AA4 (green). For SKA-Mid, the MeerKAT array standalone (blue) is also shown for comparison.

Table 1: Pulsar search specifications in the PSS systems and their values for SKA-Low and SKA-Mid.

Parameter	SKA-Low Value	SKA-Mid Value
Number tied-array Stokes I beams (AA*)	250	1125
Number tied-array Stokes I beams (AA4)	500	1500
Instantaneous bandwidth per beam	100 MHz	300 MHz
Number of frequency channels	8192	4096
Frequency resolution	13 kHz	73 kHz
Max. real-time T_{obs} , with acceleration search	10 min	10 min
Max. real-time T_{obs} , no acceleration search	30 min	30 min
Time sampling	100 μs	64 μs

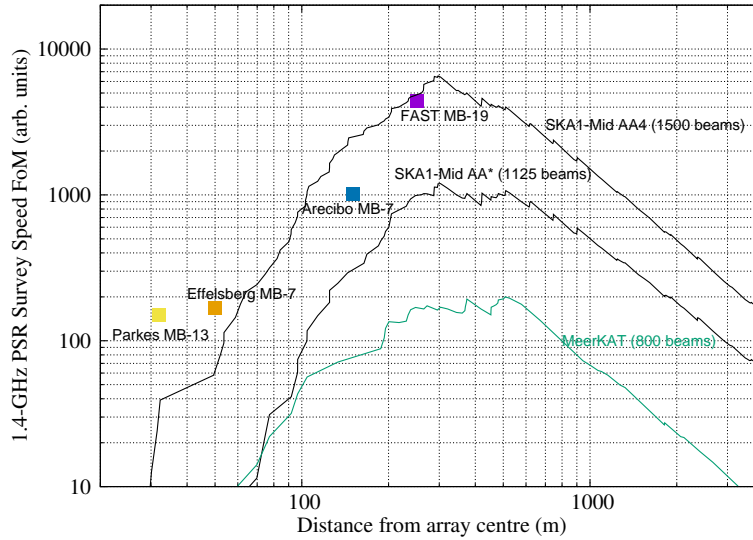


Figure 5: The 1.4 GHz survey speed metric as a function of array radius for SKA-Mid in the AA* and AA4 configurations, MeerKAT and several other radio telescopes for comparison. We use the resulting curves to model the optimal sub-array choice for untargeted pulsar searching for our pulsar yield analysis. For AA4, acceptable survey speed is found in the *diameter* range ~ 400 m to ~ 1 km; note that the horizontal axis shows *radius*. Given the need to discover binary systems, we choose the inner 1 km for our further analysis.

Band 2 is an octave feed covering 950 – 1760 MHz. For our Band 2 survey, we choose the conventional 1.4 GHz as the centre frequency over 300-MHz bandwidth. When considering which parameters to choose for Band 1, which is a 3:1 band from 350 – 1050 MHz, we examine the corresponding gain. As the gain improves with increasing frequency, we choose the highest frequency range within the band that allows for the most dishes. Since the MeerKAT dishes will not have Band 1 feeds, but rather their UHF receivers covering 580 – 1015 MHz (Jonas, 2016) we choose the top 300 MHz of *this* range, corresponding to a Band 1 central frequency of 865 MHz.

For AA4, the gain of the full SKA-Mid array in Band 2 (Band 1) is 10.0 K/Jy (9.7 K/Jy) at 1.4 GHz (865 MHz). For AA*, the corresponding full array gain in Band 2 (Band 1) is 7.0 K/Jy (6.8 K/Jy) at 1.4 GHz (865 MHz). Smaller sub-arrays allow a much larger instantaneous field of view at the expense of gain. To find an optimal combination between these two parameters, we consider the 1.4 GHz pulsar survey speed figure of merit, which is given by $\min(\text{FoV}_{\text{primary}}, N_{\text{beams}}\text{FoV}_{\text{tied}})A_{\text{eff}}^2$. Figure 5 shows the survey speed for SKA-Mid as well as a few other instruments for reference.

It is clear that for both AA* and AA4, the 1.4-GHz pulsar survey speed metric peaks at a radius of approximately 300 m from the array centre, i.e., the inner 600 m in diameter. Satisfactory survey speed is possible for sub-arrays ranging from the inner ~ 400 m to the inner 1 km, in diameter. We choose the inner ~ 1 km in this work to allow for larger instantaneous gain which is needed both for discovering fainter objects but especially for finding accelerated binary systems. For the latter, the computational scaling of acceleration searches means that one cannot compensate for a lack in gain with more observing time, as computation costs scale with the cube of the observing time (Keane et al., 2015).

The gain of SKA-Mid was determined using a sensitivity calculator⁵ used for previous analyses of the anticipated scientific performance of SKA (Keane, 2018; Braun et al., 2019), updated for the current, final, array configurations. For AA4, the gain for the innermost 1 km in Band 2 (Band 1) is 4.60 K/Jy (4.40 K/Jy) at 1.4 GHz (865 MHz). The corresponding field of view that can be tiled out for such a sub-array is 0.62 deg² (1.62 deg²) in Band 2 (Band 1).

For AA*, the gain for the innermost 1 km in Band 2 (Band 1) is 2.75 K/Jy (2.60 K/Jy) at 1.4 GHz (865 MHz). The corresponding instantaneous field of view for AA* is unchanged from AA4 for a sub-array of the same size with the exception of the linear scaling of the number of tied array beams available. We ignore this factor however, essentially meaning we consider, for AA*, a survey with (1500/1150) $\sim 1.3\times$ more pointings than for AA4.

We note that the above gains correspond to effective areas for AA4 in Band 2 (Band 1) of ~ 0.013 km² (~ 0.012 km²) for this innermost 1 km sub-array, equivalent to a fully-illuminated⁶ dish of ~ 127 m (~ 124 m) diameter. For AA*, the corresponding values in Band 2 (Band 1) are an effective area of ~ 0.008 km² (~ 0.007 km²), equivalent to a fully-illuminated ~ 98 m (~ 96 m) dish.

3.2 SKA-Low Survey Parameters

The PSS specifications for SKA-Low AA4 (AA*) are that 500 (250) tied-array Stokes I beams of 100-MHz bandwidth are available for real-time Fourier domain acceleration searches and single pulse searches. As discussed above, the maximum pointing duration for this real-time performance is 10 min if performing acceleration searches and 30 min otherwise. As for Mid, we opt again for 10 min pointings in our selection. Before we can perform the same exercise as above to choose the relevant search sub-array, we must consider the sub-band to use for a pulsar search from within the 7:1 band available. The PSS system can use 100 MHz of band from *anywhere* within the 50 – 350 MHz range. In 2015, we had considered a 150 – 250 MHz range but we now exclude the range 240 – 270 MHz which is polluted with high-occupancy radio frequency interference (RFI) (Sokolowski et al., 2016, 2017), even at the Murchison Radio Observatory, one of the most radio quiet locations on Earth. Because of this, and even though RFI from satellites is also seen across the entire band at least a few percent of the time at all SKA-Low frequencies (Grigg et al., 2025), we have chosen a frequency range of 140 – 240 MHz for our SKA-Low search range. Consequently, we examine the survey speed for SKA-Low at a central frequency of 190 MHz to determine its optimal sub-array size.

In contrast to Mid, the sensitivity of Low is more complex because it: (a) is an aperture array; (b) has a large fractional bandwidth; and (c) observes to very low frequencies that approach the ionospheric cut off. The final on-sky performance of the SKALA4.1 antennas currently being rolled out is not known, but we take the performance of the Aperture Array Verification System 2 (AAVS2, Macario et al. 2022), the most recent in a series of prototype arrays, as our guide. For

⁵<https://github.com/evanocathain/SKA>

⁶A fully-illuminated dish is not realistic. Typically aperture efficiencies are $\eta \approx 0.6$. This means that one might multiply the quoted equivalent dish diameters by $1/\sqrt{\eta} \sim 1.3\times$ for a more realistic comparison.

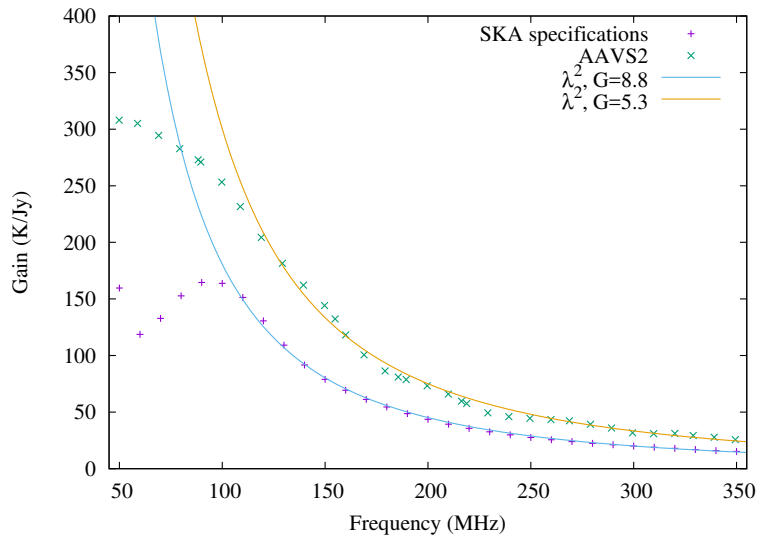


Figure 6: The gain at zenith of the full SKA-Low AA4 array (purple plus signs) is shown, along with the corresponding SKA design specification (green crosses), which we can see is surpassed. This is based on the AAVS2 prototype; the SKALA4.1 response is likely even better. The conversion from $A_{\text{eff}}/T_{\text{sys}}$ to A_{eff} goes awry at the lowest frequency, 50 MHz, as the system temperature balloons in a way not accounted for by the prescribed model, even though it allows for a factor of 2 increase in T_{sky} from 60 MHz to 50 MHz. The effective area of an antenna is given as $\lambda^2 G/(4\pi)$, where G is the directivity or gain. For illustration, a fit to each is shown above the dense-sparse transition. It is clear from this that there is frequency dependence in the directivity.

this work, we use a sensitivity calculator⁷ developed by Sokolowski et al. (2022). Figure 6 shows the resulting effective area at zenith as a function of frequency for AAVS2, and compares this to the Level 1 system requirements for SKA-Low (Caiazzo, 2021). The latter are stated in $A_{\text{eff}}/T_{\text{sys}}$ but with a prescribed model for T_{sky} (Caiazzo, 2021), the largest component of T_{sys} . We use this same sky temperature model, along with measured AAVS2 values for the temperature contributions from the low-noise amplifier and receiver components, i.e., 35 K (Bolli et al., 2022) and 12 K (Bolli, 2020), respectively, to work out the SKA specification in terms of effective area. The gain has the expected frequency-dependent shape with effective area increasing $\propto \lambda^2$, i.e. increasing as frequency decreases until the frequency-dependent size of the individual antennas in a station reach the physical spacing. At lower frequencies than this so-called dense-sparse transition, the response is not flat as one might expect for many reasons, such as coupling interactions between antennas.

Figure 7 shows the survey speed for SKA-Low at 190 MHz for zenith. Here the differences between AA* and AA4 are less drastic than for Mid. Using the same logic as above for SKA-Mid, we again choose a sub-array consisting of the inner 1 km diameter for SKA-Low. For AA4 it would also be possible to choose a sub-array consisting of the inner ~ 2 km, but this is not the case for AA* for which the array thins out significantly outside the inner kilometre, for consistency of comparison we choose the inner 1 km for our calculations in both cases. For AA4 (AA*), this consists of 217 (192) stations, for a gain of 33.4 K/Jy (29.5 K/Jy). We note that this corresponds to an effective area

⁷https://github.com/marcinsokolowski/station_beam

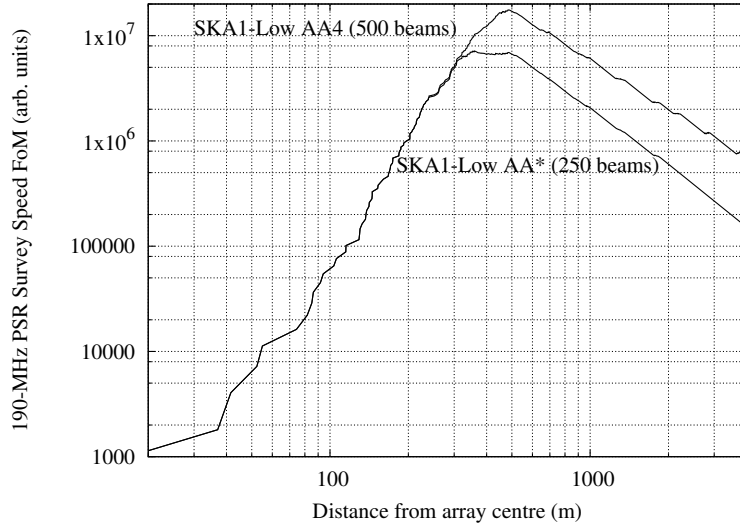


Figure 7: The survey speed of SKA-Low as a function of radius from the centre of the array. Acceptable survey speed is found for the inner ~ 600 m to 1 km diameter for AA*; for AA4 acceptable survey speed is available for inner ~ 2 km in diameter. It can be seen that, for pulsar search applications, the fact that the loss of stations between AA4 and AA* happens outside the core means the impact on the survey speed is far less dramatic than for SKA-Mid.

Table 2: The three survey options explored in this study with different balances between the three relevant bands for pulsar searches.

Survey Option 1		Survey Option 2		Survey Option 3	
Band	Latitude Range	Band	Latitude Range	Band	Latitude Range
Low	$ b > 15$ deg	Low	$ b > 10$ deg	Low	$ b > 5$ deg
Mid Band 1	15 deg $> b > 5$ deg	Mid Band 1	N/A	Mid Band 1	N/A
Mid Band 2	$ b < 5$ deg	Mid Band 2	$ b < 10$ deg	Mid Band 2	$ b < 5$ deg

of ~ 0.092 km² (~ 0.082 km²) for this innermost 1 km, equivalent to a fully-illuminated ~ 340 m (~ 320 m) dish. The off-zenith gain is less than quoted above; we account for this in our estimates. As for Mid, one could phase up a much larger Low sub-array, for targeted observations — the full array gain for the 512 (307) stations of AA4 (AA*) is 78.8 K/Jy (47.2 K/Jy).

4 Expected Yield of Pulsars

In the following, we have considered pulsar surveys up to $+30$ deg in declination for both SKA-Mid bands, and up to $+36$ deg in declination for SKA-Low. We then implemented three different strategies for Galactic latitude coverage, as defined in Table 2 and as illustrated in Figure 8. Each of these three composite surveys were unconstrained in Galactic longitude. In these analyses the bands for each survey option do not overlap spatially, so that each band detects unique pulsars. This means we do not have any duplicate sources detected in multiple bands.

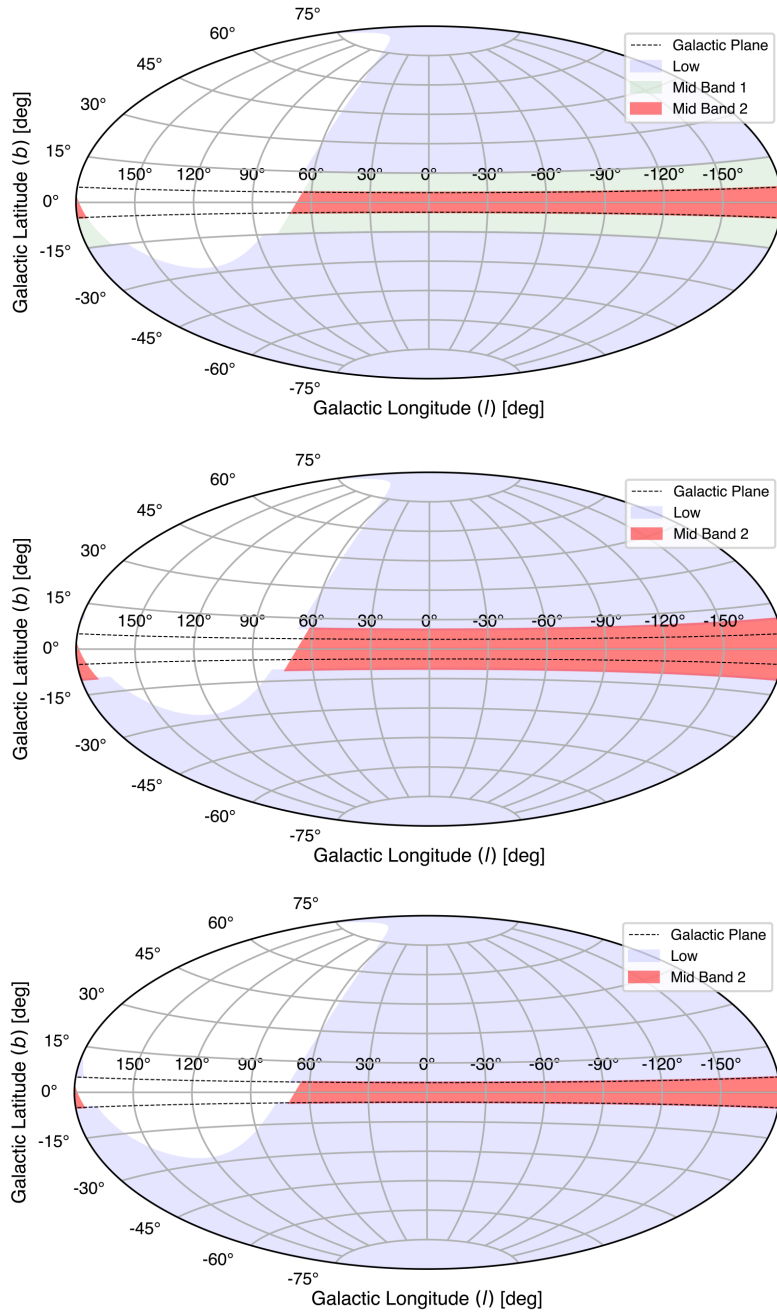


Figure 8: Aitoff projections in Galactic coordinates showing the sky coverage for the three illustrated composite survey options summarised in Table 2. SKA-Low coverage is marked in blue, SKA-Mid Bands 1 and 2 are green and red respectively.

4.1 Snapshot and evolutionary numbers

We have codified the above telescope and SKA survey parameters to define surveys for analysis with `PSRPOP` and the evolutionary approach outlined in § 2. The results using the snapshot methodology, leading to counts for slow pulsars as well as MSPs, are shown in Table 3 for our three

Table 3: Shown are the expected yields for the maximum number of pulsars one could detect using the AA* and AA4 configurations for each of three composite survey strategies as determined with our snapshot approach. We have not imposed any overall observing time constraints at either telescope. Numbers quoted are the rounded means from 100 iterations and numbers in parentheses represent the standard deviation of the values from those 100 iterations. Each band presented here covers a unique patch of sky so that one simply adds the yield from each band to determine the total. Covering the same patch of sky with more than one band increases the yield over what is stated here.

Survey Option 1			Survey Option 2			Survey Option 3		
Band	Slow PSRs	MSPs	Band	Slow PSRs	MSPs	Band	Slow PSRs	MSPs
AA4			AA4			AA4		
Low	1620(70)	280(20)	Low	2900(100)	370(20)	Low	5250(170)	470(20)
Mid Band 1	3300(100)	440(20)	Mid Band 1	-	-	Mid Band 1	-	-
Mid Band 2	8150(240)	560(30)	Mid Band 2	10800(300)	950(30)	Mid Band 2	8150(240)	560(30)
TOTAL	13070	1280	TOTAL	13700	1320	TOTAL	13400	1030
AA*			AA*			AA*		
Low	1570(60)	270(20)	Low	2800(100)	350(20)	Low	4990(170)	440(20)
Mid Band 1	2280(80)	310(20)	Mid Band 1	-	-	Mid Band 1	-	-
Mid Band 2	5400(150)	380(20)	Mid Band 2	7300(200)	640(20)	Mid Band 2	5400(150)	380(20)
TOTAL	9250	960	TOTAL	10100	990	TOTAL	10390	820

survey options. Table 4 summarises the corresponding yields of the evolutionary approach. The latter are for slow sources only as the framework is unsuited to modelling fast MSPs. Both tables show the means and standard deviations of the yields, with Table 3 being based on 100 iterations, whereas Table 4 quotes values based on 10 simulation runs. Standard deviations are notably higher in the snapshot approach because each simulation run samples from all the underlying distributions that enter the model. In the evolutionary approach, this is not possible due to the computational cost associated with evolving pulsar parameters over time. For feasibility, we have evolved a single underlying population and then applied the detection pipeline 10 times. As a result, stochasticity in the evolutionary results arises only from variability in survey modelling rather than in the underlying population itself. To illustrate the projected distribution of discoveries for these estimates, Figure 9 shows an example realisation for both approaches.

We note the very important caveat that in each case, the resulting counts are the *maximum* number of pulsars we might *detect* with AA* and AA4 in the three survey options, so as to state the full potential. To estimate *discoveries*, in the case of slow pulsars we would simply subtract the known pulsars in the sky region. For MSPs, this would result in an over-subtraction as most MSPs have not been found in blind surveys but rather in deep targeted searches, e.g., of *Fermi* point sources (Ransom et al., 2011; Cromartie et al., 2016). Indeed SKA will also perform long targeted searches (Abbate et al., 2026; Bagchi et al., 2026) so that the overall MSP numbers will be higher. We note further that the timing precision afforded by SKA in observing these MSPs will be considerably better: pulsar timing array sensitivity scales with both the number of MSPs as well as the timing precision (Shannon et al., 2026).

In all survey options, we find that the AA* configuration yields systematically fewer detected sources than AA4. The differences are less pronounced in the Low band (expected based on the dense-sparse transition discussed above) with AA* typically achieving over 90% of the AA4 yield, but become

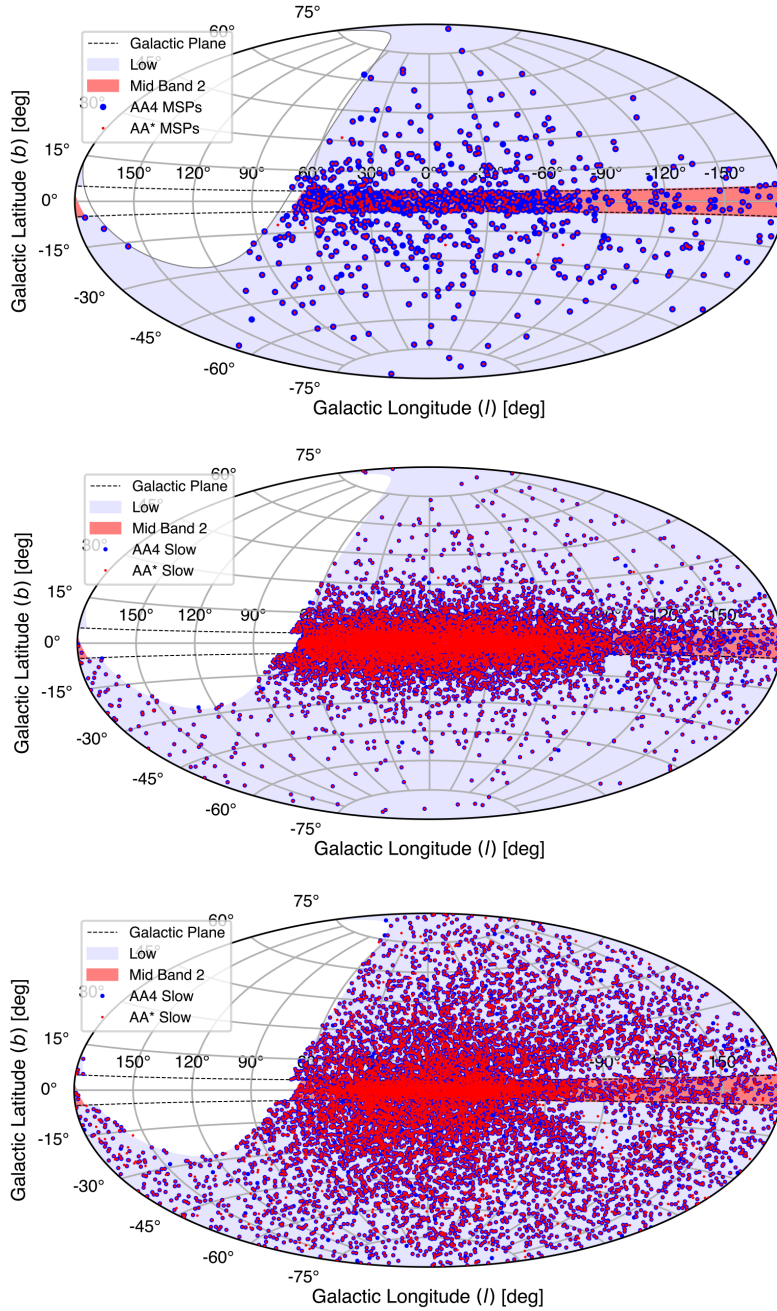


Figure 9: Aitoff projections in Galactic coordinates for Survey Option 3 showing the pulsar yield for a randomly chosen, but representative, realisation from our analyses. The top panel shows the MSPs predicted by the snapshot method; the middle panel shows the slow pulsars for the snapshot method; the bottom panel shows the slow pulsars from the evolutionary method. In each case, AA* and AA4 yields are highlighted. We note that the pulsars detected in AA* are a subset of those detected in AA4, i.e., AA* detections are shown in red, AA4 detections are both red and blue. The two slow pulsar distributions show the clear distinction in the scale height between the snapshot and evolutionary approaches, as discussed in the main text.

Table 4: Expected yields for the maximum number of pulsars in the AA* and AA4 configurations for our three survey strategies as obtained with the evolutionary simulations. As with the snapshot approach, observing time constraint is imposed. Numbers quoted are the rounded means from 10 iterations based on a fixed evolved population. Numbers in parentheses represent the standard deviation of the values from those 10 iterations. Stochasticity arises from uncertainty in the detection implementation only and not the underlying population model. Note that the evolutionary framework outlined above does not allow us to model MSPs. The first set of numbers for each survey option is a bare count of all detected sources, while the latter only counts those sources that lie above a pulsar death line (DL) based on an extreme twisted, multi-polar magnetospheric configuration.

Survey Option 1			Survey Option 2			Survey Option 3		
Band	full count above DL		Band	full count above DL		Band	full count above DL	
AA4			AA4			AA4		
Low	6320(20)	5420(20)	Low	7580(30)	6570(20)	Low	8830(20)	7750(20)
Mid Band 1	1920(10)	1850(10)	Mid Band 1	-	-	Mid Band 1	-	-
Mid Band 2	3420(20)	3360(10)	Mid Band 2	4730(20)	4630(20)	Mid Band 2	3420(20)	3360(20)
TOTAL	11660	10630	TOTAL	12310	11200	TOTAL	12250	11110
AA*			AA*			AA*		
Low	5750(20)	4980(20)	Low	6900(20)	6040(10)	Low	8050(30)	7110(20)
Mid Band 1	1350(10)	1310(10)	Mid Band 1	-	-	Mid Band 1	-	-
Mid Band 2	2570(10)	2540(10)	Mid Band 2	3490(10)	3440(10)	Mid Band 2	2570(10)	2540(10)
TOTAL	9670	8830	TOTAL	10390	9480	TOTAL	10620	9650

more significant for SKA-Mid, where the AA* yield drops to $\sim 70\%$ of the corresponding AA4 value in both bands. While the evolutionary approach does not provide information on MSPs, it allows us to explicitly track the period and period derivative evolution of each pulsar as it ages—an example $P-\dot{P}$ diagram for Survey Option 3 is shown in Figure 3 in Levin et al. (2026). Importantly, the evolutionary approach outlined in §2.2 does not impose an artificial death line below which the pulsar radio emission switches off, as this was not required to reproduce the calibration surveys outlined above (see Graber et al. 2024 for details). However, a death line may become relevant for SKA-era surveys based on the telescopes’ increased sensitivities and SKA-Low’s wide sky coverage. To estimate the death line’s potential impact, we applied a death line criterion based on a twisted multipolar magnetospheric model (Chen and Ruderman, 1993; Rea et al., 2024). This additional filter further reduces the Low counts, where older, lower- \dot{P} pulsars dominate, while having a smaller effect on the Mid bands. The ‘above DL’ columns in Table 4 provide the yields that are most directly comparable to those of the snapshot simulations, which were calibrated against existing surveys at low latitudes and are therefore unlikely to predict many sources below the death line.

Comparing the total counts for each survey option and array assembly, we find that these totals are broadly consistent between the snapshot and evolutionary approaches. However, an important difference emerges in the relative contributions of the SKA-Low and SKA-Mid bands. In the snapshot approach, the Mid bands (particularly Band 2) consistently dominate the total yield, contributing a larger fraction of detected sources than Low across all options. In contrast, the evolutionary simulations predict the opposite trend: Low detections always exceed those in Mid Band 1 and Band 2. Quantitatively, in the evolutionary approach, Low detections account for

$\sim 50 - 70\%$ of the total yield depending on the option, while in the snapshot simulations they contribute only $\sim 15 - 40\%$. This discrepancy arises despite both approaches using the same underlying spectral index distribution and identical survey parameters, and reflects differences in the assumed physics of the underlying populations, such as the luminosity prescription and the spatial distribution of evolved pulsars. We explore these differences in greater detail below.

4.2 Survey considerations

When presenting our yields, we have not attempted to optimise for the relative observing time cost of each survey, and the related Galactic latitude coverage of each component of the composite search. The relative cost of a survey of a given area of the sky is 2.7 times higher for SKA-Mid Band 2 versus SKA-Mid Band 1. The relative cost between SKA-Mid Band 2 and SKA-Low is a dramatic factor of 55. For AA* the relative costs are slightly less stark since Low has 50% fewer tied-array beams, whereas Mid loses only 25% of its tied-array beams relative to AA4. This weighting is only partially accounted for in our Galactic latitude constraints. One impact of this is that the maximum yield for SKA-Mid Band 2 is unlikely to be realised given how competitive telescope access will be, but we wished to present the maximum potential numbers here. Conversely, a truly all-sky search with SKA-Low is quite likely, including the Galactic plane, even where scattering and dispersion smearing will reduce the horizon of any survey. The Low survey speed is so much faster that the relative cost of also covering the plane is very low in comparison to Mid. Another way to state this is that Survey Option 3 is more likely closer to what will happen than Survey Option 2, which is, in turn, more likely than Survey Option 1. When the time comes to perform the surveys any and all such real-world constraints on availability can readily be incorporated. In the first instance, smaller-scale pilot surveys are likely to ensure the mechanics of observing, processing and analyses are fully tuned. This will allow verification and calibration of our estimates ahead of a large scale up. With the subset of the full arrays relevant to pulsar surveys comprising the innermost 1 km, this work may be possible to commence earlier than for other science uses of the SKA.

Another parameter which is not considered in our analyses but which will have significant real-world impact is the effect of RFI (Morello et al., 2022). The most optimistic case is where we either have time ranges and/or frequency ranges which are unusable so that we effectively have less observing time and/or bandwidth. This kind of RFI can be well mitigated with masking (Manchester et al., 2001; Kocz et al., 2010). Unfortunately, the spectral situation has changed in the past decade such that it is no longer the case that we have some frequencies that are unusable. Instead, we now have a situation where *all frequencies are contaminated some of the time*. This means that very significant effort needs to be put into RFI flagging in streaming data. Much work has been performed in this domain on MeerKAT (Rajwade et al., 2020; Morello et al., 2022) and will be applied in the PSS systems on SKA-Mid and SKA-Low. One lesson learned from MeerKAT is that the UHF band (which overlaps with SKA Band 1) is cleaner than the L band (which overlaps with SKA Band 2), meaning that we should expect the SKA-Mid Band 2 to be more affected by RFI than SKA-Mid Band 1. This issue too, once we have some initial on-sky data with SKA-Mid, will weigh into our final survey optimisation strategies. A counterpoint to this is that we might want to ensure we find as many Band 2 pulsars as possible, even given the larger relative cost in observing time. The MSPs

so found would be the most valuable for pulsar timing array applications, since in Band 2, and in the future Band 3 which will operate in S band, where the highest timing precision is possible (Shannon et al., 2026). There are additionally many other possible considerations we might employ, e.g., prioritising some of the FAST sky (Han et al., 2021) for cross-calibration purposes.

We reiterate that we present the *maximum* possible number of pulsar detections one could make for our chosen illustrative configurations and surveys. We have not specified the total observing time for these as there are still many parameters one could adjust before performing these surveys could dramatically effect these numbers. Some choices of configuration are informed by observations, e.g. the real on-sky performances and RFI occupancy seen in pilot surveys; others depend on the final SKA build. For instance, considering what LOFAR and MeerKAT have been capable of for many years, we are optimistic that SKA-Mid (of SKA-Low) will exceed 1500×300 -MHz (500×100 -MHz) tied-array beams for pulsar search. With more beams the yields remain as above, but the survey speed improves, requiring less time to find these pulsars. At the same time, we might expect to maintain the same survey speed in case more beams become available and instead increase the size of the sub-array. This would consequently lead to a larger instantaneous sensitivity, resulting in an increased MSP yield (while the slower pulsar counts would remain the same). Here, we do not find it useful to go beyond the illustrative surveys outlined above and discuss the many additional possibilities that could affect corresponding estimates, as these parameter choices will not have crystallised before SKA commences full operations.

5 Discussion & Conclusion

One can use the yield projections above to estimate the number of sub-populations that the SKA will detect. We take double-neutron-star binaries as an example (Tauris et al., 2017), as this number is an important ingredient in investigation of the neutron star equation of state using SKA (Basu et al., 2026) and tests of gravity (Venkatraman Krishnan et al., 2026). Scaling from the known pulsar population using the period distribution of double-neutron stars and of detections from Survey Option 3, one estimates ~ 140 (~ 110) double-neutron-star systems to be detected with AA4 (AA*).

In trying to estimate the uncertainty of such estimates we note that the total yield numbers presented in § 4.1 have associated uncertainties that are dominated by systematics. Both methods endeavour to recreate the same underlying population of neutron stars but clearly make differing predictions. While one might look at the total predicted yields to estimate the systematic uncertainties, e.g., compare 13070 to 10630 for AA4 Survey Option 1, or compare 10390 to 9650 for AA* Survey Option 3, the deviations are larger when focusing on just Low or just one of the Mid bands. While some degree of uncertainty is inevitable as we are modelling a complex population, extrapolating beyond currently known population sizes, and estimating the performance of an as-yet-incomplete system, it is possible to rein in some of these uncertainties, even with the information at hand, well before SKA is fully operational.

One key step toward improving yield predictions for pulsar detections with the SKA (and any other instrument) would be more accurate and complete reporting of results from existing pulsar surveys.

In particular, information on blindly detected pulsars, i.e., those discovered without prior timing knowledge, is often incomplete. The distinctions between being blindly detected in a Fourier-Transform based search, versus being detected in a phase-coherent folding approach and discovery signal-to-noise ratios versus tuned values etc. are all crucial in properly modelling pulsar survey outputs. This information is often, but not always, available in original survey papers, and it is typically missing from the ATNF Pulsar Catalogue⁸ (Manchester et al., 2005), which remains the primary input source for pulsar population synthesis. This limitation is one of our main reasons for selecting the various Parkes surveys discussed in § 2 (albeit different between the snapshot and evolutionary approaches), as they represent some of the most thoroughly searched and transparently reported surveys to date. In doing so, we are eschewing information from more recent surveys but with the completeness of the searches, and reporting thereof being unclear, we choose this conservative approach. For the evolutionary modelling framework in particular, having access to more than just the detection numbers is critical. Detailed reporting of each pulsar’s period and period derivative along with flux measurements is especially important when inferring the pulsars’ luminosity distribution (Cieřlar et al., 2020; Pardo-Araujo et al., 2025). This distribution is a key element in population synthesis, and different implementations have been employed in the literature (e.g., Faucher-Giguère and Kaspi, 2006; Cieřlar et al., 2020; Posselt et al., 2023; Graber et al., 2024; Shi and Ng, 2024; Pardo-Araujo et al., 2025). Radio flux densities are generally inconsistently reported, causing difficulties in distinguishing between approximate estimates and well-calibrated measurements. For instance, in their rigorous flux density measurements of over 400 pulsars, Jankowski et al. (2018) identify several tens of pulsars with as high as 5σ deviations between their reported and measured values. Similarly many LOFAR flux densities determined from tied-array measurements, are seen to be uncertain by a factor of 2 or more when compared with imaging observations (Kondratiev et al., 2016; McKenna et al., 2024). Uniform and systematic reporting of radio flux densities together with rotational properties would allow for more reliable comparisons across the full pulsar population, helping to constrain luminosity-related parameters more robustly. We will also require this information to fully understand the population of pulsars found by SKA — these sources will require timing *by the SKA* to be fully characterised (Levin et al., 2026), not simply found and discarded, nor timed by other facilities.

In the snapshot approach outlined in § 2.1, we chose the Parkes Southern Pulsar Survey (420 – 452 MHz), the Parkes Multibeam Pulsar Survey (1230 – 1518 MHz), and the Methanol Multibeam Survey (6303 – 6879 MHz) in part to span a broad range of observing frequencies. This matters because pulsar detection rates are sensitive to the underlying spectral index distribution. The spectral model we adopt here (see Figure 2), of a power-law spectrum for every pulsar, is likely an over-simplification, especially at SKA-Low frequencies (Jankowski et al., 2018). However, for our analyses we are able to find a solution with such a model that is consistent with the yields of all the surveys considered in this work. Incorporating additional surveys at other frequencies, such as the Green Bank North Celestial Cap (GBNCC) survey at 350 MHz (Stovall et al., 2014; Kawash et al., 2018), would allow for further constraints on the spectral properties of the population. While it is possible that no single spectral index law describes the full population, analysis across a broad frequency range can help characterise sub-populations and refine model assumptions. SKA’s

⁸<https://www.atnf.csiro.au/research/pulsar/psrcat/>

broad frequency coverage across SKA-Mid and SKA-Low will ultimately be key in determining the neutron stars' intrinsic spectral index distribution(s), and in particular similarities and differences across the slow pulsar and MSP populations (Karastergiou et al., 2024).

In contrast, the three surveys used in the evolutionary approach (namely the Parkes Multibeam Pulsar Survey, the Swinburne Intermediate-latitude Pulsar Survey, and the low- and mid-latitude High Time Resolution Universe survey, all at 1.4 GHz) were selected for their coverage across a wide range of Galactic latitudes, rather than frequencies. This is particularly important when modelling the neutron star's evolution from birth to present, as pulsars born in the Galactic plane gradually migrate to higher latitudes due to natal kicks. Surveys at higher latitudes, thus, probe older pulsars, which have evolved to lower period derivatives. These sources are important for understanding late-stage pulsar evolution, including magnetic field decay, beaming behaviour, and the potential ceasing of radio emission near the 'death line' (e.g., Chen and Ruderman, 1993). For the $P-\dot{P}$ diagrams corresponding to Survey Option 3, see Figure 3 in Levin et al. 2026. SKA-Low will be especially useful for detecting these evolved pulsars. In a sense, the pulsar discoveries made by SKA-Low will enable the death line drop-off to be 'seen'. Moreover, coverage across different latitudes informs models of both pulsar birth locations and supernova kick velocities. While the z -distribution of neutron star progenitors is relatively well constrained, the kick distribution remains less certain. Our evolutionary simulations are based on the often-used Maxwellian distribution from Hobbs et al. (2005). However, this analysis is now not only outdated as improved proper motion measurements have become available over the past two decades (e.g., Gonzalez et al., 2011; Ronchi et al., 2021; Ding et al., 2023; Shamohammadi et al., 2024), but the single Maxwellian distribution from Hobbs et al. may also incorrectly represent the pulsar's natal kick velocities, potentially overestimating them (e.g., Verbunt et al., 2017; Igoshev, 2020; Mandel and Müller, 2020; Mandel and Igoshev, 2023; Disberg and Mandel, 2025).

The treatment of the kick velocity, which ultimately controls the vertical distribution of observed pulsars in the Galaxy, has a direct impact on our predicted SKA yields. Notably, the difference in SKA-Low versus SKA-Mid counts between the snapshot and evolutionary frameworks presented in Tables 3 and 4, respectively, may stem from differences in the spatial modelling. The PSRPOPPY-based snapshot model uses an exponential z -distribution with a 330 pc scale height for the slow pulsar population, which was calibrated using low-latitude surveys (Lorimer et al., 2006). This choice may bias the inferred number of pulsars at both low and high latitudes, potentially overestimating the pulsars at low latitudes (detected by Mid) and overestimates those at higher latitudes (detected by Low) relative to the evolutionary simulations. Similar issues might affect the distribution of MSPs for which we cannot compare to an evolutionary model.

A more complete record of past surveys, including standardised reporting of pulsar parameters and detection context, would enable a more comprehensive comparison between population synthesis frameworks. Even within the snapshot and evolutionary approaches used here, different assumptions about luminosity prescriptions, beaming models, and spatial distributions can produce markedly different results (see, e.g., Xie et al. 2022; Xue et al. 2023 for different snapshot approaches and Faucher-Giguère and Kaspi 2006; Gullón et al. 2014; Cieřlar et al. 2020; Dirson et al. 2022; Shi and Ng 2024; Sautron et al. 2024 for various evolutionary population synthesis frameworks).

Making full use of existing data is not only important for refining SKA yields, but also for addressing broader open questions in neutron star astrophysics. One such issue is the birth rate of different neutron star classes, which has implications for high-energy astrophysical phenomena such as gamma-ray bursts, fast radio bursts, and superluminous supernovae (Beniamini et al., 2025; Ma et al., 2025). As Keane and Kramer (2008) outlined, there remains a gap between the birth rates inferred for different neutron star sub-populations and the overall core-collapse supernova rate. The evolutionary population synthesis frameworks outlined above estimate birth rates of about two neutron stars per century, which is consistent with supernova rates (Rozwadowska et al., 2021). However, these studies only focus on radio pulsars and do not account for other classes such as magnetars or rotating radio transients (Levin et al., 2026). Ultimately, calibrating population synthesis models against SKA survey results will be crucial for resolving these open issues and understanding the formation of neutron stars as well as evolutionary pathways between different neutron star classes.

Our final conclusions are as follows:

- SKA should expect to find $\sim 10,000$ slow pulsars and ~ 800 MSPs with AA*, and $\sim 20\%$ more with AA4. Even higher yields, especially of MSPs will result if longer surveys using SKA-Mid are possible.
- The larger effective area and survey speed of SKA-Low mean that covering extensive areas of the sky with this telescope is essential to maximise the pulsar yield. This also has the advantage of sampling the off-plane older evolved pulsar population to help us understand evolutionary questions in neutron star science.
- Pulsar population synthesis is a difficult endeavour with large systematic uncertainties. Nonetheless, major improvements could be made in our understanding of the neutron star population, and as an offshoot of our survey yield modelling, with standardised reporting procedures from archival pulsar surveys. Standardised reporting will also be important for future SKA observations.
- With the RFI environment rapidly deteriorating, even at the SKA sites, it makes sense to perform pulsar surveys as early as possible with SKA, i.e., to start the pulsar surveys on day 1 of operations. Pulsar surveys could even commence in commissioning time. As these surveys will use some of the highest resolution data products, they are also optimised for stress testing and refining the entire observational system while additionally providing relatively quick results—pulsars will be discovered with some regularity, as opposed to other experiments involving long-term data accumulation. This also fits in well with the finite resources available in SKA’s Science Data Processor (where imaging is performed), i.e. the SKA will need to perform non-imaging observations (which take data directly from the Central Signal Processor), to enable the system to ‘catch up’ with the flow of data to be imaged.

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