



FAST Low Frequency Pulsar Survey

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Introduction

The Five-hundred-meter Aperture Spherical radio Telescope (FAST) is under construction and will be commissioning in September 2016. The table below shows the current FAST receiver set.

No	Band (GHz)	Beams	Pol.	Cryo Tsys(K)	Science
1	0.07 – 0.14	1	RCP LCP	no 1000	High-z HI(EoR),PSR, VLBI, Lines
2	0.14 – 0.28	1	RCP LCP	no 400	High-z HI(EoR),PSR, VLBI, Lines
3	0.28 – 0.56	1 or multi	RCP LCP	no 150	High-z HI(EoR),PSR, VLBI, Lines Space weather, Low frequency DSN
4	0.56 – 1.02	1	RCP LCP	yes 60	High-z HI(EoR),PSR, VLBI, Lines Exo-planet science
5	0.320 – 0.334	1	RCP LCP	no 200	HI,PSR,VLBI Early sciences
6	0.55 – 0.64	1	RCP LCP	yes 60	HI,PSR,VLBI Early Sciences
7	1.15 – 1.72	1 L wide	RCP LCP	yes 25	HI,PSR,VLBI,SETI,Lines
8	1.05 – 1.45	19 L narrow multibeam	RCP LCP	yes 25	HI and PSR survey, Transients
9	2.00 – 3.00	1	RCP/ LCP	yes 25	PTA, DSN, VLBI, SETI

At the early science age, we need a receiver to work at low frequency (<1GHz) which meets early stage pointing accuracy and to do a whole FAST sky pulsar survey which L-band 19-beam is not the best option.

A 7-beam receiver is planned for early drift-scan pulsar survey. It will work around 400MHz with a bandwidth about 150MHz. To make sure it is ready in early 2016, we will use similar design like current multibeam receivers such as:



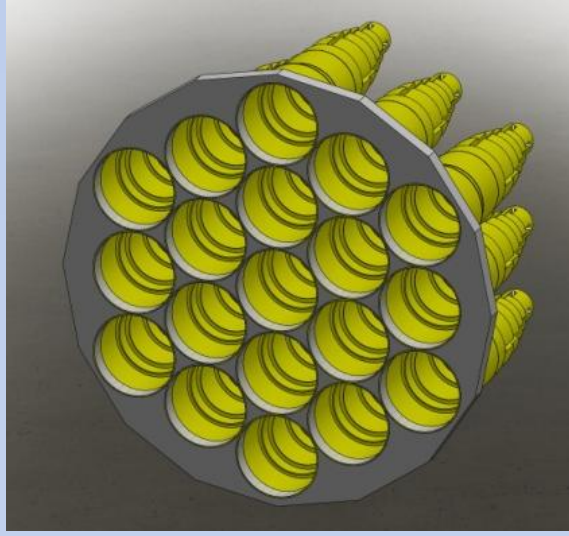
Parkes



Effelsberg



Arecibo



FAST

- Here are some tentative technical specifications of the receiver:
- Frequency ~400MHz, bandwidth ~150MHz (1/3 center frequency)
 - Cooled, T_{sys} without sky ~30K or less
 - Light weight
 - Use horn or dipole, not PAF
 - Inexpensive
 - Use 19-beam backends
 - data ~2.4PB (one whole FAST sky scan)

The 7-beam receiver will be optimized for pulsar and transient survey at early science stage (Sept 2016 or earlier). Three possible surveys are listed below:

- a) Low frequency drift-scan pulsar survey
 - Detect ~2300 normal pulsar (~1700 new)
 - Detect ~300 MSP (~200 new), good for GW detection
- b) M31/M33 pulsar survey
- c) Radio transient survey
 - Use same data set (piggyback)
 - Good option for a whole FAST sky (2.3π) survey before PAF receiver is available

Survey simulation

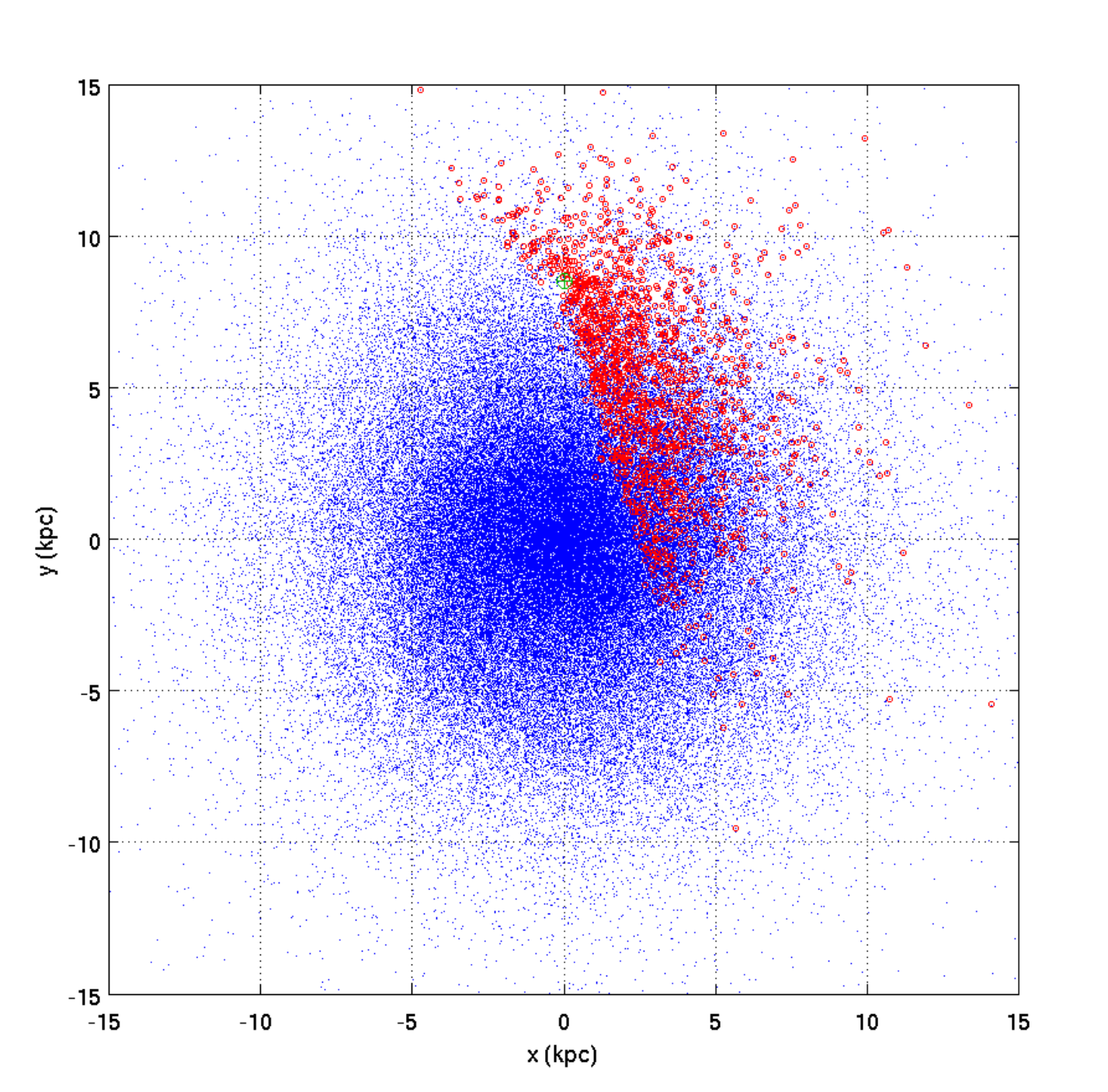
To find the best frequency for the 7-beam receiver, I have done some simulations using PSRPOP. The pulsar population generation is similar to Smits et al. (2009). Two working case are considered.

- a) Spherical surface
 - The illuminated aperture D_{ill} decreases as frequency increase, $D_{\text{ill}} \sim 200\text{m} * (f/400\text{MHz})^{1/4}$. This will be at the very early stage, when the reflector has just been laid.
- b) 300m diameter parabola

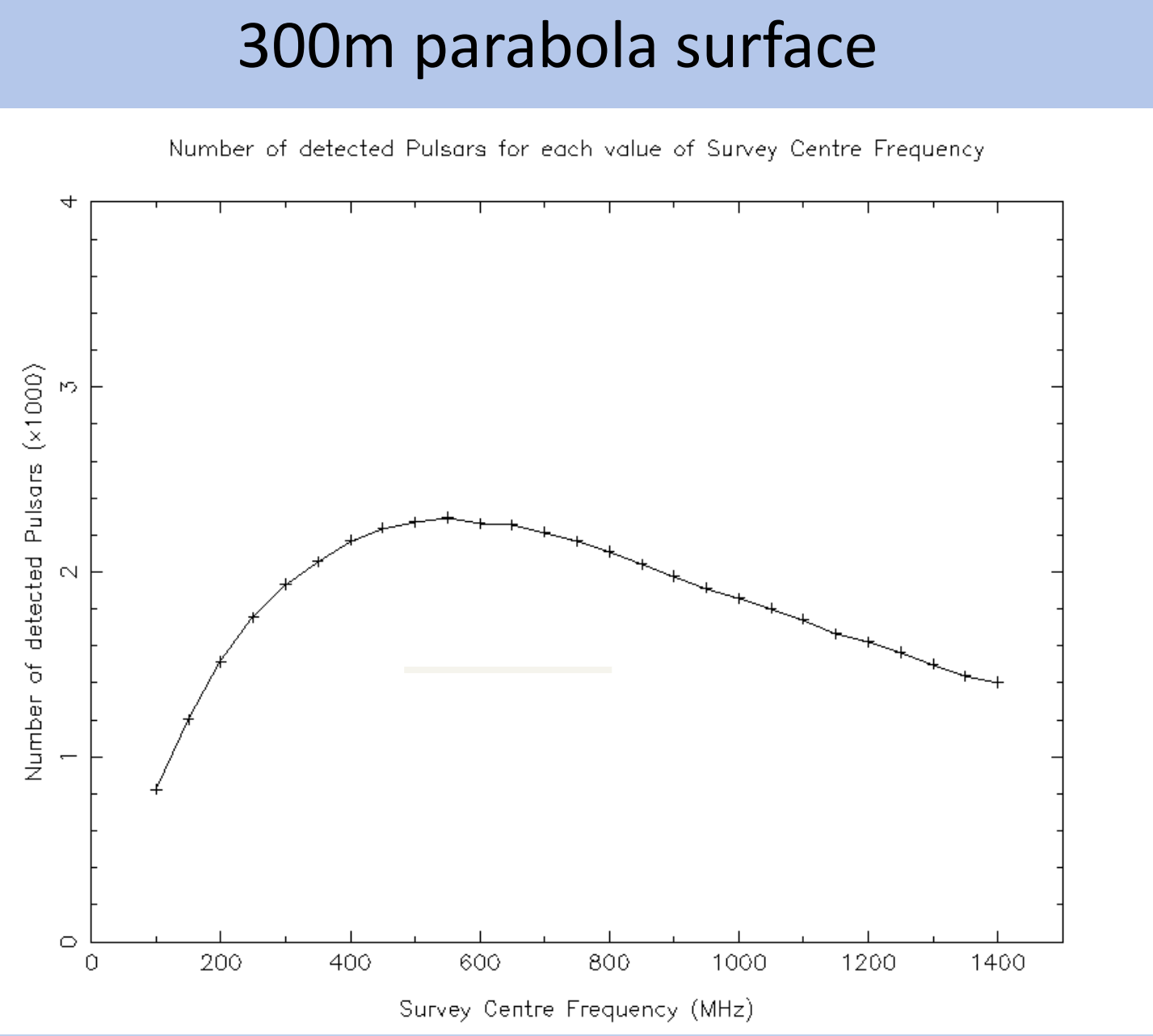
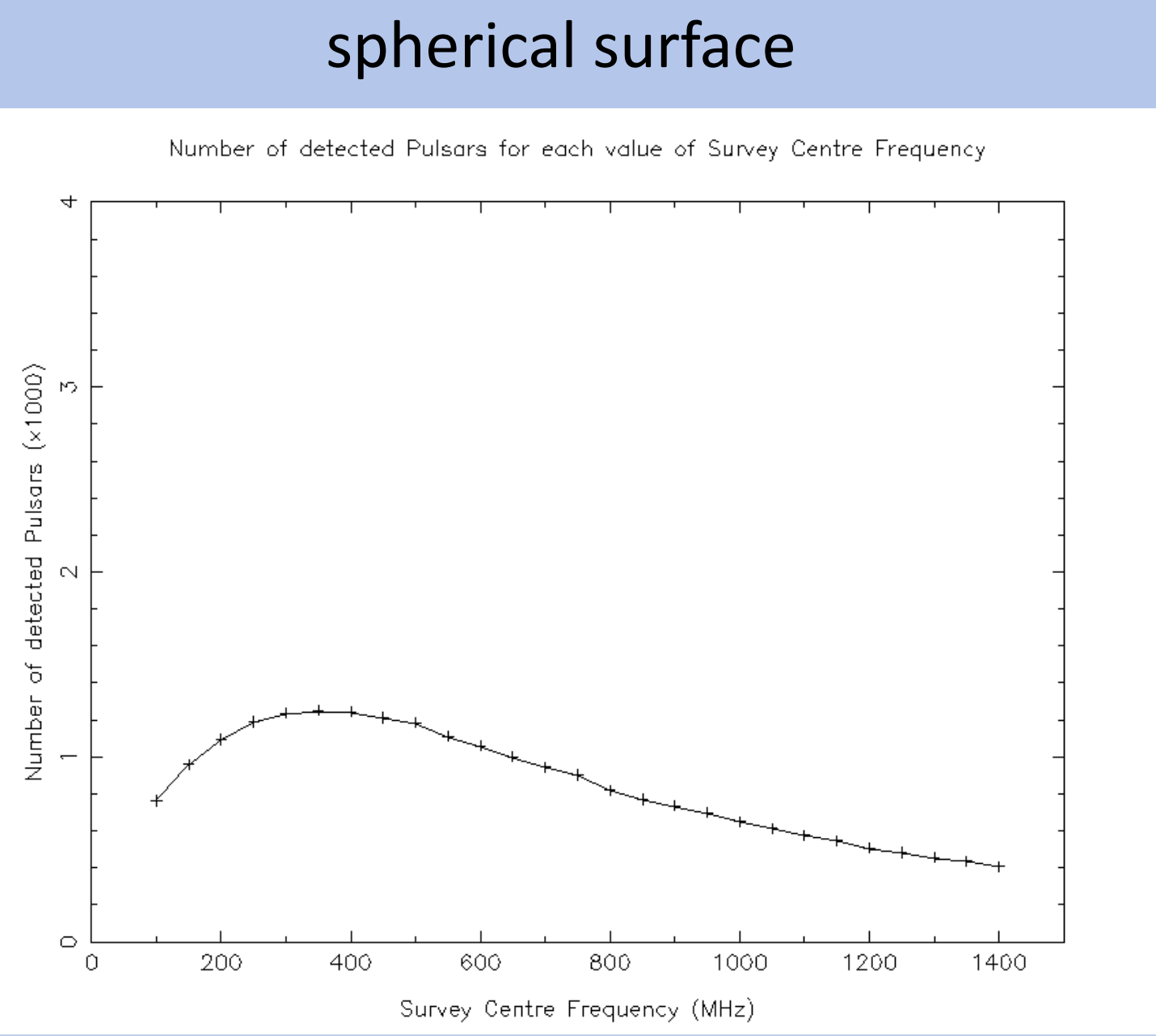
In drift scan mode, the integration time is decided by the beam width which varies according to observing frequency. It is about 40 seconds at 400MHz. The survey speed also depends on frequency. At 400MHz, the whole FAST sky (2.3π) will be covered in 2 month.

Since normal pulsar and millisecond pulsar (MSP) are different populations, they are discussed separately. Firstly, normal pulsar population is discussed.

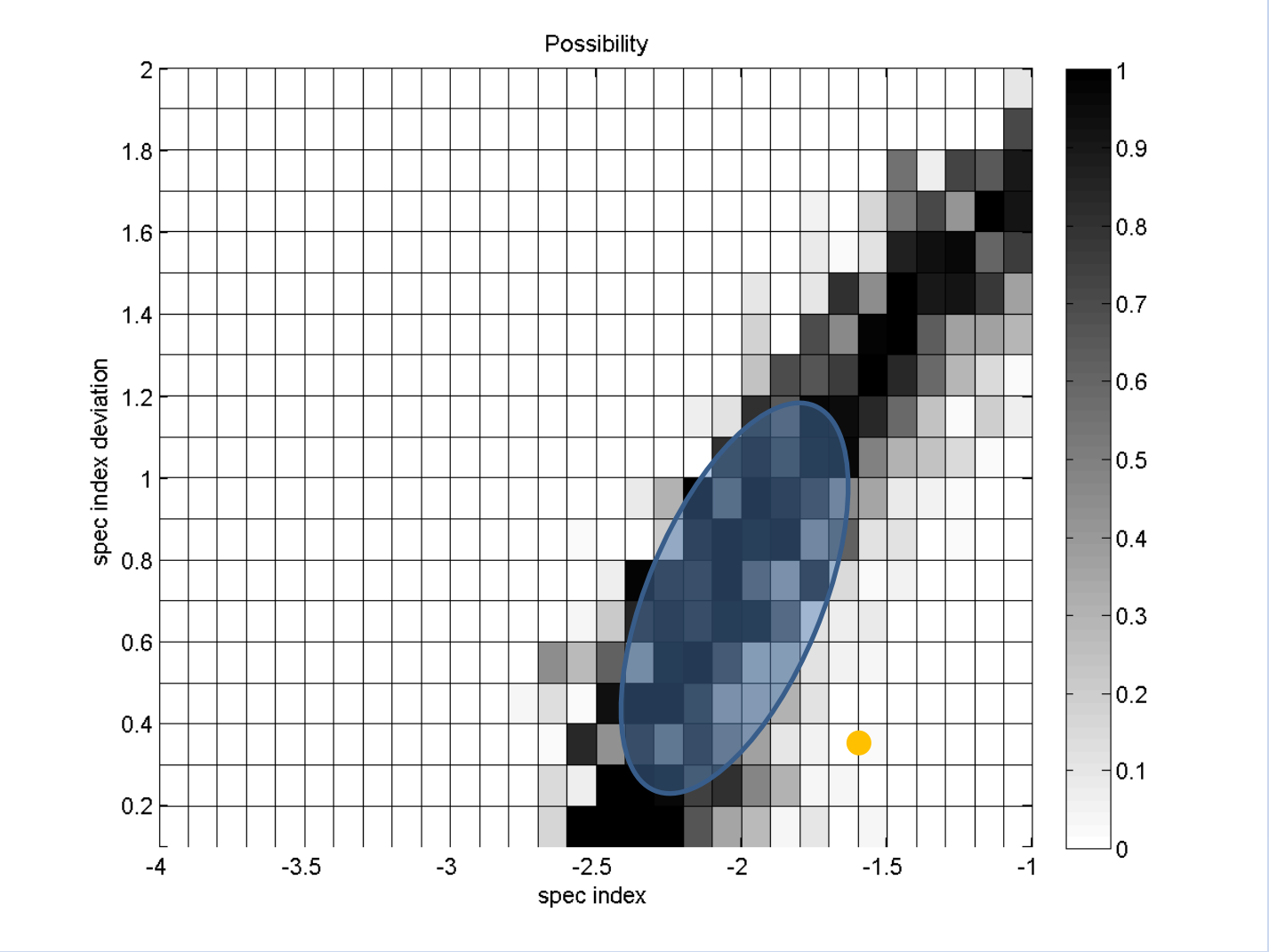
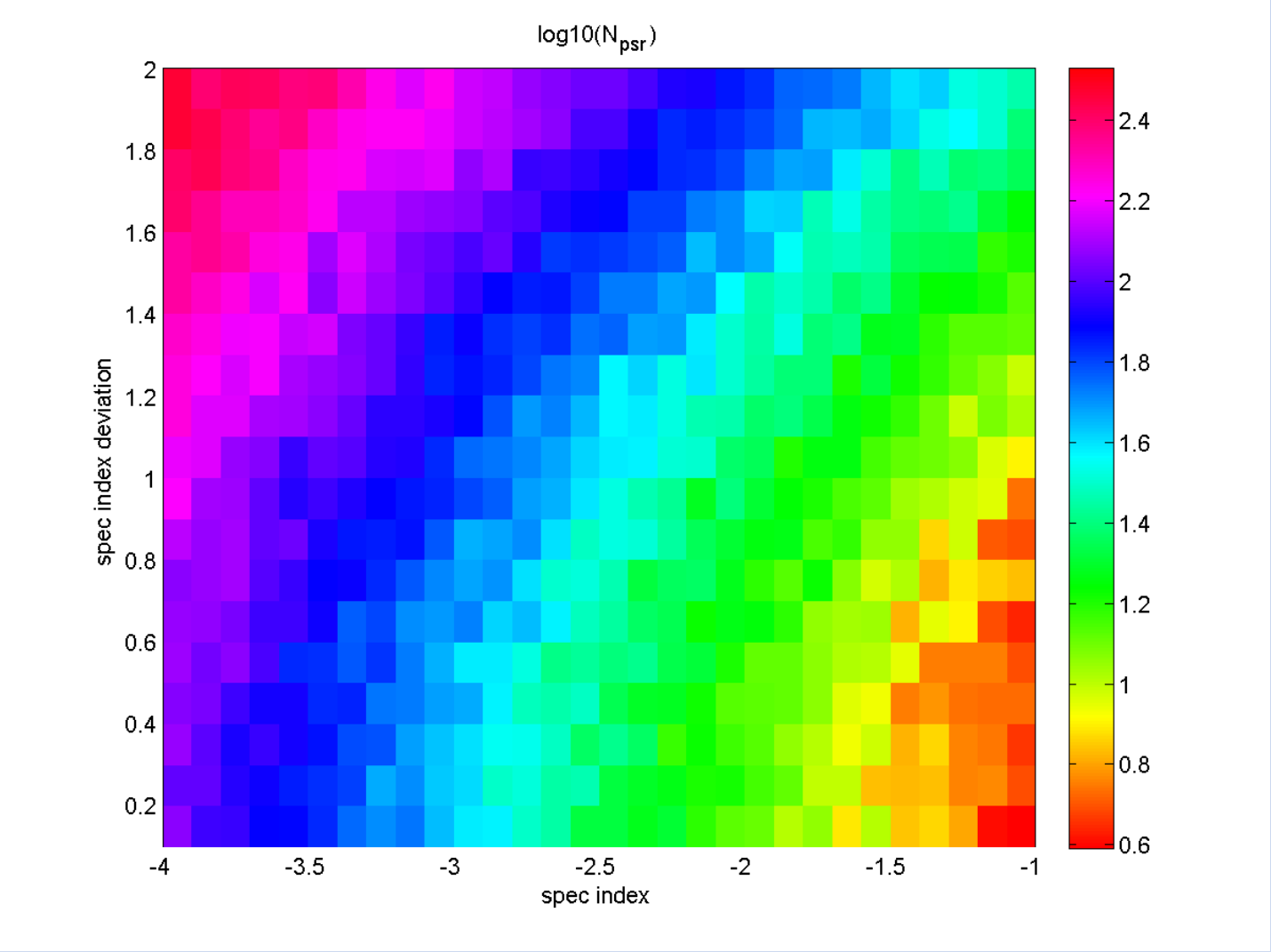
The right figure shows a simulation run. Blue: ~100k normal pulsar generated Red: ~2300 detected by FAST at 400MHz band, ~1700 would be new



The two figures below show number of normal pulsar detected at different frequencies. Bandwidth = 1/3 center frequency and Integration time = 40s *(400MHz/frequency) are used. Considering number of pulsars detected and survey speed, the best frequency is around 400MHz.

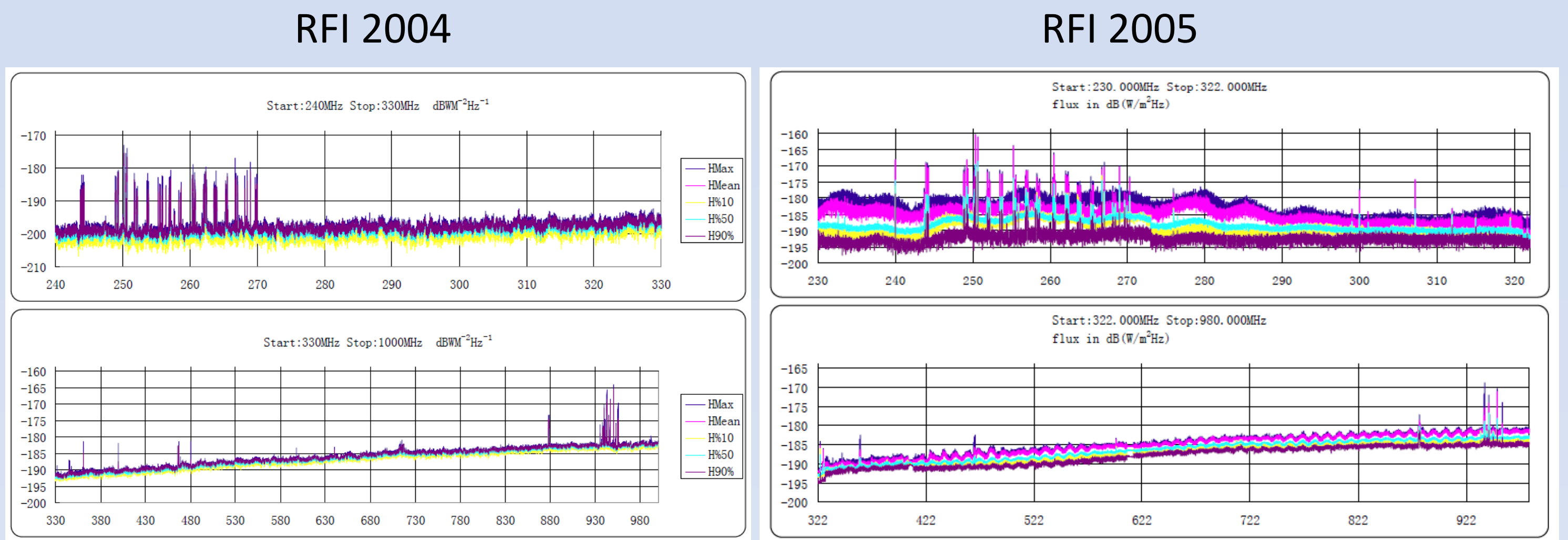


MSP is different to normal pulsars, e.g. different spectral index, spatial distribution, etc. A spectral mean -1.6 and deviation 0.35 is used by Smits et al. (2009). Here I treat spectral index and spectral index deviation as free parameter, and find in the parameter space where the simulation agrees with both Parkes multibeam survey and 70cm survey. The left figure below shows number of pulsar detected, the green region agrees with Parkes 70cm survey. The right figure below is same as left but converted to a possibility plot. The result favor steeper spectral index or larger spectral index deviation.



RFI

Pulsar survey is sensitive to RFI which should be carefully considered. Two RFI measurements in 2004 and 2005 are showed below. The overall RFI situation is good around 400MHz. Only a few narrow band RFI exists. Final frequency and bandwidth of the receiver will be decided after new measurements of RFI.



Acknowledgements

This work has been updated after discussing with Jim Condon and a lot of people from the pulsar community and FAST group.

References

Condon, J. J., 1969, CSUAC, 182
Smits, R. et al., 2009, A&A, 505, 919
PSRPOP, <http://psrpop.sourceforge.net/>
Some receiver images are from internet