An Analysis of the Sensitivity of the Arecibo Drift Scan Survey

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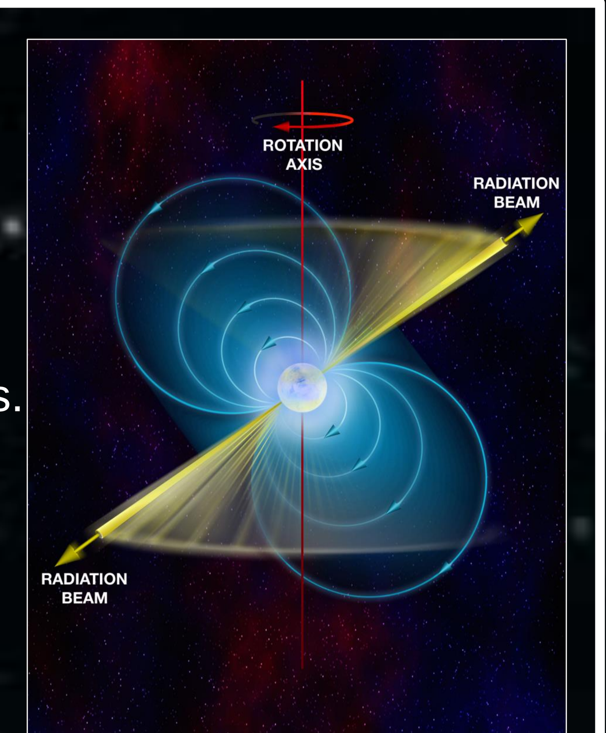
Pulsar Background

- Rapidly spinning neutron stars.
- Form from massive stars that have gone supernova.
- Mass of 1-2 times the sun and radius of about 15km.
- Emit beams of radio waves from the magnetic poles, which have a lighthouse effect.
- This effect is observable as a broadband signal by radio telescopes.
- Pulsars have a very stable spin period which makes them very important research tools.
- An example of the importance of pulsars includes the possibility of detecting gravitational waves createdby merging galaxies.



Arecibo Driftscan:

- The drift scan data were taken with the Arecibo Observatory in Arecibo, Puerto Rico.
- The data are from observations done between the years 2011-2014.
- The drift scan was a passive scan of the sky which received signals in the 350 MHz range, and recorded incoming data as the rotation of the earth caused different regions of the sky to "drift" into the telescope's field of view.
- Because the survey covers such a large portion of the sky, it is crucial to verify that it is achieving its desired sensitivity.

Compared Complexities and Time Estimates:

- The worst-case scenario for linear search is if what you are looking for is at the end of the list. This means that you would take N units of time, where N is the number of elements in the list.
- The worst-case scenario for binary search would only take log base 2 of N units of time, because at each iteration you divide the number of elements in the list by 2.
- This means that in our case, the binary search is approximately 14.52 times faster.
- If we use the estimate that the linear search takes approximately 2 seconds per pointing, then using the entire list of 23,425 pointings:

	Linear Search	Binary Search
Time to Run Entire List of Pointings	13.014 Hours	53.7912 Minutes

Known Pulsars and Discoveries:

- The drift scan covers the whole sky visible to Arecibo, at declinations of -1° to 38°.
- This means that there should be over 650 detectable pulsars.
- It is possible to calculate how long for which an object should be visible. This calculation is done in the diagram to the right.
- New pulsar detections by the drift scan are made every year.
- Discoveries made this year include J0110+11 and J0342+27
- Other important discoveries from the drift scan include a double neutron star system, milli-second pulsars and RRATs (which are neutron stars with sporadic radio emission).

Calculating beam size in radians for any spherical dish,

$$\theta = \frac{1.22 \cdot \lambda}{Diameter}$$

Using λ = 0.857 m, and D = 300m,

$$\theta = 3 \times 10^{-3}\ radians$$

Converting radians to arcminutes,

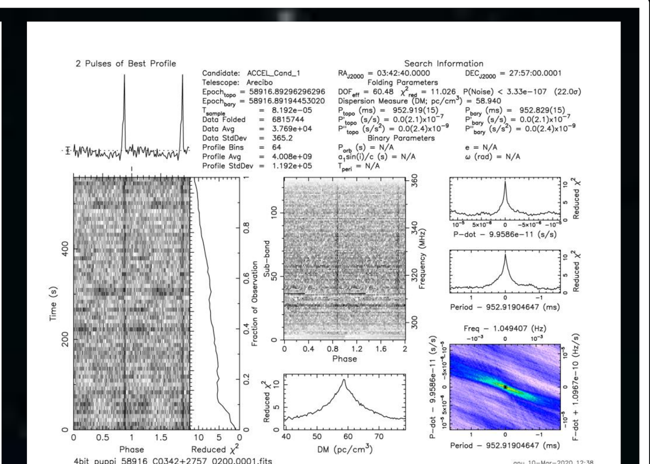
$$arcminutes = \frac{3 \times 10^{-3}\ rads \cdot 60 \cdot 180}{\pi}$$

$$arcminutes = 11.98$$

Assuming it takes the earth 4 seconds to turn 1 arcminute,

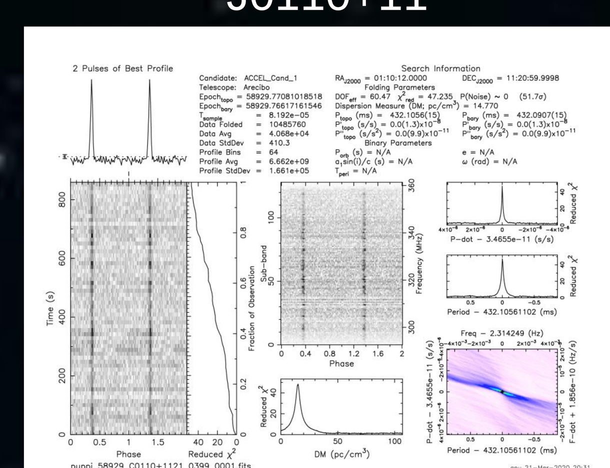
$$t = 4\ s \cdot 11.98\ arcminutes$$

Therefore, time object is observable is $t = 47.92\ s$



J0342+27

J0110+11



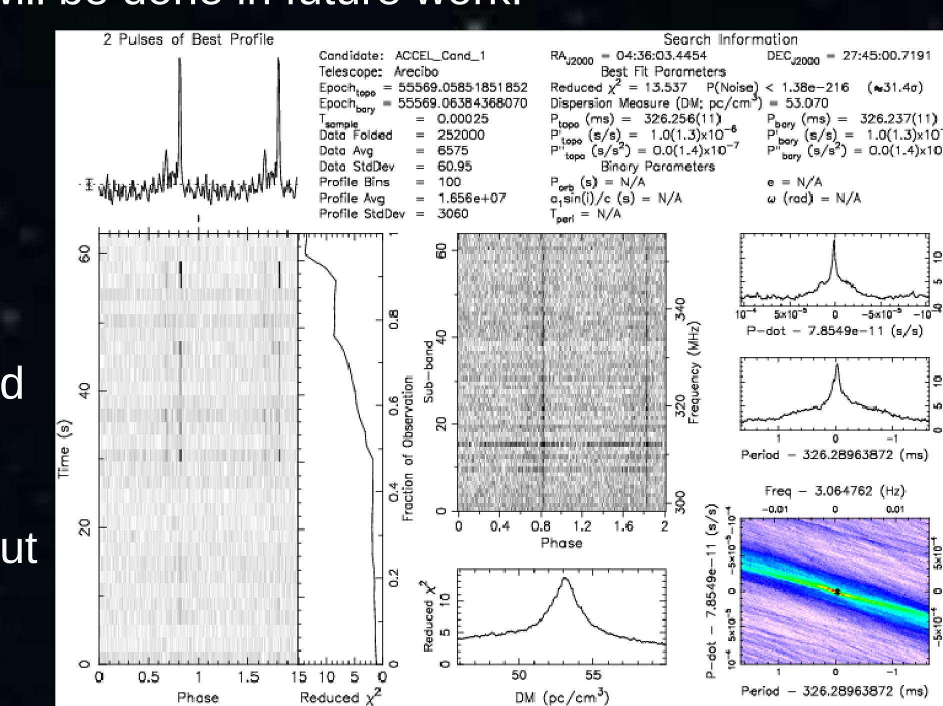
The plots above and to the left are typical prepfold plots which give us a candidate's integrated pulse profile, time domain plot, sub-band plot and DM plot. These two plots are follow-up observations of the pulsars that show very bright detections.

Changes to Original Script:

- After completing the original script, it was clear that a better method needed to be implemented so that the pulsars could be found and analyzed faster.
- In order to make the code more straightforward to use, we decided to convert everything from Bash and only use Python.
- Currently all the features are working, so that when we detect a pointing, we get the same output as the original script.
- We are currently working on making the script more flexible, with the ultimate goal of finding pulsars with full position solutions as well as those without.
- This script is mostly complete and almost ready to be tested on the full list of pointings.

Detected Pulsars:

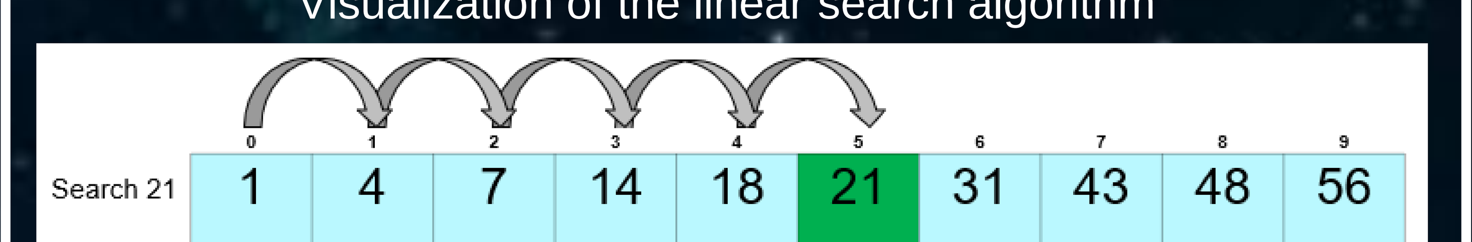
- An important aspect of evaluating the drift scan is finding plots of known pulsars.
- This ensures that the data we are taking is good, and also provides more information on the pulsar.
- Below is a first pulsar that was detected in in a directory with an arc distance 4.814 arcminutes from the actual pulsar.
- This plot is of pulsar J0435+2749 and was detected at a DM of 53.07 pc/cm³ where the original pulsar is detected with a DM of 53.19 pc/cm³. Which is a good sign.
- However, to get a full analysis of the pulsar, we will need to calculate if the flux is as we expect. This will be done in future work.
- Another reason as to why this pulsar is interesting is because it appears to be "nulling".
- This means that the pulsar suddenly misses pulses during otherwise strong and consistent pulses.
- These nulls could give us interesting information about J0435+2749's properties, however this is beyond the scope of our project.



Original Script:

- The original script was developed by Pranav Sanghavi. It was also created with the purpose to check sensitivities.
- This script was designed using a linear search as its searching algorithm and was modified to work in our environment.
- Many features were added to give information about the pulsar once it was found by the script.
- These features include displaying the period of the pulsar, the dispersion measure, and the official name of the pulsar.
- These additional features are important as they allow us to rapidly compare the properties of the pulsar and allow us to determine if the detected pulsar has the properties which we would expect.

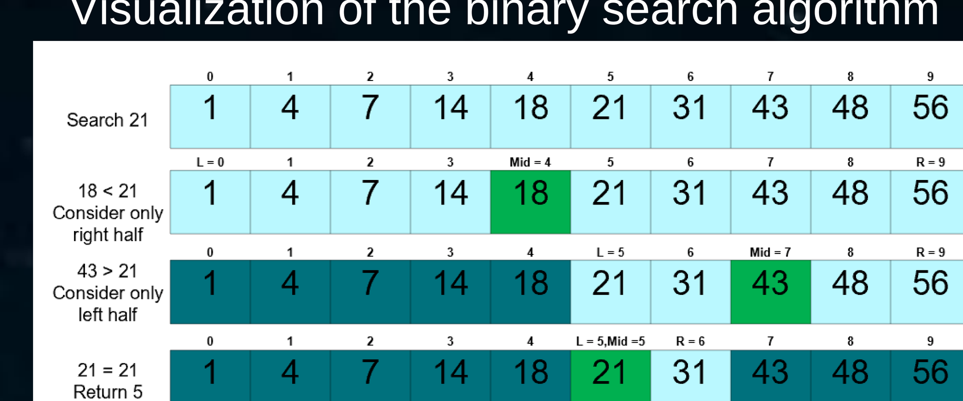
Visualization of the linear search algorithm



Binary Search:

- After completing the first code, it was clear that a faster algorithm could be developed
- After consulting with Marie Dumaz, a computer science graduate student at WVU, it was determined that the Binary Search algorithm would be much more efficient.
- This algorithm is designed to find a number 'x' in a sorted list. At each iteration, it compares x with the middle of the array. If x is bigger than the midpoint, then it eliminated the bottom half or vice-versa. It does this until the possible location is narrowed down to 1.
- Since our project involves finding 'x' in a range of about 10 arcminutes, the usual binary search code had to be adjusted to search 'x' as a range of numbers rather than a single value.
- This script can now run through every possibility before a match, skipping all the other code, and only once a match is detected, will it run the separation commands. A feature that did not exist in the previous code.

Visualization of the binary search algorithm



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References:

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