Pulsar Searching using PRESTO

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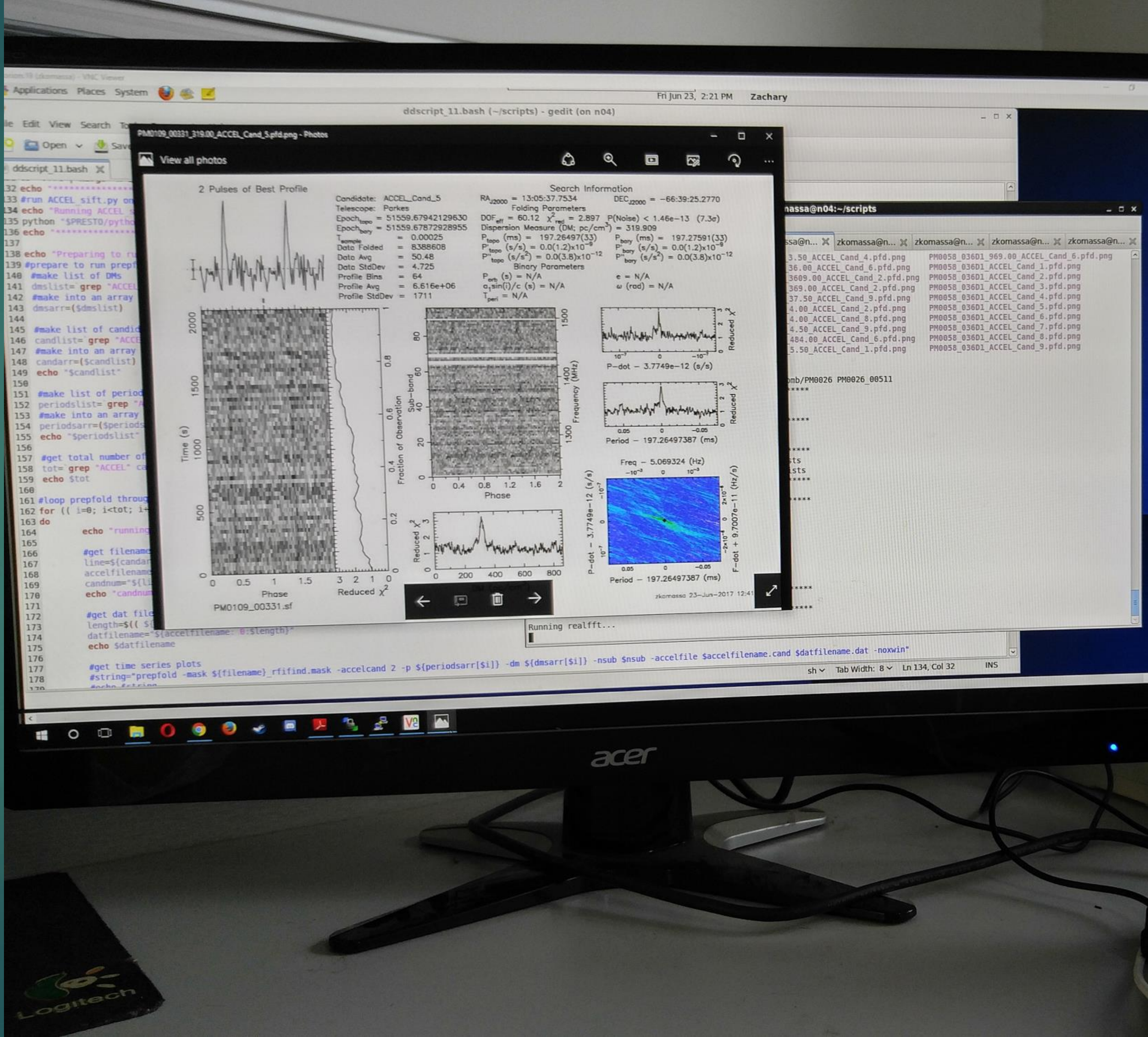
Our Pulsar Search Project

Research with professor Di Li and postdoc Zhichen Pan at NAOC in Beijing and Guiyang

Our goal was to become familiar with pulsar searching using Scott Ransom's PRESTO software

Shana and I worked through writing a bash script to process Parkes Multi-beam data and AO Drift Survey data



Why Search for Pulsars?

Make contributions to the PRESTO pipeline for NAOC and in turn for multi messenger astrophysics

Detecting pulsars is crucial to the foundation of pulsar astronomy and gravitational wave detection

First, we installed PRESTO and it’s components to each of our directories

Used NAOC and Guizhou Normal University (GZNU) login nodes

PRESTO tutorial by Scott Ransom to learn the sequence of data processing

PRESTO Pipeline

1. Rfifind – reduce RFI from the raw data file
2. DDplan.py – plan for de-dispersion
3. Prepsubband – de-disperse the data accordingly
4. Realfft – Fourier Transform to look for periodicity
5. Accelsearch – acceleration search, useful for binaries
6. ACCELsift.py – sift through all the best candidates
7. Prepfold – fold the best candidates, view output plots

Processing Parkes Multi-Beam Data

We first designed our scripts to process Parkes Multi-beam Survey data, one file at a time

Performed manual tests of each step of the pipeline

Calling “readfile” is very important for gathering info about these particular data

```
#create new folder for data files
mkdir $filename
cd $filename

#create link to file in current directory in the folder
ln -s $directory/$filename.sf ./
echo "************************************************************"
#run rfifind:
echo "Running rfifind..."
rfifind -o ./$filename -time 2 ./$filename.sf >> /dev/null
echo "************************************************************"
#get variables needed for DDplan.py from readfile:
 #low dm
 ldm=0
 #high dm
 hdm=4000
 #Parkes multibeam bandwidth
 bandw=`readfile $filename.sf | grep "Total Bandwidth" | awk '{print $5}'`
 #time resolution
 t_res=0.5
 #center frequency
 cfreq=`readfile $filename.sf | grep "Central freq" | awk '{print $5}'`
 #number of channels
 num_chan=`readfile $filename.sf | grep "Number of channels" | awk '{print $5}'`
 #sample time
 smp_time=`readfile $filename.sf | grep "Sample time" | awk '{print $5}'`
 smp_time=0.000$smp_time
 #spectra per file
 numout=`readfile $filename.sf | grep "Spectra per file" | awk '{print $5}'`
```

Re-detecting Known Pulsars

Table 1: Comparison of Characteristics of E@H Pulsars

File Name	Jname	My DM (pc/cm^3)	My Period (s)	E@H DM (pc/cm^3)	E@H Period (s)
0026_00511	J0811–38	336.2	0.4825952	336.2	0.4852594
0058_036D1	J1227–6208	369	0.034519596	363.2	0.034529685
0109_00331	J1305–66	319.9	0.1972759	316.1	0.1972763
0001_00161	J1322–62	716.1	1.0448551	733.6	1.044851
0038_01821	J1455–59	499	0.17619329	498	0.1761912
0042_00391	J1601–50	68.8	0.8607696	59	0.860777
0137_041B1	J1619–42	373.9	1.0231893	172	1.023152
0125_077C1	J1626–44	269	0.10278463	269.2	0.3083536
0039_00551	J1637–46	636.3	0.4930971	660.4	0.493091
0056_020B1	J1644–44	559	0.17390999	535.1	0.1739106
0035_02931	J1644–46	424.1	0.25094531	405.8	0.2509406
0085_02541	J1652–48	187	0.00378512514	187.8	0.0037851238
0054_015A1	J1726–31	269.4	0.12347177	264.4	0.12347018
0102_00591	J1748–3009	*N/A*	*N/A*	420.2	0.009684273
0002_00891	J1750–2536	179	0.034749160	178.4	0.034749053
0141_00971	J1755–33	241.1	0.9594445	266.5	0.959466
0137_039B1	J1804–28	218	1.273008	203.5	1.273011
0149_01081	J1811–1049	269.7	2.623845	253.3	2.6238585620
0011_03231	J1817–1938	*N/A*	*N/A*	519.6	2.0468376289
0148_01971[1]	J1821–0331	*N/A*	*N/A*	171.5	0.90231562918
0132_06271	J1838–01	*N/A*	*N/A*	320.4	0.1832948
0140_00641	J1838–1849	161.7	0.4882397	169.9	0.48824200896
0060_02061	J1840–0643	489	0.035577871	500	0.0355778755
0143_00511	J1858–0736	195.1	0.5510591	194	0.551058591

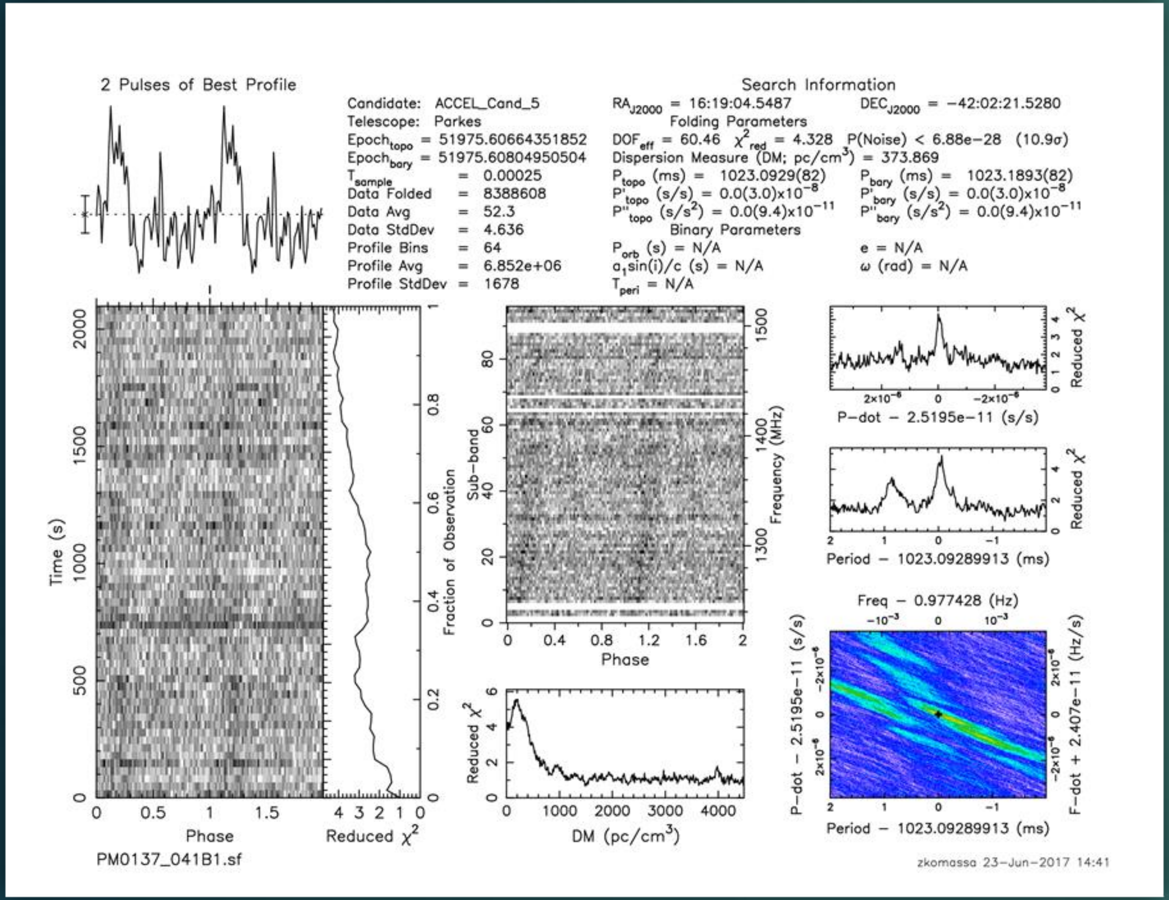
We used our scripts to re-detect a list of pulsars given from the E@H paper:

EINSTEIN@HOME DISCOVERY OF 24 PULSARS IN THE PARKES MULTI-BEAM PULSAR SURVEY
(Knispel et al. 2013)

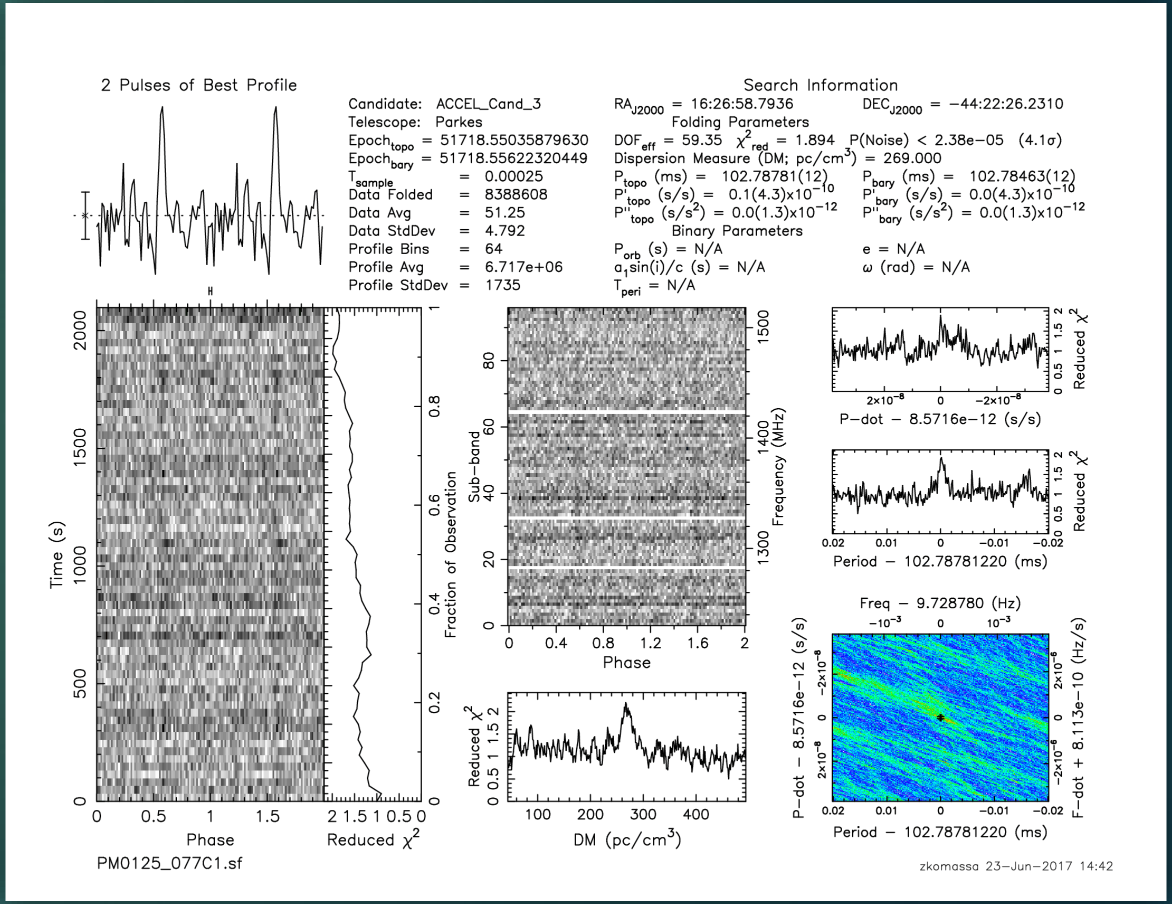
Table 2: Other Detections of Known Pulsars

File Name	Jname/Bname	My DM	My Period (s)	psrcat DM	psrcat Period (s)
0039_00551[2]	J1640–4648	478.1	0.22753398	478.8	0.455059775403
0042_00391	J1600–5044	264	0.192601587	260.6	0.1926012327811
0102_00591	B1746–30	508.6	0.6098765	509.4	0.60987364867

Discrepancies



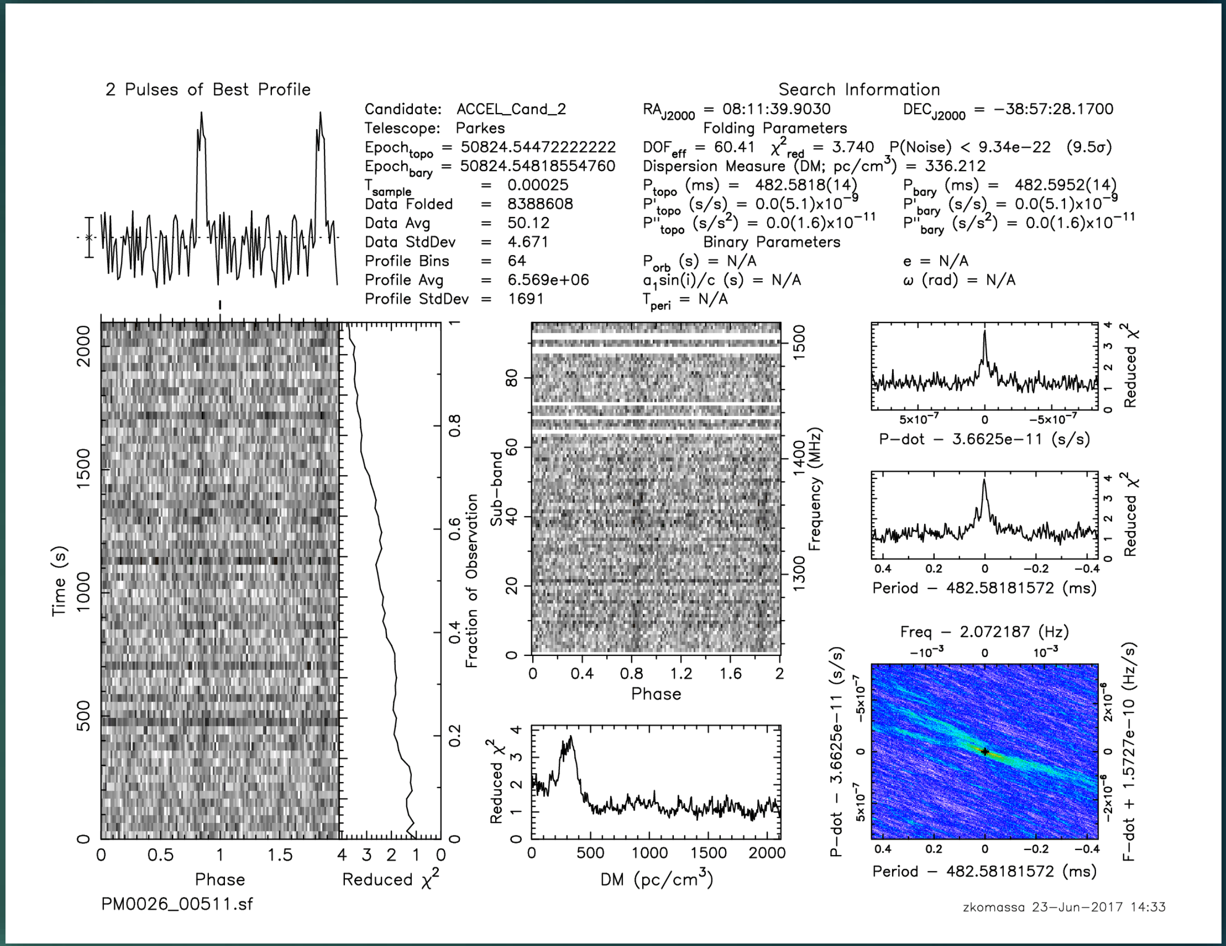
J1619-42



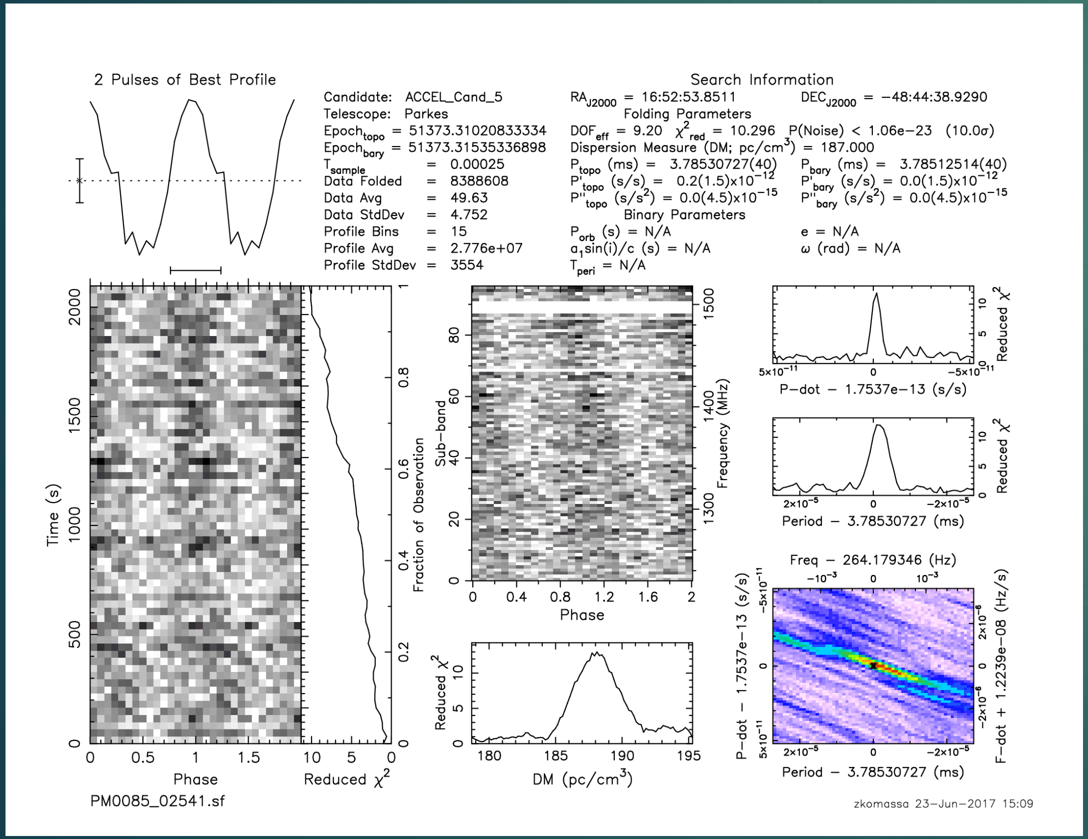
J1626-44

Period was always accurate to at least the first 4 decimal places

Highest DM error was -25.4 pc/cm^3 from the paper's values



J0811-38



J1652-48

Each file yielded ~30 candidates on average; roughly 650 candidates total for 23 files

Processing AO Drift Survey Data

We then modified our scripts to fit AO Drift Survey data sent to us

The next step was to process 28 data strips, and attempt to find the known pulsar J0509+08 in the data

Goals, Strategies and First Discoveries of AO327, the Arecibo All-Sky 327 MHz Drift Pulsar Survey

(Deneva et al. 2013)

Beam Size and Transition Time

The first step for the cutting and combining plan involves some calculations of the transition time of a source across the telescope during a drift scan. I took the central frequency (f) of these data, which is 326.972 MHz, and found the corresponding wavelength (λ) using the basic equation below, where c is the speed of light.

$$\lambda = c/f \tag{1}$$

The resulting wavelength λ comes out to be 0.916875 m. Then, with this value, I found the beam size with the given equation below, where λ is the wavelength in meters, d is the diameter of the telescope in meters (I used 216 m), and 1.22 is a constant:

$$(\lambda/d) * (1.22) * (180/\pi) \tag{2}$$

This yielded a beam size of 0.296715°, which can then be used to calculate the actual transition time of a source during the drift scan:

First, knowing that the Earth rotates 360° in 24 hours, convert 24 hours to seconds:

$$(24 \text{ hours}) * (60) = 1440 \text{ minutes} \rightarrow (1440 \text{ minutes}) * (60) = 86400 \text{ seconds} \tag{3}$$

Then divide to find the rate of Earth's rotation in degrees per second:

$$(360°) \,/\, (86400 \text{ seconds}) = 0.0041667°/\text{s} \tag{4}$$

Finally, divide the beam size by the above rate of rotation:

$$(0.296715°) \,/\, (0.0041667°/\text{s}) = 71.211030 \text{ seconds} \tag{5}$$

Given that I cut the files into sections of 72 subints with a 1/3 subint overlap in the cutting, and each file is initially 129 subints, the layout of the cutting and combining plan is as follows (all of the below values are the subints):

1. Begin File 1
   (a) cut: 0-71
   (b) cut: 24-95
   (c) cut: 48-119
   (d) combine with next file: 72-14
   (e) combine with next file: 96-38
   (f) combine with next file: 120-62
   (g) subints surpass 129: 144-215, move on to next file ↓
2. Begin File 2
   (a) cut: 15-86
   (b) cut: 39-110
   (c) combine with next file: 63-5
   (d) combine with next file: 87-29
   (e) combine with next file: 111-53
   (f) subints surpass 129: 135-206, move on to next file ↓
   (g) ...

End result was 148 files to process

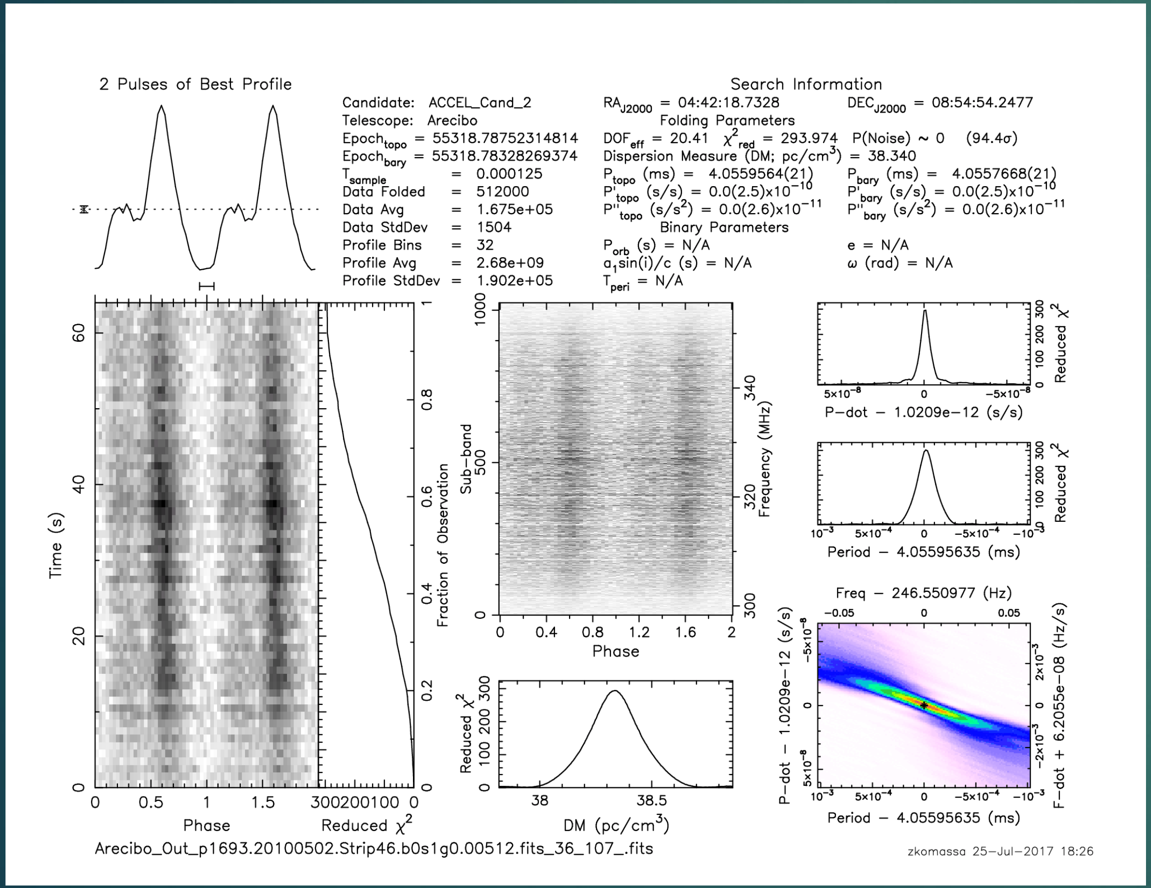
Trial and Error

The first attempt at processing yielded ~20 candidates per file; roughly 3000 candidates total after 305,510 seconds

We each failed to make any detections, and had to troubleshoot

Eventually we discovered a problem with realfft and were able to fix the error by lowering the "High DM" in DDplan.py to 1000 pc/cm^3

Detecting J0509+08



Each file was 129 sec, this detection was 27 minutes in

Processing one file took ~8 hrs as opposed to ~4 hrs from before

Number of candidates outputted from this particular file rose from 28 to 88

Table 3: Comparison of J0509+08 Detections

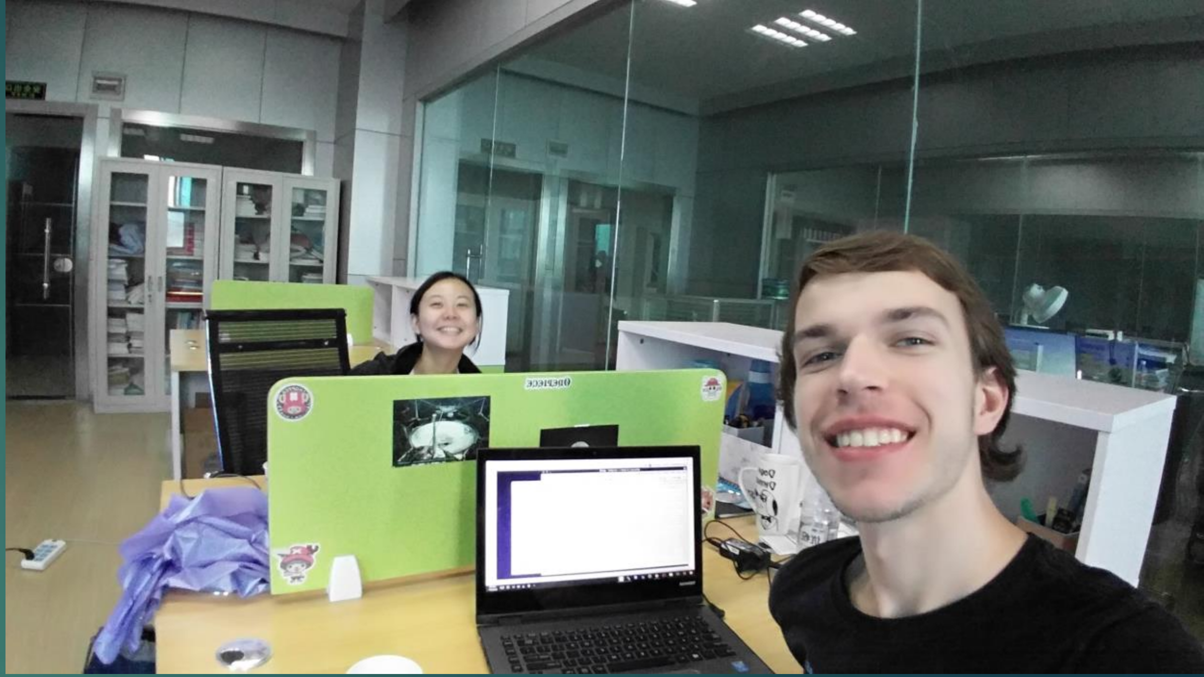
My DM (pc/cm^3)	My Period (s)	AO Drift DM (pc/cm^3)	AO Drift Period (s)
38.34	0.0040557668	38	0.00406

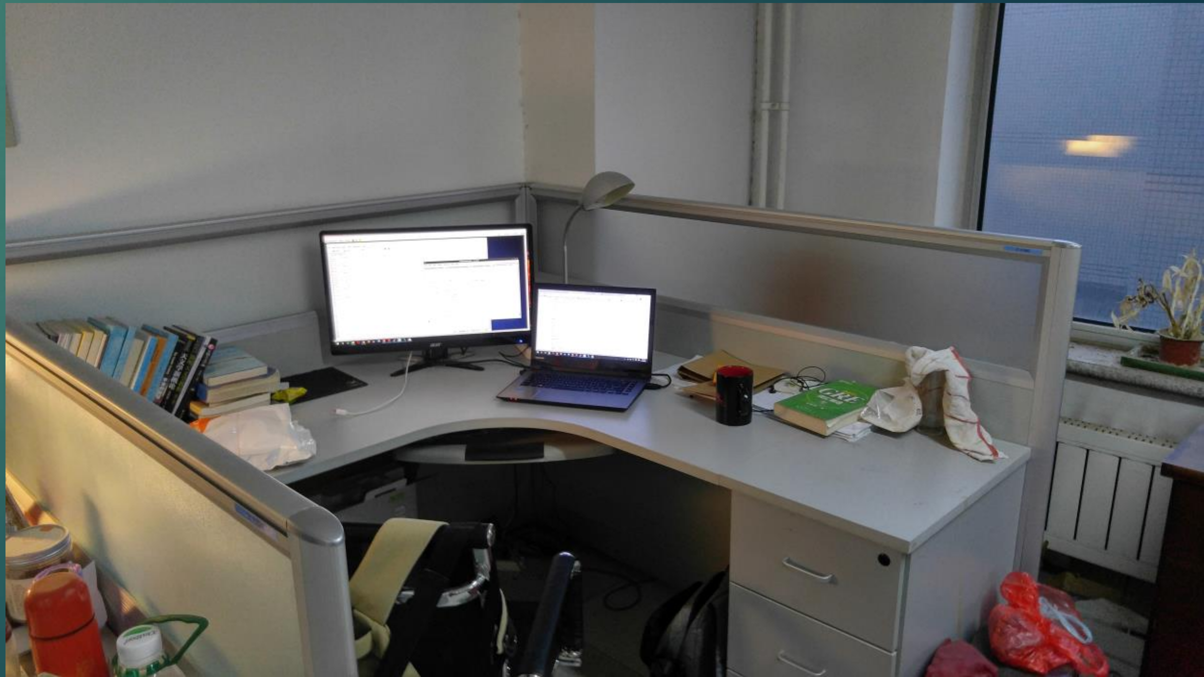
Conclusions

We were each able to accurately detect 18/24 of the pulsars from the E@H paper, as well as detecting J0509+08 from the AO Drift Survey

Future goals include creating a Python script to run more efficiently and reduce processing times

Overall, our initial experience in using PRESTO to process pulsar data went well!

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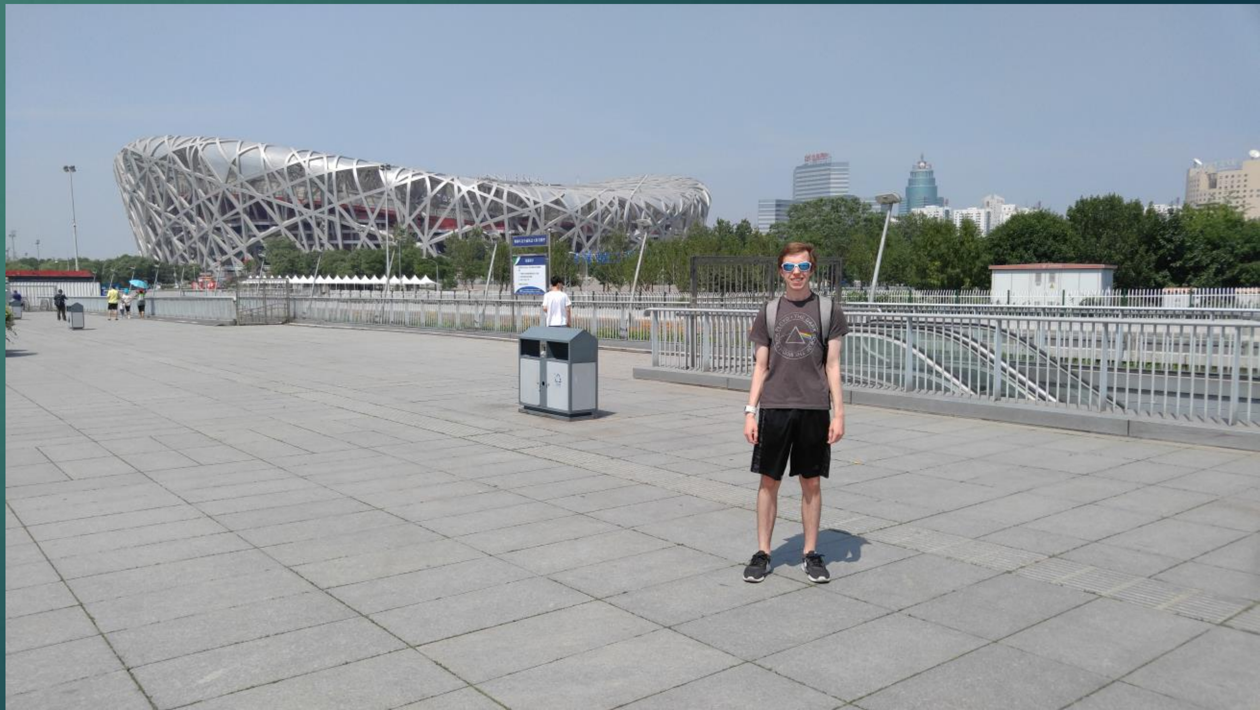

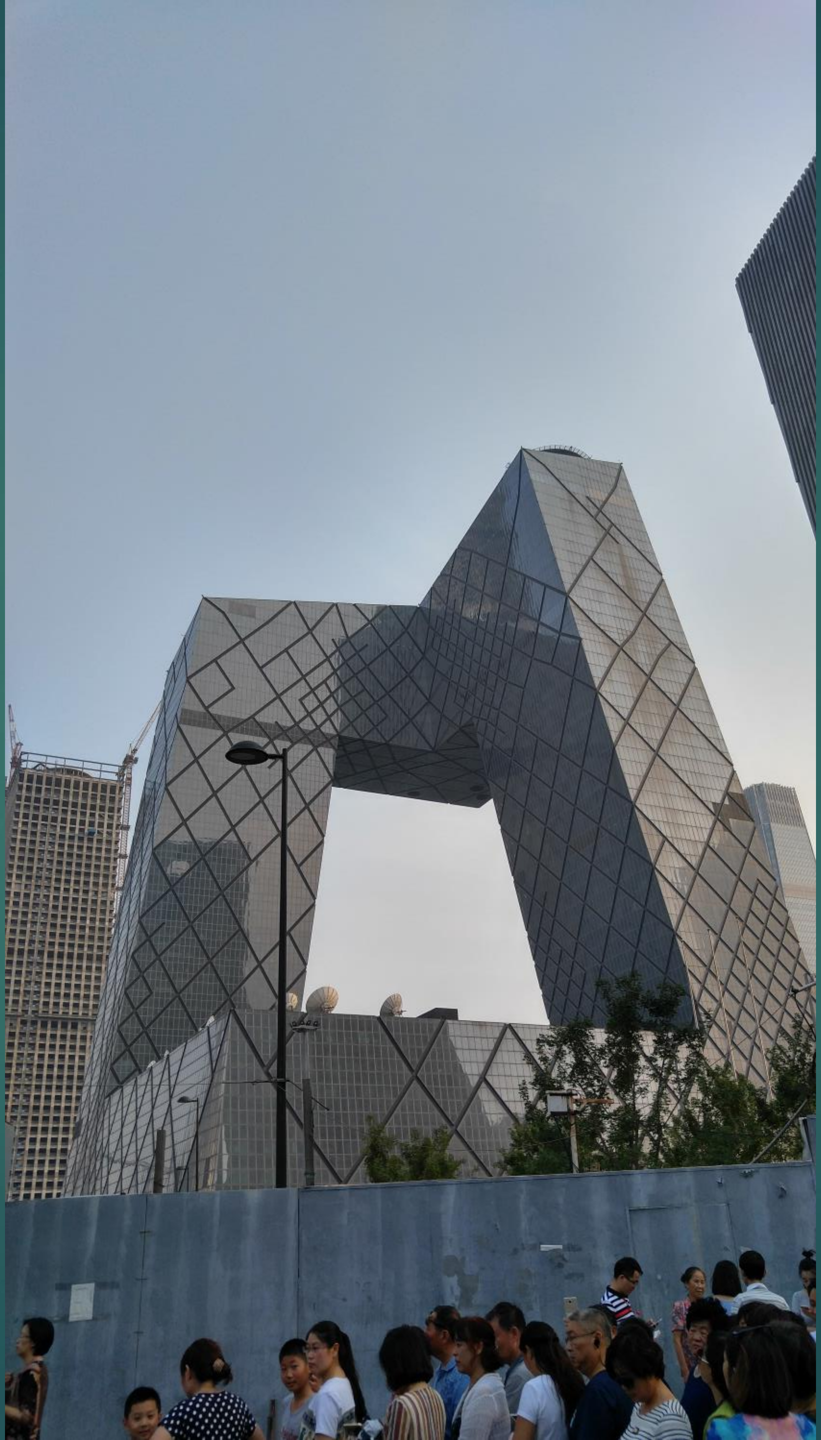


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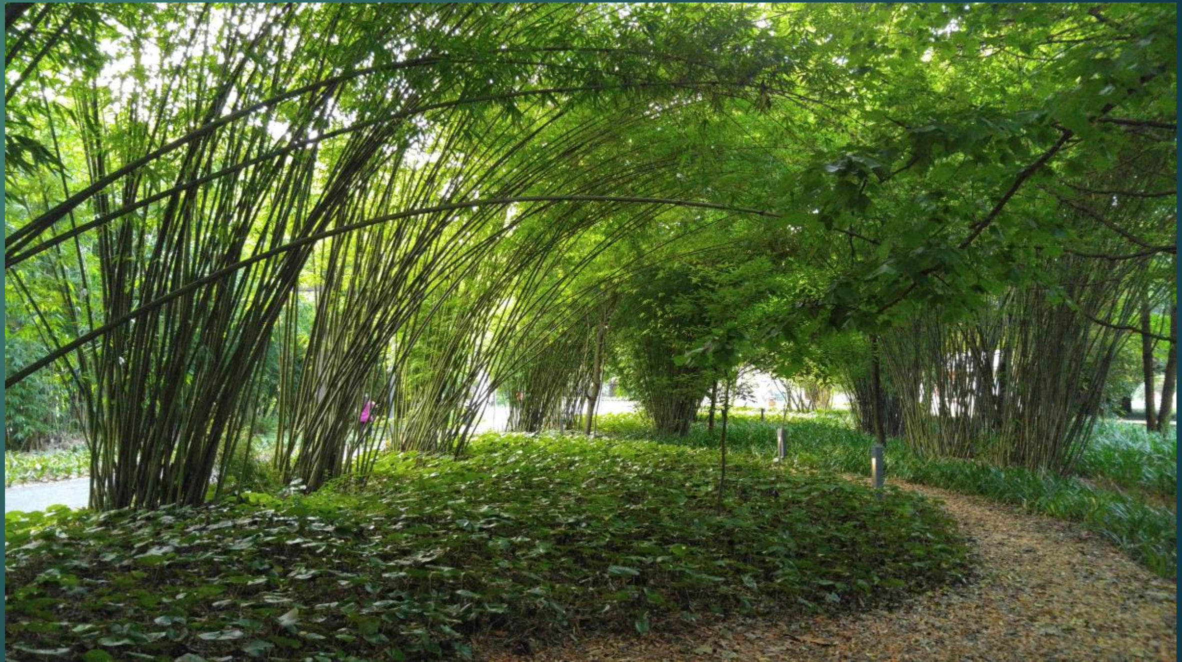


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