Single Pulse Plots

We use a software package called PRESTO to search through the data looking for pulsars. For each pointing, PRESTO computes a fast Fourier transform (FFT) and single-pulse search at various trial values for the period and dispersion measure. The fast Fourier transform is most sensitive to normal, periodic pulsar pulses. The FFT produces the "normal" pulsar plots; we also call these *prepfold* plots.

The single-pulse search produces the single pulsar plots and is designed to detect bursty, sporadic sources like some pulsars and rotating radio transients (RRATs). Some pulsars show *nulling* behavior. This means that a pulsar can "turn off" and then "turn on" again at various intervals. It is not known why this occurs, although there are various theories. A pulsar that shows this type of behavior may not show up in a regular *prepfold* plot. In addition, the single pulse plots can be used for detecting RRATs. No one knows a whole lot about RRATs except that they are, like pulsars, a type of neutron star. Instead of producing regular pulses, their pulses are sporadic, and one burst can occur anywhere from once every few minutes to once every few hours. RRATs are a very new field, as the first one was discovered in 2006! Astronomers are constantly looking and observing RRATs and it would be very exciting if we found one in the PSC data!

We are scoring the single pulse plots on the dispersion measure histogram, the signal-to-noise histogram, and the dispersion measure as a function of time. Remember how for each pointing, we are searching over many periods and dispersion measures? Each normal (*prepfold*) plot on the database shows the results for a specific trial value of the period and dispersion measure. One plot, one period, one dispersion measure. Unlike those plots, the single pulse plot shows trial values of *many* dispersion measures in one plot.

Let's think of it this way: for each trial value of dispersion measure we try to fit each one of the single pulses with that dispersion measure. If we have a real pulsar and we guess the right dispersion measure, our trial value of the dispersion measure will fit most of the single pulses. In addition, it will fit so well, that the single pulse will have a large signal-to-noise.

As an astronomy analogy, let's say we have an optical telescope with a variable aperture and it's a full moon outside. Our goal is to get a much light from the full moon into our telescope with as little light from the surrounding sky (ie. maximize signal-to-noise). If our aperture is the size of a dime, we only see part of the moon and we don't get very much light, so we have little noise but also a very small signal. If we widen our aperture to the size of a nickel, we get more moonlight, but we are still losing light because we don't see the whole moon. Our signal-to-noise is better, but not great. If we widen our aperture to the exact size of the full moon, we'll get the most moonlight and no sky background so we get the best signal-to-noise. If we then make our aperture wider than the full moon, we get all the light from the moon, but then we also get light from the surrounding sky and our signal-to-noise starts to decrease again.

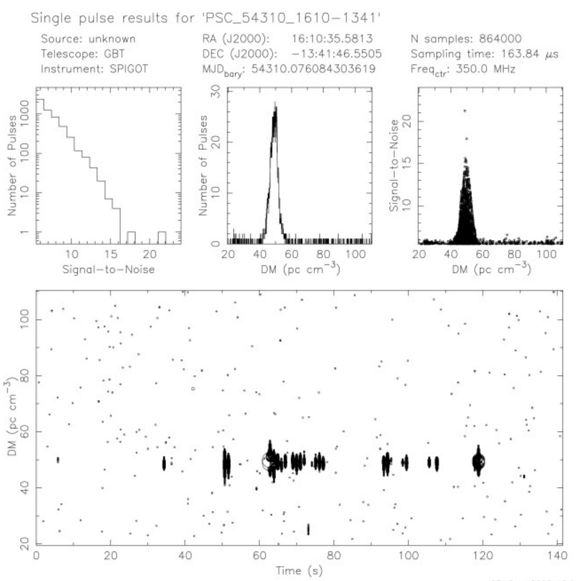
In this same way, we are try to find the correct dispersion measure for all the single pulses. So when we guess the right dispersion measure, not only will lots of single pulses have that dispersion measure, but their signal-to-noise will be very high.

The question is: what do we expect to see if it's a real pulsar?

Dispersion Measure Histogram
The dispersion measure histogram in the top center box on the single pulse plot. It is a histogram of the dispersion measure as a function of the number of pulses. For each trial value of the dispersion measure, we count how many single pulses fit that dispersion measure. When we guess the right dispersion measure, it will fit the most single pulses. When we guess a dispersion measure that is only slightly off, our guess dispersion measure will still fit many of the single pulses, but not quite as many as when we guessed the correct dispersion measure. A peak in the dispersion measure histogram at 0, just like the regular plots, is indicative of RFI.

Signal-to-Noise Histogram
This histogram is in the upper right corner and plots dispersion measure as a function of signal-to-noise. When we choose our correct value of dispersion measure, not only will it fit most of the single pulses, but the pulses will be very strong: ie. a high/large signal-to-noise.

An Example: PSR J1610-1322

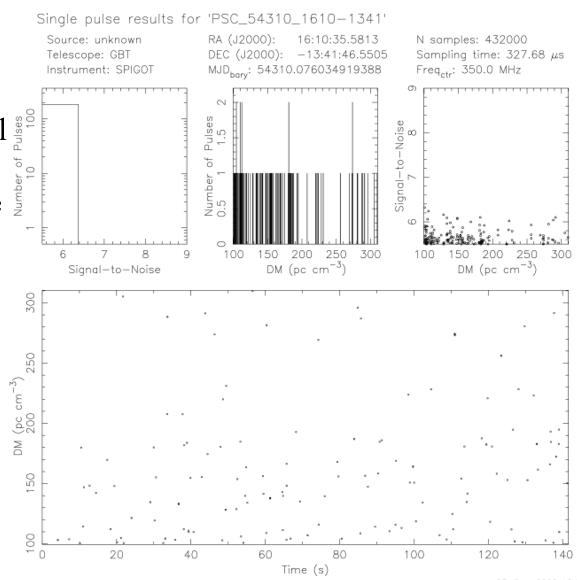


This is a single-pulse search for the known pulsar J1610-1322 and it has a dispersion measure of 49.13. This particular single pulse search is for dispersion measure ranges of 20-110.

Dispersion Measure Histogram: If you look in the top, middle box, there is a peak at a DM of 50, and the peak height is 28 pulses, meaning that there are a total of 28 single pulses. If we guess a DM of 50 (the correct DM), all the single pulses will be found.

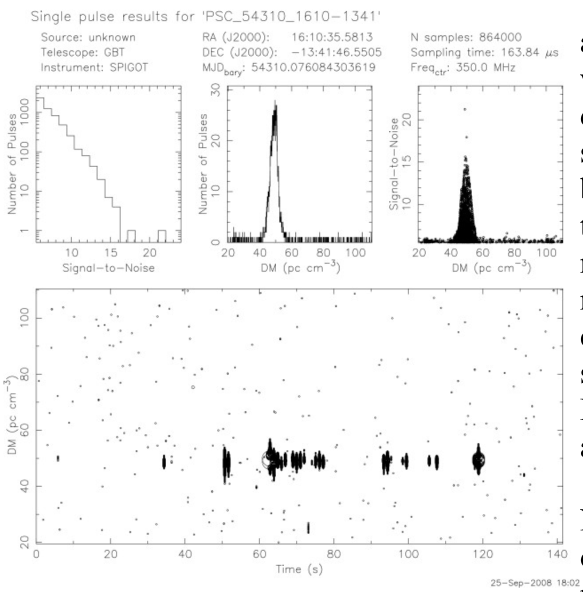
If we guess at DM of 45 or 65, since our guess is slighly off, only, say, 12 of the single pulses will be found. Therefore, if you look at the plot, at a DM or 45 and 65, the peak height is about 12. So, when we guess the correct DM, the all the single pulses will be found. Therefore, we expect a peak at the correct DM.

Signal to Noise Histogram: In the top, right hand box, there is also a peak at a DM of 50, and the peak height is 28, meaning that all at a guess DM of 50, all 28 pulses were very strong and had the highest signal-to-noise. For a guess of a DM of 45 or 65, the single pulse search didn't find as many pulses and they pulses were weaker. Therefore on this plot, the average signal-to-noise for a DM of 45 or 65 was only 15.



For comparison, for the same pulsar, the single pulse plot for dispersion measure ranges of 100-300 looks like the plot to the right. Since we do not guess the correct DM (even though there is a pulsar in the pointing), none of the single pulses will be found.

Dispersion Measure vs. Time



This is the bottom panel and it plots dispersion measure as a function of time. So, for the first few seconds we won't see anything because, remember, the pulsar has to drift into the beam of the telescope. Then, when it does, say at 50 seconds, we start seeing single pulses (not to be confused with a DM of 50). For the first pulse at a time of 50 seconds, we try a bunch of dispersion measures from about 20 to 110. The dispersion measures that fit the first pulse range from 40-55. You can see this by the vertical black line at time = 50 seconds on the x-axis. The vertical line ranges from a DM of 40-55. In fact, the vertical black line is not really a line at all, but a whole bunch of really small circles.

Now lets look at at time of 55 seconds. No guess values of dispersion measure fit any single pulses, so there are no circles at any dispersion measures.

Let's now look at a time of 62 seconds. Here our guesses of different dispersion measures find single pulses again. The vertical black "line" again ranges from about 45-55, meaning each trial dispersion measure from 45-55 found a single pulse. Notice, though that instead of a bunch of small circles, some of the circles are really big. The size of the circle is directly related to the signal to noise. So, at a time of 50 seconds, all the circles were small, meaning that all guesses of the dispersion measure from 40-55 resulted in single pulses with the same signal-to-noise. No one guess of dispersion measure was any better than another.

BUT, at a time of 62 seconds, there are some big cirlces at a DM of 50. This means, that while dispersion measures ranging form 45-55 all found single pulses, some guesses of the disperion measure resulted in finding strong single pulses with really strong signal to noise! In these cases, there is a large circle rather than a small one. In this case, some guesses of the dispersion measure *are* better than others!