Fantastic Pulses and Where to Find Them

Contents

Note: All locations mentioned in this document are on the machine called KAVERI at NCRA

Getting Started

The latest version of the code for the program to analyze individual pulses of pulsars is stored on the machine “kaveri” at NCRA at the following location :

```
/Data/ygupta/psr_micro_work/kishalay/dualFreqAnalysis/dualFreqView
```

and is named **`autocorr.c`**

The names of the folders are misleading, since the program works for both single and dual frequency analyses (and therefore should be changed). To run the C program, one must compile it first, using the script titled **‘`compile`’** (located in the same folder):

```
compile autocorr.c
```

(It is necessary to compile the program only after making changes, and not each time). Once the code is compiled, an executable file called ‘autocorr’ is generated. To run the program, use:

```
autocorr
```

You will now be asked if you want to analyze pulses at a single frequency, or at two frequencies. After your input, a list of pulsars will be displayed along with the input to run the analysis for any one of them. In single frequency analysis you will be asked if you want to analyze the lower frequency data or the higher frequency data (indicated by ‘lf’ and ‘hf’). The lower frequency band is centred at 325 MHz (GSB, bandwidth 32 MHz) and the higher frequency band is centred at 610 MHz (GWB, bandwidth 100 MHz).

After your input, the code will take some time to display the folded profile. The program reads the details of pulsars from text files (Parameters3.txt for single frequency analysis and Parameters2.txt for dual frequency analysis) as mentioned in the subsection Adding new pulsars to the list. You will be asked to enter pulse start and end phases by looking at the folded profile. This is used to define on- and off-pulse regions for baseline and noise statistics. A list of instructions is also displayed to tell you what the program can do. This is elaborated in the next section.

Basic Functionalities

How to analyze pulses (from given list of pulsars)

The basic commands to browse through the pulses are displayed in the list of instructions:

```
Use 'n' to go to next pulse
Use 'b' to go the earlier pulse
Use 'p <start phase> <end phase>' to set a phase range (Default is full period)
Use 's <phase shift>' to shift phase window (Phase shift should remain between 0 and 1 !)
Use 'f' to show folded profile
Use 'h' to hide folded profile
Use 'i <Integration>' to integrate profile
Use 'g <Pulse Number>' to get profile for a specified pulse number
```

The following features of the code can be used in order to obtain both qualitative and quantitative insights about the data:

```
Use 'a <Time lag>' to get autocorrelation plot for the current pulse, integration and phase range
Use 'c <MinSNR>' to get list of pulse numbers above a given threshold
Use 't <MinSNR>' to get list of pulse numbers with peak above a given SNR
Use 'v <Time lag(ms)> to get the average ACF for the strongest pulses
```

All of the aforementioned routines are common to both single and dual frequency analysis, with the following exceptions:

- ‘c <MinSNR>’ in case of single frequency analysis and ‘m <min SNR>’ in case of dual frequency analysis do the same thing, only the letter used is different

More specialised routines developed only for either single or dual frequency analysis are described in the following sections.

Note that:

- ‘a <lag>’ will plot the autocorrelation plot for current pulse, integration and phase range.
- ‘v <lag> will plot average autocorrelation function for the strongest pulses and save the data to a file titled ‘**`avgcorr.txt`**’. This routine is also used to get the reference width used in microstructure analysis.

Features unique to single frequency analysis

- ‘w’ will produce histograms of on-pulse and off-pulse energy (on- and off-pulse are defined by the user). These histograms are used to quantify the phenomenon of nulling pulses.
- ‘x’ will start a subroutine to display a grayscale plot of all pulses stacked vertically. This is used to observe nulling and drifting pulses in the data.
    - Entering the subroutine, you will be asked the phase range to use (phase start and end may or may not be the same as the ones entered in the beginning), and the number of horizontal bins to divide the phase range into.
    - Next, you will then be asked to enter the number of pulses to collapse or average over. To view all pulses, enter 1. To smoothen the plot by averaging adjacent pulses, enter 2, and so on.
    - Lastly, you will be asked the number of pulses you wish to examine (enter 0 to see all), and the plot will be generated.

Features unique to dual pulse analysis

```
Use ‘e <time lag (ms)>’ to produce average CCF up to a time lag
Use 'o <lag>' for cross-correlating the folded profile'
Use ‘w p’ to print the current pulse in a ps file
Use ‘w a’ to print the current pulse ACF in a ps file
Use ‘w f’ to print the folded profile in a ps file
Use ‘x’ to plot a ratio of the pulses at the two frequencies
Use ‘j’ to plot an average ratio of the pulses at the two frequencies
```

- e <time lag(ms)> - produces the cross-correlation function(ccf) of the current pulse from (-time lag(ms),+time lag(ms))
- o <lag> - produces the ccf of the folded profile from (-lag,+lag). Can be used to align the high and low frequency data.
- ACF - auto-correlation function
- x - plots the ratio of the intensities of the pulses at the two frequencies and so does j (but j plots the average over all pulses)

Microstructure analysis

At single frequency

```
Use 'd <smoothing(ms)> <lag(ms)> <SGorder>' to obtain autocorrelation of residuals of current pulse
Use 's <smoothing(ms)> <lag(ms)> <SGorder>' to obtain power spectrum of residuals of current pulse
Use 'y <smoothing(ms)> <RMS deviation cutoff> <SGorder>' to find quasiperiods and widths of microstructures

Note: 'v <lag>' needs to run before 'y' or 's' to calculate the width used by the latter.
```

- ‘d <smoothing> <lag> <SGorder>’: Calculates the residual of the current pulse and its autocorrelation. The pulses are smoothed and the smoothed version is subtracted from the original pulse to get the residuals. These residuals show structure which is indicative of micropulses.
- ‘s <smoothing> <lag> <SGorder>’: Calculates the power spectrum of the residuals of the current pulse. Residuals are computed in the same way as above.
- ‘y <smoothing> <RMS cutoff> <SGorder>’: Runs an automated microstructure analysis routine that computes the quasi-periods and width of the micropulses.

  Note that ‘v <lag>’ needs to be run before ‘s’ or ‘y’ to calculate the reference widths used by these routines.

At two frequencies

```
SUBTRACTION FEATURE:

Use 'd <smoothing (ms)> <microCuttOff(SNR)> <SG order>’ to run Analysis of Current Pulse, that smoothes the pulse, subtr
acts the smoothed version, and then computes widths from the subtracted ACF smoothed with a Savitzky Golay filter and co
mputes periods from the power spectrum of the subtracted features
Use ’s <smoothing (ms)>’ to view power spectrum of subtracted pulse

 Automated Analysis:
This command can only be used if we know the Avereage Widths, which can be calculted using 'v <Time lag(ms)>
Use ‘c <smoothing (ms)> <microCuttOff>’ to run an automated microstructure analysis routine, that smoothes the pulse, su
btracts the smoothed version, and then computes widths from the subtracted ACF and computes periods from the power spect
rum of the subtracted features
Use ‘y <smoothing (ms)> <microCuttOff> <SG order>’ to run an automated microstructure analysis routine, that smoothes th
e pulse, subtracts the smoothed version, and then computes widths from the subtracted ACF smoothed with a Savitzky Golay
 filter and computes periods from the power spectrum of the subtracted features
<microCutOff> is the minimum RMS above which microstructure will be identified
<SG order> is the order of the Savitzky Golay filter to be used for smoothing the ACF
```

[See the self-explanatory image above]

Advanced features

Reading pulses from file (FILE mode) (for pulsars in the list)

a. Once you have run the autocorr, one can run the “n<single space>k” command to get a hold over how you can read pulses from a loaded pulsar file.
b. There are basically two ways to enter into the FILE mode:
    i. At the beginning of the program, when asked, enter the file path.
    ii. In between the program enter "n<single space>s" and then give the appropriate file path.
c. Browsing in the file mode:
    i. Now "n" will take you to the next pulse in the file and "b" will take you up the list.
    ii. "n<single space>e" will allow you to exit the FILE mode and continue general browsing.
    iii. Once out of the FILE mode one can switch back to it in two ways:
        1. Enter "n<single space>e" to enter back at succeeding pulse from which you left.
        2. Enter "n<single space>s" , this gives two options again:
            a. "c" - Use this to jump to the top of the file you are in.
            b. "d" - Use this to switch to a new file.

Adding new pulsars to the list

To analyse a pulsar using the program, its details must be added to its parameters file. For single frequency analysis, the data/parameters of several pulsars are stored in the file:

```
/Data/ygupta/psr_micro_work/kishalay/dualFreqAnalysis/dualFreqView/Parameters3.txt
```

To add a new pulsar to this list, add its details to a new row in this file, in the following format:

```
<index>)<pulsar_name>   <resolution(ms)>   <period(ms)>   <DM(pc/cc)>   <filepath>
------------------
```

For dual frequency analysis, the data is stored in the file:

`/Data/ygupta/psr_micro_work/kishalay/dualFreqAnalysis/dualFreqView/Parameters2.txt`

To add a new pulsar to this list, add its details to a new row in this file, in the following format:

`<index> <pulsar_name> <offset(s)> <resolution1(ms)> <resolution2(ms)> <period(ms)> <DM(pc/cc)> <filepath1> <filepath2> <timestamp1> <timestamp2>`

After adding the pulsars to the file, the corresponding sections of the code (in the main() function) must also be changed to see the pulsars in the list displayed during analysis.

Analysis of polar mode data [is this part of document really complete -- it appears to be very brief]

The C program is stored at:

`/Data/ygupta/psr_micro_work/kishalay/new_codes/microStokes/viewStokes/normPulse`

And is titled `normPulseStokesFloat.c`

To run the C program, one must compile it first, using the script titled '**`compilePulsePolFloat`**' (located in the same folder):

```
compilePulsePolFloat normPulseStokesFloat.c
```

(It is necessary to compile the program only after making changes, and not each time). Once the code is compiled, an executable file called '**`normPulseStokesFloat`**' is generated. To run the program, use:

```
normPulseStokesFloat <stokesFile> <TimeResolution>
<FoldingPeriod> <numChans> <startChan> <endChan> <phaseShift>
[what is the meaning of these parameters -- can you add a basic explanation]
```

`[is there a list of pulsar's with polar data and the values of these parameters available, like the file Parameters2.txt is there for the total intensity data ?]`

The polar data for several pulsars is stored in the directory:

`/Data/ygupta/psr_micro_work/polar_data`

Channel calibration

The polar mode data must be calibrated in order to recover the linearly polarised part of the signal. The program offers an efficient way of doing this by looking at the plots. After running the program, the folded profile of the pulsar will be generated (white), along with circular (red) and linear (green) polarisation, the latter of which is close to zero before recovery. You will be asked to enter the phase range (the window that you want to be displayed) and the pulse range (the phase range where the pulse is present) and the pulse phase (peak of the folded profile). The bottom of the plot will now show a plot of Position Angle vs. Frequency channel, and you will be asked to enter the start, end and reference channel for calibration. Once you enter this, the PA vs Freq. plot will display a red line, which is supposed to be the approximation of the noisy white curve. You will be asked if you think this is a good approximation; if you think it is then you can move on, else you should try again. Once you are done you will notice that the linearly polarised part of the plot (in green) has been recovered.

Features and commands

The basic commands to browse through the pulses, show/hide folded profile, set the phase window, set the integration, find autocorrelation of the current pulse and find the average ACF remain the same as before.

Additional commands to save the plots (‘w’) are also provided by the program.

In order to look for microstructures, one can use the smoothing feature (the ‘u’ command), which will smooth the pulse and find the residuals.

```
WELCOME TO SINGLE PULSE STOKES VIEWER!

Instructions:
Use 'n' to go to next pulse
Use 'b' to go the earlier pulse
Use 'p <start phase> <end phase>' to set a phase range (Default is full period)
Use 'f' to show folded profile
Use 'h' to hide folded profile
Use 'i <Integration>' to integrate profile
Use 'g <Pulse Number>' to get profile for a specified pulse number
Use 'a <Time lag>' to get autocorrelation plot for the current pulse, integration and phase range
Use 'v <Time lag>' to get average autocorrelation for the current integration and phase range
Use 't <MinSNR>' to get list of pulse numbers with peak above a given SNR
Use 'u <smoothing (ms)> <time lag (ms)> to show pulse after subtraction from smoothing and its ACF up to a given time la
g
Use 'w <Option>' to output a plot to a file, where Option is 'p' for pulse window, 'f' for folded profile
Use 'k' to see these instructions
```