PsrPopPy Documentation

Release 1

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CHAPTER ONE

INTRODUCTION

1.1 What is PsrPopPy?

PsrPopPy is a Python (for the most part) implementation of Duncan Lorimer's PSRPOP code. All of the user-facing (in normal circumstances) code is written in Python, with some remaining FORTRAN functions (e.g. NE2001, coordinate conversion) for speed.

1.2 Why is PsrPopPy?

For the development of a research project, I was modifying the PSRPOP code, but found it somewhat tricky. I decided to re-write the code with much heavier reliance on functions and with added OO design. This makes modifying the code and addition of new features much more simple, with little speed loss since the difficult number crunching is still done in FORTRAN. The added bonus of re-writing the code is the detection of a number of bugs in the original code, which have hopefully been eliminated.

1.3 Who can contribute?

In short - anybody. The code is up on github and I'll be happy to accept suggestions for future modifications and improvements.

1.4 Acknowledgements

Many thanks to Duncan Lorimer for giving his blessing to this project and of course for generating the codebase which has inspired this project.

CHAPTER

TWO

INSTALLATION

To get started with PsrPopPy there are a few steps you'll need to go through.

PsrPopPy is currently supported on Linux and Mac OS X, and for full feature support, it is recommended to install the Matplotlib package and either use Python versions >2.6, or install the argparse module.

2.1 Download the package

The source for PsrPopPy can be downloaded from GitHub from the PsrPopPy page. The source will contain the Python modules and scripts needed both for basic and advanced use.

2.2 Compile the FORTRAN

Although PsrPopPy is a Python-based package, some of the algorithms have been kept in their native FORTRAN for speed and ease of programming (e.g. the NE2001 electron model, coordinate conversion...). Therefore, it is necessary to compile the FORTRAN.

Two scripts are provided for just this purpose (though I hope to find someone willing to contribute configure scripts). From the base directory:

```
> cd fortran
```

then edit either `make_mac.csh` or `make_linux.csh`, depending upon your system, so that the `gf` variable points to your local gfortran/f77 compiler. Running the script:

```
> tcsh make_<os>.csh
```

should then compile a series of `.so` files in the `fortran` directory. Assuming this went to plan, the installation process is completed.

CHAPTER

THREE

COMMAND-LINE SCRIPTS

3.1 populate.py

-n `<number of pulsars>`
Required: Number of pulsars to generate; or to detect in a survey

-o `<output>`
Output file name for population model (def=populate.model)

-surveys `<SURVEY NAME(S)>`
List of surveys to use when trying to detect pulsars (default=None)

-z `<scale height>`
Scale height of pulsars about Galactic plane, in kpc (default=0.33)

-w `<width>`
Pulse width to use when generating pulsars (default=0, use beaming model)

-si `<SImean SIsigma>`
Spectral index mean and standard deviation (default=-1.6, 0.35)

-sc `<scatter index>`
Spectral index of scattering law to use (default=-3.86, Bhat et al model)

-pdist `<distribution name>`
Distribution type for pulse periods (default=lnorm)

Supported: 'lnorm', 'norm', 'cc97'

-p `<mean stddev>`
Mean and standard deviation to use in period dist 'lnorm' or 'norm' (def=-2.7, 0.34)

-rdist `<radial model>`
Model to use for Galactic radial distribution of pulsars

Supported: 'lfl06', 'yk04', 'isotropic', 'slab', 'disk'

-dm `<Electron model>`
Model to describe the Galactic electron distribution

Supported: 'ne2001', 'lm98'

-gps `<fraction 'a'>`
Add <fraction> pulsars with GHz-frequency turnovers with index a

-doublespec `<fraction alpha1>`
Add <fraction> pulsars with low-frequency (below 1GHz) spectral index of alpha1

-nostdout
Turn off writing to stdout. Useful for many iterations eg. in large simulations

3.2 dosurvey.py

-f `<filename>`
Input population model to use (default=populate.model)

-surveys `<SURVEY NAME(S)>`
Required: Name(s) of surveys to simulate on the population model

-noresults
By default, a .results file is written, containing a model of the population detected in the survey. This option switches off the writing of this file.

-asc
Write the survey model in plain ascii (psrpop old style). Not recommended, since the cPickle '.results' file is easier to work with.

-summary
Write a short .summary file (per survey) describing number of detections, number of pulsars outside survey area, number smeared, and number not beaming

-nostdout
Turn off writing to stdout. Useful for many iterations eg. in large simulations

3.3 view.py

-f `<input model>`
Select the population model to view (default=populate.model)

-p `<param name>`
Select the population parameter to plot

Supported: 'period', 'dm', 'gl', 'gb', 'lum', 'alpha', 'r0', 'rho', 'width', 'spindex', 'scindex', 'dist'

-logx
Plot log10 of the values

3.4 visualize.py

-f `<model>`
Select a population model to plot (default = populate.model)

-frac `<F>`
Plot a fraction <F> of the population for speed gains

CHAPTER

FOUR

TUTORIAL - BASIC USAGE

This page will outline a very simple pipeline for basic population simulations with PsrPopPy.

4.1 Generate Population Model

Population models are generated using the `populate.py` script. A common use would be to generate a population of normal pulsars using the Parkes Multibeam Pulsar Survey as a basis. This survey detected 1038 pulsars (at last count). Using default radial distribution, period and luminosity models, we can generate such a population using the command:

```
python populate.py -n 1038 -surveys PMSURV
```

This will then run for a few minutes, until the model PMSURV survey has detected 1038 pulsars. The file `populate.model` will be produced by default, which is a pickled population object.

If, instead, you wanted to use the Lyne & Manchester (1998) electron distribution, and for whatever reason wanted to store the output in the file `pop_lm98.model`, then we could run:

```
python populate.py -n 1038 -surveys PMSURV -dm lm98 -o pop_lm98.model
```

A different output file will then be produced, where the population uses the new simulation parameters.

4.2 Simulate a Pulsar Survey

Once you've generated a pulsar population model, the `dosurvey.py` script can be used to run the model through a past, present or future, pulsar survey (as specified in files in the `survey` directory — see *_model-survey-files*).

For example, say we want to take the population model we just created, `pop_lm98.model`, and estimate from this how many pulsars would be detected in a putative LOFAR pulsar survey. This can be simply done using:

```
python dosurvey.py -f pop_lm98.model -surveys LOFAR
```

Which will print out the results of the survey, and write a results file called `LOFAR.results`, which again is in the Pickle format. To write an ascii summary file, and an ascii file containing the parameters of all detected pulsars, simply add some extra flags:

```
python dosurvey.py -f pop_lm98.model -surveys LOFAR --asc --summary
```

Note that multiple model surveys may be run at once. To do so, just list as many as required after the `-surveys` flag. The results file can also be turned off:

```
python dosurvey.py -f pop_lm98.model -surveys LOFAR GMRT GBNCC --noresults
```

4.3 Visualising a Pulsar Model

There are two ways to visualise the populations generated by either `populate.py` (`.model`) or `dosurvey.py` (`.results`). To plot basic histograms of various parameters, use the `view.py` script:

```
python view.py -f <model> -p <parameter>
```

Here <parameter> could be `period`, `dm`, or several other options, as outlined in *_view_docs*. Assuming the Matplotlib package is installed, this will generate a histogram which can then be saved or printed as necessary.

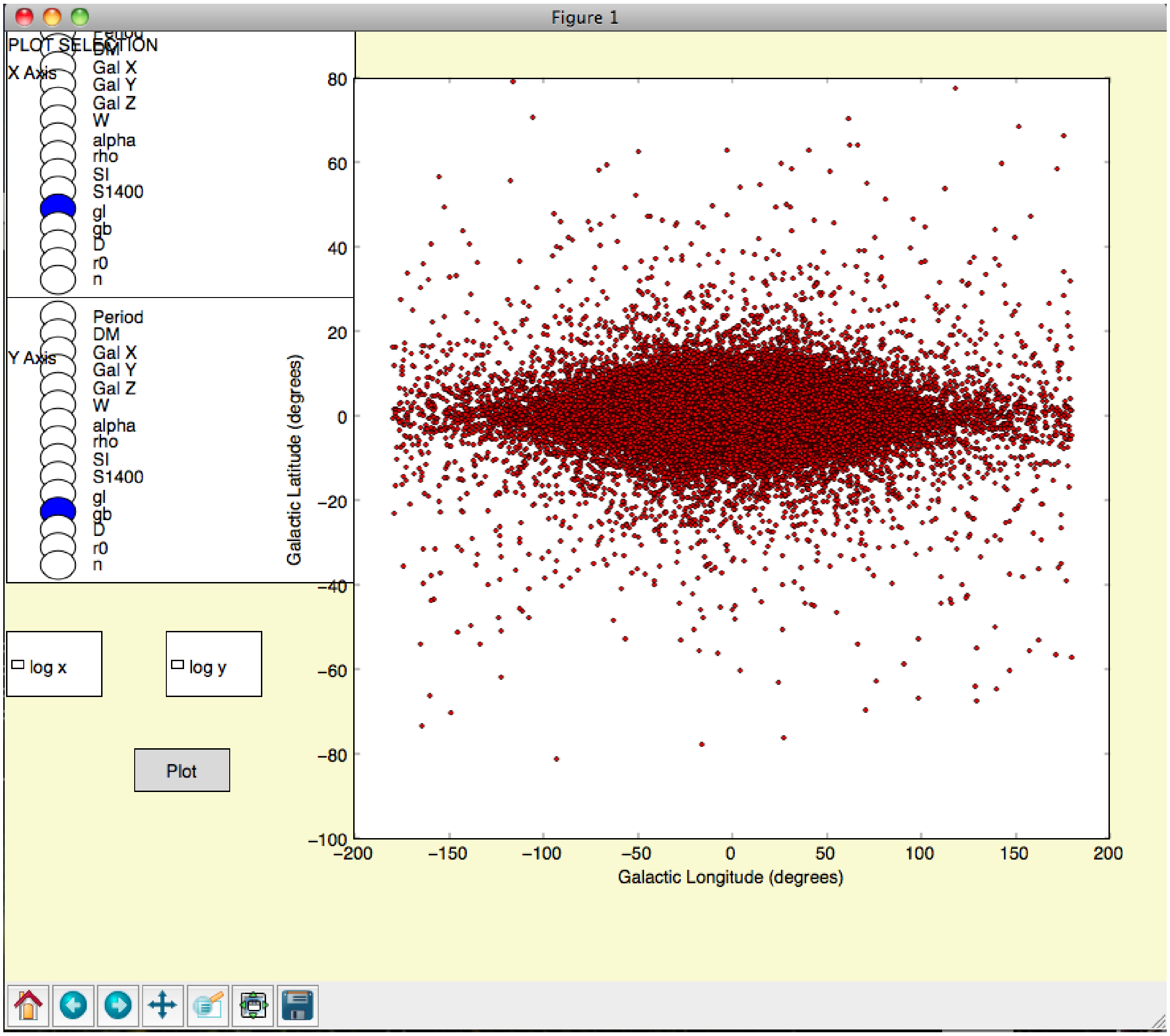
To create a histogram of the logarithm of the selected parameter, use:

```
python view.py -f <model> -p <parameter> --logx
```

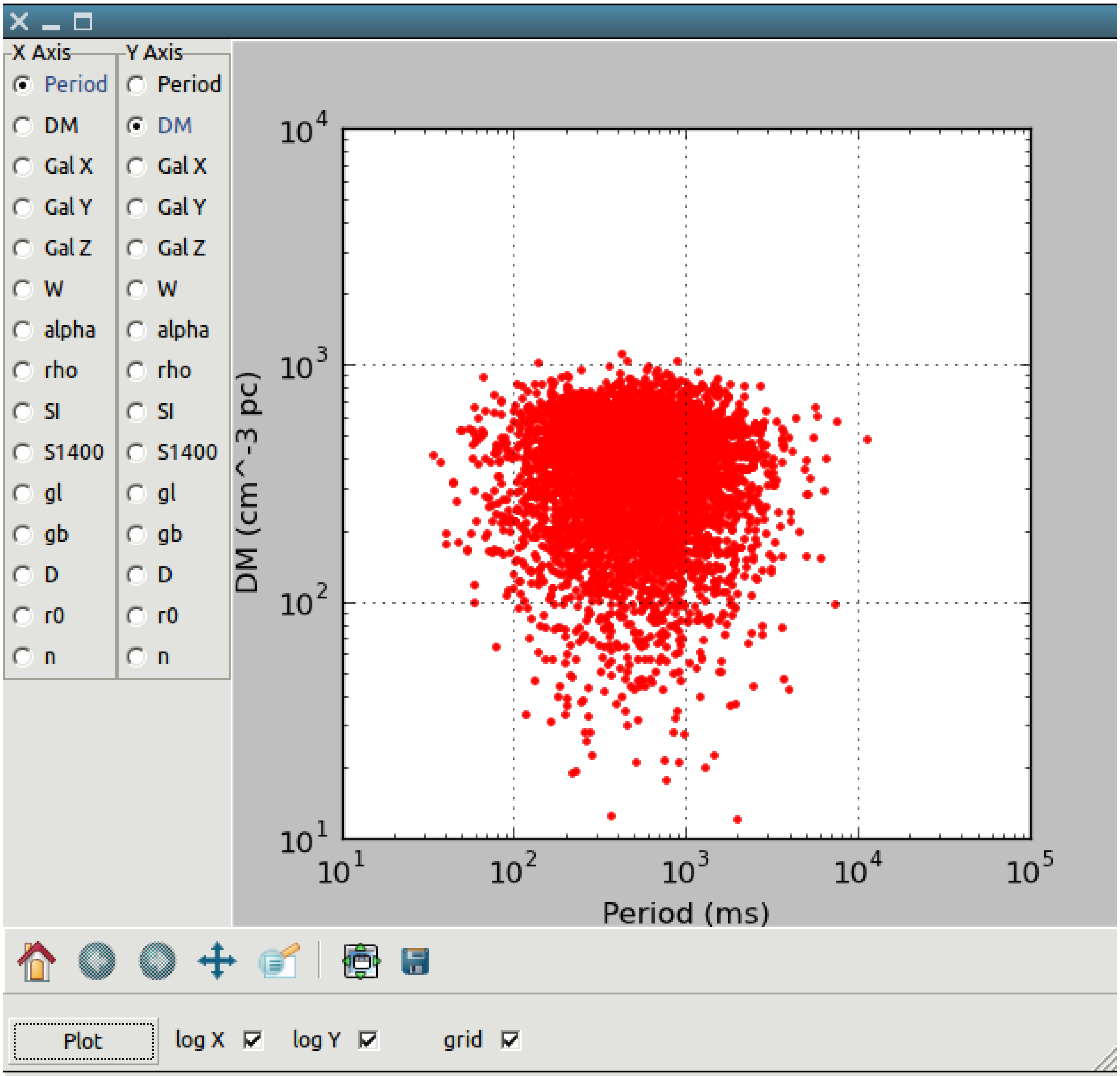
For more detailed information, sometimes it may be useful to plot two parameters against one another. For this, use `visualize.py`:

```
python visualize.py -f <model>
```

This will open a window with some radio buttons on the left-hand-side. Select a parameter for the x-axis, one for the y-axis, and select whether you want to plot the logarithms of these parameters (see screenshot below).



If you have the wxPython plugin working (seems on newer macs this is a non-trivial piece of software to install!) then I recommend using `wxView.py` in place of `visualize.py`. This code is a bit more robust, faster, and more pleasing to the eye (see another screenshot below).


X Axis
Period
DM
Gal X
Gal Y
Gal Z
W
alpha
rho
SI
S1400
gl
gb
D
r0
n
Y Axis
Period
DM
Gal X
Gal Y
Gal Z
W
alpha
rho
SI
S1400
gl
gb
D
r0
n
10^4
10^3
10^2
10^1
DM (cm^-3 pc)
10^1
10^2
10^3
10^4
10^5
Period (ms)
Plot
log X
log Y
grid

CHAPTER

FIVE

MODULE-LEVEL DOCUMENTATION

5.1 `pulsar` – Creates/stores a pulsar object

class `pulsar.`**`Pulsar`**

`Pulsar.`**`__init__`**`(`[*period*, *dm*, *gl*, *gb*, *galCoords*, *r0*, *dtrue*, *lum_1400*, *spindex*, *alpha*, *rho*, *width_degree*, *snr*, *beaming*, *scindex*, *gpsFlag*, *gpsA*, *brokenFlag*, *brokenSI*]`)`

Initialise the pulsar object

`Pulsar.`**`s_1400`**`()`

Returns the flux at 1400 MHz, calculated as

$S_{1400} = \frac{L_{1400}}{D^2_{\rm true}}$

`Pulsar.`**`width_ms`**`()`

Returns the pulse width in milliseconds, calculated as

$W_{\rm ms} = P_{\rm ms} \times W_{\rm degree}/360$

5.2 `population` – Creates/stores a population

class `population.`**`Population`**

`Population.`**`__init__`**`(`[*pDistType*, *radialDistType*, *lumDistType*, *pmean*, *psigma*, *simean*, *sisigma*, *lummean*, *lumsigma*, *zscale*, *electronModel*, *gpsFrac*, *gpsA*, *brokenFrac*, *brokenSI*, *ref_freq*]`)`

Initialise the population object

`Population.`**`__str__`**`()`

Defines how the operation `print Population` is performed

`Population.`**`size`**`()`

Returns the number of pulsars in the population object

`Population.`**`join`**`(`*poplist*`)`

Joins each of the populations in list `poplist` to the current population

`Population.`**`write`**`(`*outf*`)`

Uses cPickle to dump the population to file `outf`

`Population.`**`write_asc`**`(`*outf*`)`

Writes the population to an ascii file in the old psrpop way

5.3 `survey` – Read a survey file into a survey object

class `survey.`**`Survey`**

`Survey.`**`__init__`**`(`*surveyName*`)`
Read in a (correctly formatted!) survey file

`Survey.`**`__str__`**`()`
Define how to perform `print Survey`

`Survey.`**`nchans`**`()`
Returns the number of channels, calculated as

$n_{\text{chans}} = \frac{\text{BW}_{\text{total}}}{\text{BM}_{\text{chan}}}$

`Survey.`**`inRegion`**`(`*pulsar*`)`
Determines if `Pulsar` is inside survey region. Returns True or False accordingly

`Survey.`**`inPointing`**`(`*pulsar*`)`
Determines if `Pulsar` is inside one of the survey's `pointings`. Returns the offset from beam centre to the pulsar.

`Survey.`**`SNRcalc`**`(`*pulsar*, *pop*`)`
Calculates the SNR of a `Pulsar` from `Population pop` in the survey. Returns -1 if pulse is smeared, and -2 if pulsar is outside survey region. SNR is calculated (with familiar terms) as

$\text{SNR} = \frac{S_{1400} G \sqrt{n_{\text{pol}} BW \tau}}{\beta T_{\text{tot}}} \sqrt{\frac{1-\delta}{\delta}} \eta$

where

$\eta = \exp(-2.7727 \times \text{offset}^2/\text{fwhm}^2)$

class `survey.`**`Pointing`**

`Pointing.`**`__init__`**`(`*coord1*, *coord2*, *coordtype*`)`
Converts (coord1, coord2) into correctly formatted (l, b). Coordtype must be either `eq` or `gal`. If `eq`, the RA and Dec are converted internally

5.4 `populate` – Create a population object

class `populate.`**`Populate`**

`Populate.`**`generate`**`(`*ngen*[, *surveyList*, *pDistType*, *radialDistType*, *electronModel*, *pDistPars*, *siDistPars*, *lumDistType*, *lumDistPars*, *zscale*, *duty*, *scindex*, *gpsArgs*, *doubleSpec*, *nostdout*]`)`
The method called by the `populate.py` command-line-script

`Populate.`**`write`**`(`*outf=populate.model*`)`
Writes the `Population` model into file outf as a cPickle dump

5.5 `radialmodels` – Container for radial distn models

class `radialmodels.`**`RadialModels`**

`radialmodels.`**`seed`**`()`
Call the FORTRAN routine to make a seed

`radialmodels.`**`slabdist`**`()`
Pick a point from a "slab" distribution around the Galactic plane

`radialmodels.`**`diskdist`**`()`

Pick a point from a distribution purely along the Galactic plane

`radialmodels.`**`lfl06`**`()`

Pick a point from the Lorimer et al (2006) Galactic distribution

`radialmodels.`**`ykr`**`()`

Pick a point from the Yusifov & Kucuk Galactic distribution

5.6 `galacticops` – Container for functions relating to the Galaxy

class `radialmodels.`**`GalacticOps`**

`radialmodels.`**`calc_dtrue`**`(`*(x, y, z)*`)`

Calculate the distance from the Sun to Galactic coords (x, y, z) (NB. tuple)

`radialmodels.`**`calcXY`**`(`*r0*`)`

Given a Galactic radius r0, choose an (x, y) position at random θ

`radialmodels.`**`ne2001_dist_to_dm`**`(`*dist, gl, gb*`)`

Given a distance and Galactic coordinates, calculate DM according to NE2001

`radialmodels.`**`lm98_dist_to_dm`**`(`*dist, gl, gb*`)`

Given a distance and Galactic coordinates, calculate DM according to lm98

`radialmodels.`**`lb_to_radec`**`(`*gl, gb*`)`

Convert Galactic coordinates to equatorial

`radialmodels.`**`ra_dec_to_lb`**`(`*ra, dec*`)`

Convert equatorial coordinates to Galactic

`radialmodels.`**`tsky`**`(`*gl, gb, freq*`)`

Calculate sky temperature at observing frequency freq and at Galactic coordinates gl, gb according to Haslam et al

`radialmodels.`**`xyz_to_lb`**`(`*(x, y, z)*`)`

Convert the tuple (x, y, z) to Galactic sky coordinates.

Returns l, b in degrees

`radialmodels.`**`lb_to_xyz`**`(`*l, b, dist*`)`

Convert Galactic sky coordinates at a distance dist to x,y,z coordinates.

Returns position as a tuple

`radialmodels.`**`scatter_bhat`**`(`*dm, scatterindex, freq_mhz*`)`

Calculate the scatter time according to Bhat et al at. Frequency in MHz, pulsar with dispersion measure dm, and using a scattering spectral index of scatterindex.

Calculated as

$\tau = -6.46 + 0.154\log_{10}(\mathrm{dm}) + 1.07\log_{10}(\mathrm{dm})^2 + \mathrm{scatterindex} \times \log_{10}(\frac{\mathrm{freq\_mhz}}{1000})$

and typically $\mathrm{scatterindex} = -3.86$ (but there is an option to vary it!)

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SIX

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