Introduction to \textit{GNUPLOT}

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7\textsuperscript{th} \& 8\textsuperscript{th} of November 2013
katharina@fierli:~$ gnuplot

GNUPLOT
Version 4.4 patchlevel 3
last modified March 2011
System: Linux 3.2.0-24-generic

Thomas Williams, Colin Kelley and many others

gnuplot home: http://www.gnuplot.info
faq, bugs, etc: type ”help seeking-assistance”
immediate help: type ”help”
plot window: hit ’h’

Terminal type set to ’wxt’
gnuplot>
GNUPLOT is a freely distributed command-line based interactive plotting program

- **installing GNUPLOT**
  - Windows: get .exe from sourceforge.net/projects/gnuplot/files
  - Mac: get .tar.gz from sourceforge.net/projects/gnuplot/files
  - open shell, go to download directory, type “configure”, “make”, “sudo make install”
  - Linux: use package management system

- **starting GNUPLOT**
  - Windows: GUI
  - Linux, Mac: open shell, type “gnuplot”

- **closing GNUPLOT**
  - Windows: GUI
  - Linux, Mac: type “exit” or “quit”
Assignment 0

- Go to a command line.
- Start gnuplot by typing `gnuplot`.
- Check which gnuplot version you have. The loop syntax changed between the versions 4.4 and 4.6.
- Check which terminals you have installed by typing `set terminal`. You want (at least) wxt, png, latex and tikz. If you don’t have them, install the missing packages.
- You can check your current terminal with `show terminal`.
- If you type `test`, gnuplot will show you the line types and point types available for your current terminal type.
- Check if you have ImageMagick installed by typing `!convert`.

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**GNUPLOT syntax basics**

- **GNUPLOT** can display the manuals for its commands
e.g. type `help plot` to get information on the `plot` command
- commands can be shortened
e.g. `rep` instead of `replot` or `p` instead of `plot`
- `reset` restores the defaults
- If you want to use more than one **GNUPLOT** command in one line, you have to separate the commands by `;`
- **GNUPLOT** comments start with `#`
- shell commands (e.g. `vi`) in **GNUPLOT** start with `!`
- file names have to be enclosed in single or double quotes
Simple example

To plot a sine curve open GNUPLOT and type:

- \( f(x) = \sin(x) \) # define a function
- plot \( f(x) \) # plot this function
- repplot \( f(2 \times x) \) # plot another function

GNUPLOT will open a window with your plot. The curves will not look smooth.
Fix this by increasing the sampling rate:

- set samples 200 # sampling rate
- set ytics 0.5; set mytics 5
- rep # update plot

Now let's set the x-range and x-tick-labels

- set xrange \([-\pi:\pi]\) # x range
- set xtics \(-\pi\) -\(\pi\), \(-\pi/2\) -\(\pi/2\), 0, \(\pi/2\) \(\pi/2\), \(\pi\) pi)
For your scientific work you will prefer scripts. Store the commands in a text file.

**myscript.gnuplot**

```plaintext
set term wxt
set ytics 0.5
set mytics 5
set xrange [-pi:pi]
set xtics ("−pi", "−pi/2", "−pi/2,0", "pi/2", "pi")
set samples 200
set key at −pi/8, 0.8 invert samplen 2
f(x) = sin(x)
plot f(x) t "sin(x)", f(2*x) t "sin(2x)"
pause −1 "hit ENTER to exit script"
```

# select display type
# define distance of labeled tick marks on the y-axis
# number of small tick marks on the y-axis
# set x range of the plot
# custom labels
# increase sampling rate
# place and format
# key of symbols
# define a function
# plot two functions
# don’t close gnuplot

load this script in GNUPLOT by typing either

- gnuplot myscript.gnuplot on the command-line
- load 'myscript.gnuplot' in GNUPLOT
Tabulating a function

To tabulate the function \( f(x) \) and to store the result in a file called tablefile.txt use

- `set table "tablefile.txt"
- `plot f(x)`
- `unset table`

**Assignment 1**

- Define a function.
- Choose a number of points.
- Write the tabulated function to a file.
- Plot this file. Use `plot` followed by the file name in quotes. For plot styles see next page. Try scatter plots and line plots.
- If you type `test`, gnuplot will show you the line types and point types available for your chosen terminal type.
GNUPLOT can also read data from files

- **scatter plot:**
  plot 'data.txt' using 1:2
  plot 'data.txt' using 1:2 with points

- **example for the short format:**
  p 'data.txt' u 1:2 w p pt 1 lt 2 lw 2
  notitle

- **line plot:**
  plot 'data.txt' using 1:2 with lines

- **multiple data series:**
  use replot or separate by commas
  plot 'data.txt' using 1:2, 'data.csv'
  using 1:3

- **set key:**
  plot 'data.txt' using 1:2 title "key"

---

1 2.1 3.2
2 2.2 4.3
3 2.1 3.6
4 2.1 4.8
5 2.0 3.2
6 2.2 4.5
7 2.2 2.5
8 2.0 6.3
9 2.1 1.1

data.txt

produced via
F ORTRAN IO
or C++ IO
If you want to draw a circle you can use:

- \texttt{set parametric}
- \texttt{set trange [-pi:pi]}
- \texttt{plot \sin(t),\cos(t)}
- \texttt{unset parametric}

In the parametric mode, the variable is “t” (instead of x).

**Assignment 2**

- Define two functions to plot an ellipse in parametric mode.
  You can use \texttt{a=1} if you want to define a variable \texttt{a} with a value \texttt{1}. You can use such variables in your functions.
- Choose a number of points.
- Write the tabulated function to a file and plot this file.
- Use the commands from the next two pages. Try different line widths. For presentations you sometimes need thicker lines to make sure that the projector will display the lines. Add labels.
Labels, arrows, key

- place or hide key
  `set key top center, set nokey`

- set a title
  `set title "the title"`

- define axis labels
  `set xlabel "x [pc]", set ylabel "y [pc]"`

- change the number format
  `set format x "%.10.3f"`

- plot an arrow
  `set arrow from 0.5,0 to 0.5,1`

- define a label
  `set label "rarefaction wave" at 0.5,0`

- set border style
  `set border lw 3`
Other useful commands

- do math on columns
  $0 \ldots$ running index, $1 \ldots$ first column, $2 \ldots$ second column
  plot './data.txt' u ($0*10):(2*10**($1)) w lp

- blank lines in data files
  if blocks of data are separated by blank lines the `index` command can be used to plot individual blocks

- color, width and shape of lines/points
  linetype / lt, pointtype / pt,
  linewidth / lw, pointsize / ps

- logscale
  [un]set logscale [xy],

- select zoom
  set xrange [0:10] \ldots manually selected range of x-axis,
  set yrange [*:*] \ldots select zoom of y-axis automatically,
  set autoscale \ldots select zoom of any axis automatically
If you want to draw a rosette shaped curve you can use:

- `set polar`
- `set size square`
- \( f(t) = a \sin (b \cdot t) \)
- \( a = 2 \)
- \( b = 2 \)
- `plot f(t)`
- `unset polar`

In the parametric mode, the variable is “t” (instead of x).

**Assignment 3**

- Draw some rosette shaped curves.
Sometimes you want to use several panels in a plot.

**Assignment 4**

- Open the file `2013_data/stars_3r.214.dat` in an editor and find out what is tabulated in the columns.
- Use the examples on the next pages and combine four plots. e.g. (1) x+z position (2) y+z position (3) x,age (4) y,age
- Label your plots.
- Now try a different number of panels e.g. 3 rows, 1 column.
• stack several \texttt{plot} commands
  
  \texttt{set multiplot}

• scale the plot
  
  \texttt{set size}

• place the plot
  
  \texttt{set origin}

• leave multiplot mode
  
  \texttt{unset multiplot}

\texttt{set multiplot}
\texttt{set origin 0,0}
\texttt{set size 0.5,0.5}
\texttt{plot x**x**x t ”x^3”}
\texttt{set origin 0,0.5}
\texttt{plot x t ”x”}
\texttt{set origin 0.5,0.5}
\texttt{plot x**x t ”x^2”}
\texttt{set origin 0.5,0}
\texttt{plot x**x*x**x t ”x^4”}
\texttt{unset multiplot}
Multiple graphs - y1 and y2 axis

set ytics nomirror
set y2tics 0, 10
set key top center
plot x axis x1y1, x*x axis x1y2
Fitting data

Gnuplot can also fit your data with functions.

Assignment 5

- Use your ellipse from assignment 2. You can add scatter with awk and the rand() function. e.g.

```
awk '{ if ($3=="i") {$1=$1+(rand()-0.5)*0.01; $2=$2+(rand()-0.5)*0.1; print $0}}' ellipse.txt > ellipse.scatter
```

- Note: if you use German language settings in your shell, you might need to say LANG=C or LANG=en_US.UTF-8 on the shell to avoid conflicts with decimal points or commas.

- Plot it.
- Try to fit it.
- Also plot the fit.
- A possible solution can be found in ellipse.solution
- Now try to tilt your ellipse by 45 degrees and try to fit it again.
awk

awk commands can have three blocks:

```
awk 'BEGIN{ i=0}{ i++} END{ print "number of lines: ", i}'
```

2013_data/gas_3r.214.dat

- The “BEGIN” block contains commands that should be executed directly after awk starts. Typically initializations.
- The main part loops over all lines in the input file.
- The “END” block is read directly before awk exits.

All blocks are enclosed in curly brackets and commands in a block are separated by ;. You can also use loops in awk:

```
awk 'BEGIN{ srand(); i=0; j=0; k=0; }
    { while (j<10) {
        while (k<10) {
            T=rand()*1e4; print j, k, T; k=k+1;
        }
        k=0; print " "; j=j+1;
    }' 1 line
```
Fitting data

define a power law
\[ f(x) = a \times x^b + c \]

fit your data - you might need to set initial values for \( a, b, c \)

```bash
fit [1.5:*] f(x) ’data.txt’ using 1:2 via a,b,c
```

clip the fit to the fitted area

\[ f_{\text{cut}}(x) = x < 1.5 \ ? \ 1/0 : \ f(x) \]

display the fit

```bash
rep f_{\text{cut}}(x) t sprintf("[1.5:4] %g x^\{%g\} + %g", a,b,c)
```

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![Graph showing fitting results](image-url)
plot 'data.txt' u 0:1:2:3 w yerrorbars

uses

• column 1 as y values,
• column 2 as lower end of the vertical error bar and
• column 3 as the upper end of the vertical error bar.

horizontal error bars are created with xerrorbars
set term latex, tikz, eps, png ...

Example:
set terminal png
set output "plot.png"
set multiplot
...
unset multiplot
set term wxt

You can customize the terminal:
set terminal png nocrop enhanced font FreeSansBold 18
size 800,600
Assignment 6

The file `gas_3r.214.dat` contains the (x,y,z) coordinates of a point and the temperature. Use the example on the next two pages and plot color coded temperatures at the xy position of the point. The example uses a scale running from red to blue, but feel free to test other palettes.

```awk
# awk 'BEGIN { srand (); ind=10;}
# { while (ind > 0) {
#   x=rand()*10; y=rand()*10.;
#   z=rand()*10; T=rand()*1e4;
#   print x, y, z, T; ind=ind-1}}'
# x y z T
0.59582 3.94872 6.1967 7998.84
6.5519 7.6995 5.57703 3189.28
2.18446 4.24577 8.66912 1837.28
9.1135 0.627003 8.04655 8363.9
1.98704 6.17223 6.72384 7623.37
6.02263 2.42297 2.81232 6649.25
3.89771 8.89551 6.84724 1554.17
0.970098 4.41485 4.21257 690.311
2.06219 9.2371 7.89356 7030.08
4.48321 9.24652 6.26523 9672.72
9.96331 3.41045 9.51404 10.3592
1.4666 9.07461 7.048 203.987
3.69213 3.68113 8.76336 195.501
8.30955 8.55802 4.67305 9369.63
1.84836 5.38461 9.17682 78.5009
7.89623 1.98271 3.33848 8015.49
3.37396 6.16493 3.95816 85.7048
0.041832 3.0696 0.683514 1341.57
4.52064 8.32836 4.73786 4954.87
6.02226 6.12297 8.839 650.453
```

data file with x[pc] y[pc] z[pc] T [K]
set title "\( \log(T) \) [K]"
# data x y z T
set palette defined ( 1 "blue", 2 "yellow", 3 "orange", 4 "red" )
set cbrange [1:4] # 10 to 1e4 Kelvin
#2d
set xlabel "x [pc]"
set ylabel "y [pc]"
plot 'xyzT.txt' u 1:2:(log($4)/log(10.)) with points palette pt 7 notitle
pause -1 # press ENTER to proceed to 3d
#3d:
set ticslevel 0 # zero-point of z axis
set zlabel "z [pc]"
splot 'xyzT.txt' u 1:2:3:(log($4)/log(10.)) with points palette pt 7 notitle
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3d plots

- Use `splot` to produce a plot with the positions of the stars or the gas data in the 2013_data folder. Click on the plot and change the viewing angle.
- Use `awk` and plot only a certain temperature range. An example is on the page after the next page.
3d, splot

log (T) [K]
3d, splot and awk

```bash
rep "<awk -v Tmax=1000 \\
    '{if ($4 < Tmax) print $1, $2, $3, $4}' xyzT.txt " u 1:2:3 lt 1 t "star formation"
"

rep "<awk -v MAXcoldfraction=0.6; rhoSFR=1; Tmax=1000 \\
    '{if (NF==6) {if (($5 > MAXcoldfraction) || (($6 > rhoSFR) && ($4 < Tmax))) print $1, $2, $3, $4} else if ($4 < Tmax) print $1, $2, $3, $4}'} xyzT.txt " u 1:2:3 lt 1 t "star formation"
"
```

![Graph showing star formation](chart.png)

```
log (T) [K]
```

```
star formation
```

```
x [pc]
```

```
y [pc]
```

```
z [pc]
```

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Typical grid code data

A file contains the (x,y) coordinates of a cell and a temperature.
The data is arranged in blocks
The temperature will be plotted color coded on a scale running from red to blue.

```
# x y T
#awk 'BEGIN{ srand(); i=0; j=0; k=0;}
# { while (j < 10) {
#   while (k < 10) {
#     T=rand()*1e4;
#     print j, k, T; k=k+1;}
#   k=0; print " "; j=j+1; }
#}
0 0 2539.97
0 1 9259.75
0 2 8698.62
0 3 7780.29
0 4 3295.49
0 5 7360.98
0 6 5922.8
0 7 4545.35
0 8 3687.71
0 9 9291.88
1 0 8663.94
1 1 4920.67
1 2 1738.12
1 3 2604.78
1 4 8554.96
1 5 3204.42
1 6 6657.76
1 7 7011.96
1 8 9935.54
1 9 6665.75
```

data file with x[pc] y[pc] T [K]
Grid code data: color maps with pm3d

```plaintext
set title "log\(_e\)(T)\([\text{K}]\)"
# 2d data x y T
set palette defined (1 "blue", 2 "yellow", 3 "orange", 4 "red")
set cbrange [1:4] # 10 to 1e4 Kelvin
set xlabel "x\([\text{pc}]\)"
set ylabel "y\([\text{pc}]\)"
set size square
set view 0,0
set pm3d at b corners2color c1 clip4in map
unset surface
set term tikz
set output "Txy.tikz"
splot 'gridxyzT.txt' u ($1):($2):($3)/log(10.) notitle
set output "TxyCLIP.tikz"
```

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Grid code data: color maps with pm3d
zrange [1.e3:1.e4]
Movies

- produce png images for all snapshots
- combine with libmagick
  ```shell
  !convert -delay 20 -loop 1 frame_?????.png movie.gif
  (inside GNUPlot, otherwise no exclamation mark)```

Introduction to GNUPlot
Assignment 9: Make a movie from your 3d positions.

- If you use gnuplot 4.6 you can use a do loop:
  To rotate the view, try e.g.
  do for [t=0:18]{set view t*5,30,1,1;rep;pause -1}.
  If you want to store the snapshots use:
  do for [t=0:18]{outfile=sprintf('view%03.0f.png',t);
    set view t*5,30,1,1;set output outfile; rep}

- In earlier versions you have to place your code in two files and
  to use “reread”:
  File 1: t=0; tmax=18;load "file2.gnuplot"
  File 2: t=t+1;outfile = sprintf(’view%03.0f.png’,t);
    set view t*5,30,1,1;set output outfile; plot
    data.txt; if(t<tmax) reread;
Loops in Gnuplot 4.6

Gnuplot 4.6 can handle loops:

```plaintext
# simple loop example – (slowly) rotates a 3d plot
set term x11 # package gnuplot – x11 has to be installed
splot sin(x)*sin(y) # any 3d plot
# set term png # for movies: store as png
do for [t=0:45] {
  # Gnuplot 4.6 or higher
  # t: loop variable, running from 0 to 45. step size: 1
  # outfile = sprintf('franz%03.0f.png', t) # numbered
  output files franz001.png, franz002.png ...
  # set output outfile # use these filenames
  set view 60, 2*t, 1, 1 # define viewing angle
  pause 0.2; # slow down rotation in x11
  rep # update plot
}
# libmagick can convert these files into an animated gif: "convert –delay 20 –loop 1 franz???_.png movie .gif"
```
Optimizing plots

1. Focus on the purpose of the figure. What do you want to show?

2. Keep it simple and efficient. Which variable is independent (plot on x axis) or dependent (y axis)? Choose good units for the axes. Scale the axes to make good use of the figure’s area.

3. Explain what you plot: label the axes, find a good title, add a key to symbols and write a clear and complete caption [not just re-stating what’s on the axes]. The plot should be self explanatory – the intended audience should understand it even without reading the text of your paper.

4. Show you figure to a colleague – optimally somebody not directly working with you – to check if it is clear. Try to make your plot as simple as possible.
Checklist for good plots

- enough information in well chosen title / caption?
- content of labels (e.g. units)?
- content of key of symbols?
- too much information for a single graph?
- plot type suited for purpose?
  scatter vs. line graph; error bars; fits
- is x the independent variable and y the dependent variable?
- large enough font size of labels?
- sufficient line width?
  (e.g. a few pixels for presentations with data projectors)
- optimized number of tick marks, minor tick marks?
- plot looks ”empty”? zoom ... make good use of the plot area
- plot format (eps, png, tikz) suited for the purpose?
• **GNUPlot** homepage [www.gnuplot.info](http://www.gnuplot.info)
• Introduction to **GNUPlot** and Not so FAQ and Solutions [http://t16web.lanl.gov/Kawano/gnuplot/index-e.html](http://t16web.lanl.gov/Kawano/gnuplot/index-e.html)
• Download e.g. Windows version [http://sourceforge.net/projects/gnuplot/files/gnuplot/4.6.0/](http://sourceforge.net/projects/gnuplot/files/gnuplot/4.6.0/)
test shows linetypes