Astrophysics Lab Work – Computational Basics

This exercise will help you to become acquainted with some basic features of `Linux` and `gnuplot`, in order to be able to solve the problems involving computational aspects in the various parts of your lab work.

The exercises can be performed either

i) **recommended**: on your own computer, by connecting with the `numprakt` accounts of some of the instute's machines (`ltsp04 ... ltsp17`) via `tigervnc` with active `eduVPN` tunnel.
NOTE: if your machine is "busy" (other users already logged in), try another machine. Try to work always on the same machine. If this is not possible, copy (via scp) your working directory (see Exercise 1) from your former machine to the currently used one.

ii) on your own computer, if you have LINUX installed (either directly, or as a virtual system), and a working internet connection. To connect to our numprakt-machines, the `eduVPN` tunnel must be active.

iii) on your own computer under any operation system, when you have an X-server running and can connect to the hosts according to i) via `ssh`. To connect to our numprakt-machines, the `eduVPN` tunnel must be active.

Passwords and machine/session numbers have been provided to you in the "intro"-lab.

Please log all your commands from exercise 1 and 2 (plus additional comments/information from the other exercises) to a file `YourName_logfile.txt` within your working directory (see below). Log only successful commands!

Exercise 1 – files and directories

Please log all commands (see above)

- Login to your home directory or to `numprakt` on the USM-hosts (see above)
- Create a directory called `YourName`, where `YourName` should be replaced by your actual name. This will be your working directory.
- In this directory, create a subdirectory `Europe`.
- Within this directory, create two subdirectories called `Germany` and `Italy`.
- Change to `Germany` and create the (empty) files `Roma_I Freiburg_D Milano_I Salzburg_A Berlin_D Hamburg_D Ingolstadt_D` and `Wien_A`.
- Move all files containing an `I` in their names to the directory `Italy`.
- Delete all files (within `Germany`) which contain a `burg` in their names.
- Rename file `Wien_A` to `Stuttgart_D`.

- Enter directory `Italy` and copy all files ending with `_D` to directory `Germany`.
- Delete all files which contain a `_D`.

Exercise 2 – file editing

For this exercise, use the editor `emacs`. Again, log all your commands (see above), and provide the commands used inside `emacs`.

Exercise 2a – line editing

- Open an `ssh` connection to `numprakt@ltsp08.usm.uni-muenchen.de`.
- List the content of `public/Europe` in long listing format onto your screen. Redirect this listing to a file called `public/YourName_Europe.txt`.
- Logout the ssh connection.
- Copy, via `scp`, the file `public/YourName_Europe.txt` from `numprakt@ltsp08.usm.uni-muenchen.de` to your working directory.
- Open this file with `emacs` and edit the content via *cut and paste* in such a way that all files with the ending `.Germany` appear first, followed by the files with ending `.Italy`. Delete all other lines, and save the file. For this task, do *not* use the commands from the menu bar, but learn to control emacs by keys. In the end, this works much faster.
- Convert the file to pdf (hint: first, create a `ps` file via `a2ps`).

Exercise 2b – column editing

- Again, log your commands, including those used inside `emacs`.
- Copy, via `scp`, the file `public/wlr.dat` on `numprakt@ltsp08.usm.uni-muenchen.de` to your working directory, under name `YourName_wlr.dat`, and open it with `emacs`.
- Delete columns 5 to 9, 11 to 15 and the last column (17), via the corresponding `..._rectangle` command, and insert them below the modified table, allowing for one empty line in between.
- The new file should consist of two tables, the first one with 6 columns, the second one with 11 columns. The first table will be used in **Exercise 3b**, and contains the following information about a sample of Galactic O-stars:
  1. Name, identifed by HD number (Henry-Draper catalogue),
  2. lc, luminosity class,
  3. Teff (effective temperature), in units of 1000 K,
  4. Rstar (stellar radius), in units of solar radius,
  5. vinf (terminal velocity of stellar wind), in units of km/s,
  6. Mdot (mass-loss rate of stellar wind), in units of 10^{-6} solar masses per year.

Rename the (modified) files from Exercise 2 to `1_Europe.pdf` and `2_wlr.dat`, respectively.

Exercise 3 – Gnuplot

In this exercise you will become acquainted with `gnuplot`. You needn't log the single commands. Again, use the editor `emacs` for editing. (If you are working in your own linux-environment, and you have not installed `gnuplot`, please install it)

Exercise 3a – demo tour and first edits

- `locate` the file-path to the directory `gnuplot/demo` on numprakt@ltsp08.usm.uni-muenchen.de, denoted by `$GPATH` in the following.
- Copy the directory `$GPATH/gnuplot/demo` to a new one, `YourName_gnuplot`, in your working directory.
- Change to `YourName_gnuplot` and start `gnuplot`.
- Let `gnuplot` introduce itself, by starting the demo-tour with the command `load 'all.dem'`.
- Check for an example which impresses you most, locate the corresponding `.dem` file, and describe briefly the purpose of this script (including its name) in your log-file.
- Have a careful look into the capabilities of `gnuplot`. Move the mouse cursor over the plot, and type 'h'. Study the output and 'play around' with the figure. Consider, e.g., the possibilities to zoom in and out, replot the data, switch the grid on and off, switch the log scale(s) on and off etc. (<B1> to <B3> refer to the mouse buttons). When 3-D data are plotted, try to rotate the figures with the mouse.

  For future work, you might use specific examples as templates for your own plots!
- Find out which `.dem` file creates the world map, and modify this file in such a way that only the 2-D world map is plotted (new filename = `3_world.dem`). Create a corresponding postscript file (filename = `4_world.ps`), and print the map.
- Modify the data in such a way that only "Munich" is located within the map, and create another `ps`-file (filename = `5_world_munich.ps`) with this modification.

Exercise 3b – a first own plot

In this exercise, you will derive the so-called *wind-momentum luminosity relation* (WLR) for Galactic supergiants, which relates the momenta of their radiation driven winds, modified by the `sqrt` of their radii, with their luminosity. To this end, proceed as follows:

- Copy `2_wlr.dat` to `my_wlr.dat`.
- In `my_wlr.dat`, delete the 2nd table. Within the first table, comment all entries with l.c.$\neq$1 by inserting a hash `#` at the beginning of the corresponding lines. (The hash is the comment sign for shell scripts and gnuplot). In this way, only data for lc=1 objects (supergiants) will be processed by `gnuplot`.
- As a first test, plot radius as a function of Teff for the Galactic O-supergiants via `gnuplot`. Convince yourself that the correct number of objects are plotted. Save the `ps`-version of this plot under `6_ostars.ps` (inspect it via `gv`).

In the following, you will calculate and plot the modified wind momenta of the stars as a function of their luminosity (log – log plot, data from file `my_wlr.dat`), and overplot a corresponding linear regression. The result will display the WLR for Galactic supergiants.

- Work with two windows in parallel: one for `gnuplot`, where you can test your solution, and one for `emacs`, where you create and modify a corresponding `gnuplot`-script, which should be named as `my_wlr.gpl`.
- By means of this script, plot the modified wind-momenta read and calculated from file `my_wlr.dat` (see **Exercise 2b**) as a function of luminosity as symbols, i.e., plot $\log_{10} D_{\rm mom}$ as a function of $\log_{10} L/L_\odot$, where

$$\begin{aligned} D_{\rm mom} &= \dot{M} \cdot v_{\rm inf} \sqrt{R_{\rm star}/R_\odot} \\ L/L_\odot &= (R_{\rm star}/R_\odot)^2 \cdot (T_{\rm eff}/T_{\rm eff,\odot})^4 \end{aligned}$$

  with $T_{\rm eff,\odot}$ the solar effective temperature, 5777 K. Calculate $D_{\rm mom}$ by providing $\dot{M}$ in units of $10^{-6} M_\odot/yr$ and $v_{\rm inf}$ in units of km/s.
- Perform a linear fit to the (log-log) data, $f(x) = ax + b$, and overplot the linear regression.
- From these results, write down the WLR for Galactic supergiants (i.e, $\log D_{\rm mom} =$?) within your log-file
- Finally, add a *meaningful* title, axis-labels and legend.
- Plot the corresponding figure as a `ps file`, and inspect this file via `gv`.

Rename your files to `7_my_wlr.dat`, `8_my_wlr.gpl`, and `9_my_wlr.ps`, respectively.

Finalizing the exercise

When you are finished with all your exercises, please check your log-file carefully, and provide a version which is easily readable and understandable. Of course, it is not forbidden to create a complete write-up via `Latex` or similar tools. Convert your log-file/write-up to pdf, and save it under the filename `0_YourName_logfile.pdf`.

Now, you should have (among others) the following files in your working directory:

```
0_YourName_logfile.pdf
1_Europe.pdf
2_wlr.dat
3_world.dem
4_world.ps
5_world_munich.ps
6_ostars.ps
7_my_wlr.dat
8_my_wlr.gpl
9_my_wlr.ps
```

and the directory `Europe`.

When you are satisfied with everything, *delete all other files and directories*, so that your working directory consists of these 10 files plus directory `Europe` only. **If there are other files left or the files have the wrong names, this will have a significant impact on the grade for your exercise.**

Tar and gzip your working directory to `YourName_ex.tgz`, and email this file to your supervisor.