Simulating Leptogenis

Public python code is available to compute the baryon asymmetry of as a result of Leptogenesis. In this hands-on session, you have opportunity to run this code and play with the parameters (masses, mixing angles and phases) of the heavy (and light) Majorana neutrinos.

The package we will be using is called Ulysses:

Abstract

ULYSSES is a python package that calculates the baryon asymmetry produced from leptogenesis in the context of a type-I seesaw mechanism. The code solves the semi-classical Boltzmann equations for points in the model parameter space as specified by the user. We provide a selection of predefined Boltzmann equations as well as a plugin mechanism for externally provided models of leptogenesis. Furthermore, the ULYSSES code provides tools for multi-dimensional parameter space exploration. The emphasis of the code is on user flexibility and rapid evaluation. It is publicly available at https://github.com/earlyuniverse/ulysses.

Step 1 : Download & have a look at the manual :

Get it from https://arxiv.org/abs/2007.09150 and give it a look to see what kind of information and guidance is available.

Step 2: get the code

Either get it from github https://github.com/earlyuniverse/ulysses

```
export ULYSSES=/where/you/put/it
export PYTHONPATH=${PYTHONPATH}:${ULYSSES}
export PATH=${PATH}:${ULYSSES}/bin
uls-calc -m 1BE3F   $ULYSSES/examples/1N3F.dat -o plot.png
```

```
display plot.png
```

Or use the download modified version* from www.nikhef.nl/~t61/ulysses.zip

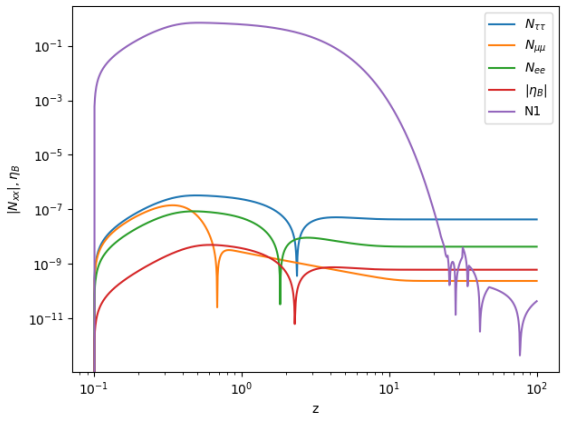
```
export ULYSSES=/where/you/put/it
export PYTHONPATH=${PYTHONPATH}:${ULYSSES}
export PATH=${PATH}:${ULYSSES}/bin
uls-calc -m 1BE3F   $ULYSSES/examples/1N3F.dat -o plot.png
display plot.png
```

Or, if you're at nikhef (.e.g. stoomboot)

```
ssh -Y you@stbc-i1.nikhef.nl
source /cvmfs/sft.cern.ch/lcg/views/LCG_97python3/x86_64-centos7-gcc8-opt/setup.sh # setup a reasonable python3+numpy environment
export ULYSSES=/user/t61/ulysses
export PYTHONPATH=${PYTHONPATH}:${ULYSSES}
export PATH=${PATH}:${ULYSSES}/bin
uls-calc -m 1BE3F   $ULYSSES/examples/1N3F.dat -o plot.png
display plot.png
```

* the modified version has been changed so that it also outputs the number

of heavy neutrino's (purple line below) along with the lepton on and baryon asymmetries.



Step 3: Explore

Now that it works, check the meaning of the input parameters. What is `1BE3F?` , have a look at the input file `$ULYSSES/examples/1N3F.dat` and use the manual to understand it [the meaning of the parameters x_1, x_2..y_3 is described in the manual around equation (5)] . What happens when you do `"-o dat.txt" ?`

Step 4: Play!

You can now start varying the model parameters and try to get a feeling which models work. You can parse the .txt output files, or hack the python code of e.g. uls-calc to automate thins. (same for uls-scan).

Possible questions you can answer:

- What happens when you change the mass the right-handed neutrinos? (remember what is on the x-axis ☺)
- Try to find a model that produces the Baryon Asymmetry with only the low-mass dirac phase
- At which time after the big bang do the heavy neutrinos exists? (from when to when? – convert the z-variable a time (googling allowed)).
- …

Step 5 : When you have a nice result / something to discuss put it here:

https://docs.google.com/presentation/d/1z7byYuIU7x4VIgceI8-0kW9TwaK8iNiM5G-7yd_WFEI/edit?usp=sharing