Geneva workshop on tools for cosmology:
The CLASS and Monte Python codes

The topics covered by this workshop will be:

Topic I: the simulation of cosmological perturbations in the universe, and the computation of the CMB anisotropy and Large Scale Structure power spectra. The programme includes:

- an overview of the underlying theory,
- a presentation of its numerical implementation in the Cosmic Linear Anisotropy Solving System (CLASS, `http://class-code.net`), written in C,
- some sessions dedicated to the practical use of the code,
- some exercise sessions, in order to learn how to modify the code.

For this part, the lectures will be structured in the same way as the modules of the CLASS code:

1. input parameters
2. homogeneous background
3. thermodynamical evolution
4. cosmological perturbations
5. primordial spectrum and initial conditions
6. non-linear corrections
7. transfer functions
8. lensing
9. power spectra
10. output of the code

For each of these sections, we will discuss the theory, the numerical aspects, and we will propose exercises. The modules 6-10 are more trivial and will be grouped together.

For simplicity, the main presentation will focus on the minimal ΛCDM model. In parallel, there will be short lectures focusing on specific topics: massive neutrinos, quintessence, advanced numerical methods.

Topic II: the extraction of cosmological parameters from observational data, using a Monte Carlo algorithm. We will briefly expose the principle of several algorithms, and their implementation in Monte Python (`http://montepython.net`). This code is written in Python and interfaced with CLASS, with the official WMAP and Planck likelihood, etc. This part will consist mainly in sessions dedicated to practise and exercises. The participants will learn the basic use of the code, and how to adapt it to their new projects.

	DAY I : Monday 31th March	
10:00-11:00	Introduction to CLASS. *Brief history of Boltzmann codes.* *Goals and philosophy of CLASS.* *Structure of the code.*	JL
11:00-11:20	Coffee	
11:20-11:50	Introduction to CLASS. *Basic input and output.* *Plotting facilities.*	JL
11:50-12:50	CLASS Practise. *Looking at all possible outputs of CLASS.* *Vizualizing them using the CLASS Plotting Unit, Gnuplot,* *Matlab, or one's own favorite plotting software.*	BA, JL, TT
12:50-14:00	Lunch break	
14:00-15:00	Cosmological parameter extraction from data. *Overview of the main methods and existing codes.*	BA
15:00-15:15	pause	
15:15-16:15	Introduction to Monte Python I. *Goals of Monte Python.* *Installation and basic use.*	BA

Speakers and/or tutors: BA = Benjamin Audren, JL = Julien Lesgourgues, TT = Thomas Tram

	DAY II: Tuesday 1st April	
10:00-11:00	Homogeneous cosmology. Theory and Numerics. *Equations to be solved.* *Presentation of the module background.c* *Dynamical indexing and error management in CLASS*	JL
11:00-11:20	Coffee	
11:20-12:20	Homogeneous cosmology. Exercises. *Plotting the background evolution.* *Implementing a new species.*	BA, JL, TT
12:20-12:50	Thermodynamical evolution. Theory and Numerics. *Recombination. Presentation of RecFast and HyRec.* *Reionization history. Presentation of the module thermodynamics.c*	JL
12:50-14:00	Lunch break	
14:00-15:00	Introduction to Monte Python II. *Modules of the code, how they interact.* *Example of complete session.* *Analyzing and plotting the results*	BA
15:00-15:15	pause	
15:15-15:45	Practise with Monte Python I *Downloading and installing the code.* *Running a simple session* *Exercise: ΛCDM parameter forecast with the Planck_bluebook likelihood*	BA, JL
15:45-16:15	Perturbations. Theory I. *Gauges. Power spectra and transfer functions.* *Boltzmann equation. Line-of-sight integral.*	JL

	DAY III : Wednesday 2nd April	
10:00-10:30	Perturbations. Theory II and numerics. *Acoustic oscillations.* *Presentation of the module perturbation.c*	JL
10:30-11:00	CLASS Exercises. *Visualizing the time evolution of perturbations.*	BA, JL, TT
11:00-11:20	Coffee	
11:20-11:50	Focus on massive neutrinos. *Boltzmann equation for massive neutrinos.* *Available input for massive neutrinos.* *Non-thermal distorsion, sterile neutrinos, WDM*	TT
11:50-12:20	CLASS Exercises. *Implementing a trivial modification of gravity.*	BA, JL, TT
12:20-12:50	Primordial spectrum. Theory and numerics. *Initial conditions. Adiabatic and isocurvature modes.* *Presentation of the module primodial.c.* *The in-built inflation simulator.*	JL
12:50-14:00	Lunch break	
14:00-15:00	Using Monte Python in new projects *The classy wrapper. Using new parameters.* *Adding a new likelihood.*	BA
15:00-15:15	pause	
15:15-16:15	Practise with Monte Python II *Plotting the results of the previous exercise.* *Introducting new parameters.*	BA, JL

	DAY IV : Thursday 3rd April	
10:00-10:10	Nonlinear corrections. *Presentation of the module nonlinear.c*	JL
10:10-10:30	Transfer functions. Theory and Numerics. *Presentation of the module thermodynamics.c* *Using test_transfer to visualize transfer functions.*	JL
10:30-11:00	CLASS Exercises. *Playing with the transfer function of tensor temperature.*	BA, JL, TT
11:00-11:20	Coffee	
11:20-11:50	Focus on curvature *Boltzmann hierarchy in curved space.* *Hypersherical Bessel functions.* *Advanced interpolation schemes.*	TT
11:50-12:05	Overview of last CLASS modules *Presentation of spectrum.c, lensing.c, output.c*	JL
12:05-12:20	Focus on quintessence. *Existing implementation.* *Coding new models.*	TT
12:20-12:50	CLASS Exercises. *Finishing previous exercises.*	BA, JL, TT
12:50-14:00	Lunch Break	
14:00-14:20	Focus on advanced numerical methods used in CLASS. *Ordinary Differential equation solvers.* *Gaussian quadrature.*	TT
14:20-14:30	CLASS conclusions. *Future of the code. Bibliography.*	JL
14:30-15:00	Using the GitHub repositories for CLASS and Monte Python	BA
15:00-15:15	pause	
15:15-16:15	Practise with Monte Python III *Using the Planck likelihood.* *Introducing a gaussian prior on σ_8.* *Using Monte Python in a forecast (e.g. for Euclid).* *Using Multinest and CosmoHammer inside Monte Python.*	BA, JL

Prerequisites:

- a basic knowledge of cosmology (at least homogeneous cosmology, and some general ideas about CMB anisotropies).
- prior knowledge of C would help. Participants familiar with fortran will anyway find C obvious. C++ users automatically know C.
- prior knowledge of python would help for the part related to advanced used of Monte Python (creating new likelihoods). People use to matlab will find it very similar.

Some instructions on how to download the relevant codes will be circulated to participants one week before the workshop, in order to save time on the first days, and to avoid network saturation at the beginning of the exercise sessions.