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

For each of these sections, we will discuss the theory, the numerical aspects, and we will propose exercises. The modules 6-9 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, large scale structure, quintessence.

Topic II: the extraction of cosmological parameters from observational data, using a Monte Carlo algorithm. We will briefly expose the principle of several algorithms, their implementation in Monte Python, the parameter extraction code interfaced with CLASS (`http://montepython.net`), written in Python. 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 17th March	
9:45-10:45	Introduction to CLASS. *Brief history of Boltzmann codes.* *Goals and philosophy of CLASS.* *Structure of the code.*	JL
10:45-11:15	Coffee	
11:15-12:15	Homogeneous cosmology. Theory and Numerics. *Equations to be solved.* *Presentation of the module background.c*	JL
12:15-13:30	Lunch break	
13:30-14:30	Homogeneous cosmology. Practise. *Downloading and compiling CLASS.* *Using test_background to visualize the homogeneous quantities.* *Exercise: implementing a new component in the background evolution and plotting its evolution.*	BA, JL, MZ
14:30-15:30	Cosmological parameter extraction from data. *Overview of the main methods and existing codes.* *Goals of Monte Python.*	BA

Speakers and/or tutors: BA = Benjamin Audren, JL = Julien Lesgourgues, MZ = Miguel Zumalacarregui

	DAY II: Tuesday 18th March	
9:45-10:45	Thermodynamical evolution. Theory and Numerics. *Recombination. Presentation of RecFast and HyRec.* *Reionization history. Presentation of the module thermodynamics.c*	JL
10:45-11:15	Coffee	
11:15-12:15	Perturbations. Theory I. *Gauges. Power spectra and transfer functions.* *Boltzmann equation. Line-of-sight integral.*	JL
12:15-13:30	Lunch break	
13:30-14:30	Basic use of Monte Python. *Installation. The classy wrapper.* *Input and output. How to organise the directory.* *Example of complete session.* *Analyzing and plotting the results*	BA
14:30-15:30	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

	DAY III : Wednesday 19th March	
9:45-10:45	Perturbations. Theory II. *Anisotropy spectrum. Acoustic oscillations.*	JL
10:45-11:15	Coffee	
11:15-12:15	Perturbations. Numerics. *Presentation of the module perturbation.c*	JL
12:15-13:30	Lunch break	
13:30-14:30	Perturbations. Practise. *Using test_perturbations to visualize the source functions.* *Exercise: Plotting the ISW power spectrum* *and other individual contributions.*	BA, JL, MZ
14:30-15:00	Focus on massive neutrinos. *Boltzmann equation for massive neutrinos.* *Optimal quadrature scheme.* *Available input for massive neutrinos.* *Non-thermal distorsion, sterile neutrinos, WDM*	JL
15:00-15:30	Focus on quintessence. *Existing implementation.* *Coding new models.*	MZ

	DAY IV : Thursday 20th March	
9:45-10:15	Primordial spectrum. Theory and numerics. *Initial conditions. Adiabatic and isocurvature modes.* *Presentation of the module primodial.c.* *The in-built inflation simulator.*	JL
10:15-10:45	Transfer functions. Theory and Numerics. *Presentation of the module thermodynamics.c* *Using test_transfer to visualize transfer functions.*	JL
10:45-11:15	Coffee	
11:15-11:45	Overview of other modules *Presentation of spectrum.c, nonlinear.c, lensing.c, output.c*	JL
11:45-12:15	CLASS output. Practise I *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, MZ
12:15-13:30	Lunch Break	
13:30-14:30	CLASS output. Practise II *Plotting and understanding physically the effect* *of each cosmological parameter.*	BA, JL, MZ
14:30-15:00	Using Monte Python in new projects *Why adding parameters in Monte Python is trivial.* *Adding a new likelihood.*	BA
15:00-15:30	Practise with Monte Python II *Plotting the results of the previous exercise.*	BA, JL

	DAY V : Friday 21th March	
9:45-10:15	Focus on large scale structure. *Relativistic corrections in CLASSgal or CAMBsources.* *Non-linear corrections: existing schemes and prospects.* *Implementing modified gravity models.*	JL
10:15-10:45	Focus on advanced numerical methods used in CLASS. *Ordinary Differential equation solvers.* *Gaussian quadrature. Advanced interpolation schemes.* *Hypersherical Bessel functions.*	JL
10:45-11:15	Coffee	
11:15-12:15	Practise with Monte Python III *Using the Planck likelihood.* *Exercises: introducing new parameters.* *Introducing a gaussian prior on σ_8.*	BA, JL
12:15-13:30	Lunch Break	
13:30-15:00	Practise with Monte Python IV *Using Monte Python in a forecast (e.g. for Euclid).* *Using Multinest and CosmoHammer inside Monte Python.*	BA, JL
15:00-15:30	Using the GitHub repositories for CLASS and Monte Python	BA

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.