Kavli IPMU 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. harmonic 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.

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.

	DAY I : Monday 27th October	
9:30-10:30	Introduction to CLASS I. *Brief history of Boltzmann codes.* *Goals and philosophy of CLASS.* *Structure of the code.*	JL
10:30-11:00	Coffee	
11:00-12:00	Introduction to CLASS II. *Basic input and output.* *Plotting facilities.*	JL
12:00-13:30	Lunch break	
13:30-15:00	Cosmological parameter extraction from data. *Overview of the main methods and existing codes.*	BA
14:45-15:00	CLASS Exercises 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, TT
15:00-15:45	Tea Time	
15:45-16:15	CLASS Exercises I continued.	BA, JL, TT

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

	DAY II: Tuesday 28th October	
9:30-10:30	Homogeneous cosmology I. Theory and Numerics. *Equations to be solved.* *Presentation of the module background.c* *Dynamical indexing in CLASS*	JL
10:30-11:00	Coffee	
11:00-12:00	CLASS Exercises II. *Plotting the background evolution.* *Implementing a new species.*	BA, JL, TT
12:00-13:30	Lunch break	
13:30-14:30	Introduction to Monte Python I. *Goals of Monte Python.* *Installation and basic use.*	BA
14:30-15:00	Homogeneous cosmology II. Numerics. *Error management in CLASS*	JL
15:00-15:45	Tea Time	
15:45-16:15	CLASS Exercises II continued, or for those who did not do it before: Downloading and installing Monte Python.	BA, JL, TT

	DAY III : Wednesday 29th October	
9:30-10:30	Thermodynamical evolution. Theory and Numerics. *Recombination. Presentation of RecFast and HyRec.* *Reionization history.* *Presentation of the module thermodynamics.c*	JL
10:30-11:00	Coffee	
11:00-12:00	Perturbations I. Theory. *Gauges. Power spectra and transfer functions.* *Boltzmann equation. Line-of-sight integral for temperature,* *polarisation and tensors.*	JL
12:00-13:30	Lunch break	
13:30-14:30	Introduction to Monte Python II. *Modules of the code, how they interact.* *Example of complete session.* *Analyzing and plotting the results*	BA
14:30-15:00	Practise with Monte Python I *Running a simple session* *Exercise: ΛCDM parameter forecast* *with the Planck_bluebook likelihood*	BA, JL, TT
15:00-15:45	Tea Time	
15:45-16:15	Perturbations II. Numerics. *Presentation of the module perturbation.c*	JL

	DAY IV : Thursday 30th October	
9:30-10:00	Primordial spectrum. Theory and numerics. *Initial conditions. Adiabatic and isocurvature modes.* *Presentation of the module primodial.c.* *The in-built inflation simulator.*	JL
10:00-10:10	Nonlinear corrections. *Presentation of the module nonlinear.c*	JL
10:10-10:30	Harmonic transfer functions. Theory and Numerics. *Presentation of the module transfer.c* *Using test_transfer to visualize transfer functions.*	JL
10:30-11:00	Coffee	
11:00-11:30	CLASS Exercises III. *Visualizing the time evolution of perturbations.* *Implementing a trivial modification of gravity.*	BA, JL, TT
11:30-12:00	Focus on massive neutrinos. *Boltzmann equation for massive neutrinos.* *Available input for massive neutrinos.* *Non-thermal distorsion, sterile neutrinos, WDM*	TT
12:00-13:30	Lunch break	
13:30-14:30	Introduction to Monte Python III *The classy wrapper. Using new parameters.* *Adding a new likelihood.* *Using Multinest within Monte Python*	BA
14:30-15:00	Practise with Monte Python II *Plotting the results of the previous exercise.* *Introducting new parameters.*	BA, JL, TT
15:00-15:45	Tea Time	
15:45-16:15	Practise with Monte Python II continued	BA, JL, TT

	DAY V : Friday 31th October	
9:30-9:45	Overview of last CLASS modules *Presentation of spectrum.c, lensing.c, output.c*	JL
9:45-10:15	CLASS Exercises IV. *Playing with the transfer function of tensor temperature.*	BA, JL, TT
10:15-10:30	Focus on quintessence. *Existing implementation.* *Coding new models.*	TT
10:30-11:00	Coffee	
11:00-11:30	Focus on curvature *Boltzmann hierarchy in curved space.* *Hypersherical Bessel functions.* *Advanced interpolation schemes.*	TT
11:30-11:45	Focus on advanced numerical methods used in CLASS. *Ordinary Differential Equation solvers.*	TT
11:45-12:00	CLASS conclusions. *Future of the code. Bibliography.*	JL
12:00-13:30	Lunch Break	
13:30-14:00	Version control and automatic testing for CLASS and Monte Python *Using the GitHub repositories.* *Using nose tests.*	BA
14:00-15:00	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.* and/or finishing the CLASS exercises	BA, JL, TT
15:00-15:45	Tea Time	