COSMOMC EXERCISES

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BASIC EXERCISE

- Modify COSMOMC products.
- Add HST information to Planck chains. Planck chains are at :

  /home/prof6/CosmoMC-Nov2016/chains/Planck_chains
- What to do? Pick your favourite HST measurement of H0 and its errorbar and reweight Planck chains according to HST likelihood.

$$weight \rightarrow weight \times Likelihood_{HST}$$

$$Likelihood_{HST} = e^{\frac{1}{2}\frac{\left(H_0(data) - H_0(theo)\right)^2}{error^2}}$$

INTERMEDIATE EXERCISE

- Imagine you are planing to perform a CMB experiment and have some angular power spectra as a forecasting. How do you check how well will it constrain cosmological parameters?
- Easy! COSMOMC has an exact likelihood already implemented for that (Lewis 2005).
- Get any angular power spectra from CAMB (or the default one from Planck) and use it as a forecasting CMB experiment.

- python/makePerfectForecastDataset.py
- select your preferences:
  - lensedTotClFileRoot = os.path.join(os.path.dirname(__file__), '..', 'data', 'MyFavouriteCl.theory_cl')
  - outDir = 'data/MyForecast/'
  - etc …
- Run python makePerfectForecastDataset.py
- It will generate three files:
  - test_lensedCls_exactsim.dat : data for input in COSMOMC readable file.
  - test_lensedCls_exactsim.dataset : especifications of your data set.
  - test_lensedCls_exactsim_Noise.dat : noise coming from the resolution of your experiment.
- remove all likelihoods (or not, depending on what you want) from the .ini file and add
- cmb_dataset[MyForecast] = data/MyForecast/test_lensedCls_exactsim.dataset
- Submit the code to the queue and check the results!

ADVANCED EXERCISE

- Modify COSMOMC from the inside with a new likelihood of your own.
- Suggestion: do it with “Double probe” likelihood

  https://arxiv.org/pdf/1607.03152.pdf

  Section 5
- Why? Because we provide the solution and because it is a very complete (in terms of learning) and fast likelihood.

“Double Probe likelihood”

- Encodes CMB(Planck2015)+LSS(BOSSdr12) information in “few parameters”
- First, define likelihood:

$$\chi^2_{\rm CMB+galaxy} = \Delta_{\rm CMB+galaxy} M^{-1}_{ij,\rm CMB+galaxy} \Delta_{\rm CMB+galaxy}, \quad \Delta_{\rm CMB+galaxy} = \begin{pmatrix} f\sigma_8(0.59) - f\sigma_8(0.59)_{\rm obs} \\ H(0.59) r_{\rm s}/r_{\rm s,fid} - H(0.59)_{\rm obs} r_{\rm s}/r_{\rm s,fid} \\ D_{\rm A}(0.59) r_{\rm s,fid}/r_{\rm s} - D_{\rm A}(0.59)_{\rm obs} r_{\rm s,fid}/r_{\rm s} \\ f\sigma_8(0.32) - f\sigma_8(0.32)_{\rm obs} \\ H(0.32) r_{\rm s}/r_{\rm s,fid} - H(0.32)_{\rm obs} r_{\rm s}/r_{\rm s,fid} \\ D_{\rm A}(0.32) r_{\rm s,fid}/r_{\rm s} - D_{\rm A}(0.32)_{\rm obs} r_{\rm s,fid}/r_{\rm s} \\ R - R_{\rm obs} \\ l_{\rm a} - l_{\rm a,obs} \\ \Omega_{\rm b} h^2 - \Omega_{\rm b} h^2_{\rm obs} \\ n_{\rm s} - n_{\rm s,obs} \\ \ln(10^{10} A_{\rm s}) - \ln(10^{10} A_{\rm s})_{\rm obs} \\ \Omega_{\rm k} - \Omega_{\rm k,obs} \end{pmatrix}.$$

	$\Omega_{bc}h^2$	l_a	$\Omega_b h^2$	n_s	$\ln(10^{10}A_s)$	$f\sigma_8(0.59)$	$\frac{H(0.59)}{r_{s,fid}/r_s}$	$\frac{D_A(0.59)}{r_s/r_{s,fid}}$	$f\sigma_8(0.32)$	$\frac{H(0.32)}{r_{s,fid}/r_s}$	$\frac{D_A(0.32)}{r_s/r_{s,fid}}$	Ω_k
$\Omega_{bc}h^2$	1.0000	0.4607	-0.6377	-0.8376	0.0145	0.0075	0.0536	0.0672	-0.0870	0.0317	0.0049	0.3794
l_a	0.4607	1.0000	-0.4977	-0.5042	-0.0470	0.0201	-0.0525	0.0043	-0.0216	0.0765	0.0912	0.2919
$\Omega_b h^2$	-0.6377	-0.4977	1.0000	0.7188	-0.0241	-0.0016	-0.0625	-0.0879	0.0692	0.0299	0.0149	-0.2708
n_s	-0.8376	-0.5042	0.7188	1.0000	0.0475	-0.0131	-0.0591	-0.0499	0.0717	0.0268	-0.0686	-0.2894
$\ln(10^{10}A_s)$	0.0145	-0.0470	-0.0241	0.0475	1.0000	0.0095	-0.0352	-0.0065	0.0773	0.0225	0.0053	0.5576
$f\sigma_8(0.59)$	0.0075	0.0201	-0.0016	-0.0131	0.0095	1.0000	0.6546	0.5223	0.2427	0.2074	0.0634	0.1538
$H(0.59)r_s/r_{s,fid}$	0.0536	-0.0525	-0.0625	-0.0591	-0.0352	0.6546	1.0000	0.3777	0.0586	0.0615	0.0015	-0.0025
$D_A(0.59)r_{s,fid}/r_s$	0.0672	0.0043	-0.0879	-0.0499	-0.0065	0.5223	0.3777	1.0000	-0.0598	0.0272	-0.0474	-0.0578
$f\sigma_8(0.32)$	-0.0870	-0.0216	0.0692	0.0717	0.0773	0.2427	0.0586	-0.0598	1.0000	0.6531	0.4819	0.1487
$H(0.32)r_s/r_{s,fid}$	0.0317	0.0765	0.0299	0.0268	0.0225	0.2074	0.0615	0.0272	0.6531	1.0000	0.1686	0.1165
$D_A(0.32)r_{s,fid}/r_s$	0.0049	0.0912	0.0149	-0.0686	0.0053	0.0634	0.0015	-0.0474	0.4819	0.1686	1.0000	0.0049
Ω_k	0.3794	0.2919	-0.2708	-0.2894	0.5576	0.1538	-0.0025	-0.0578	0.1487	0.1165	0.0049	1.0000

Table 6. Correlation matrix of the double-probe measurements obtained with varying Σm_ν (corresponding to Table 5, see Sec. 7.1).

$f\sigma_8(0.59)$	0.495 ± 0.051
$H(0.59)r_s/r_{s,fid}$	97.5 ± 3.2
$D_A(0.59)r_{s,fid}/r_s$	1419 ± 27
$f\sigma_8(0.32)$	0.431 ± 0.066
$H(0.32)r_s/r_{s,fid}$	78.9 ± 3.6
$D_A(0.32)r_{s,fid}/r_s$	964 ± 26
$\Omega_{bc}h^2$	0.1413 ± 0.0022
l_a	301.75 ± 0.14
$\Omega_b h^2$	0.02209 ± 0.00025
n_s	0.9639 ± 0.0068
$\ln(10^{10}A_s)$	3.062 ± 0.040
Ω_k	-0.009 ± 0.006

Table 5. Results of double-probe analysis obtained with varying Σm_ν. The units of $H(z)$ and $D_A(z)$ are $\mathrm{km\,s^{-1}\,Mpc^{-1}}$ and Mpc (see Sec. 7.1).

- Second, implement it in COSMOMC.

- Solution at:

  /home/prof6/CosmoMC-Nov2016/source

  /home/prof6/CosmoMC-Nov2016/paramnames

  all files with *_DoubProbe root

  in order to make it work remove the _DoubProbe root from files or change the Makefile adding this root.

- Doing the exercise (the ugly but useful way):
  - Find a module that suits your needs (suggestion: bao.f90 in this case)
  - Read the data and covariance matrix given in the paper or at:

    /home/prof6/CosmoMC-Nov2016/Imp_Samp_Double_probe_2z_nosystematcs_planck15_LCDM_map_params_newweight.covmat

    /home/prof6/CosmoMC-Nov2016/double_probe.data

    suggestion: Use subroutines called Likelihood_Add so that you don't repeat the reading of data all over again. Only called once.

    And compute covariance matrix inverse

– Compute χ^2 and substitute yours with the previous one (if you want to add the one you are substituting you can always sum them up).

Suggestion: In BAO_MGS_loglike (for example) use the functions:

- **CMB params**

  ode0= CMB%omv

  om0 = (CMB%omc + CMB%omb)

  omegab = CMB%omb

  omegabh2 = CMB%ombh2

  omegac = CMB%omc

  hh = CMB%h

  H0 = 100.0*CMB%h

  Omegak = (CMB%Omk)

  Omegabch2 = om0*(hh**2.0)

  mnu = CMB%omnuh2*neutrino_mass_fac/(standard_neutrino_neff/3)**0.75_mcp

- **Shift parameters**

  RR = sqrt(om0*(H0**2.))*r_zstar/299792.458

  la = 3.14159265*r_zstar/rs_zstar

- **Derived parameters**

  rs_zstar = this%get_rs_star(Theory) * this%rs_rescale

  r_zstar = this%Calculator %AngularDiameterDistance(zstar)*(1.0+zstar)

  zstar = Theory%derived_parameters(derived_zstar)

  rs = this%get_rs_drag(Theory) * this%rs_rescale

- **LSS parameters at redshift z1**

  Hz_z1 = this%Calculator%Hofz_Hunit(zz_1)*rs/rs_fid

  DA_z1 = this%Calculator %AngularDiameterDistance(zz_1)*rs_fid/rs

  fsigma8_z1 = Theory%growth_z%Value(zz_1)

- **Fiducial cosmology**

  rs_fid = 147.66