Tools 2020 - COFFE tutorial

Exercise 1 - correlation function

As a start, let's compute the 2PCF at $\bar{z} = 0.8$ at $\mu = [0, 0.5, 1]$ with contributions only from density, for separations $r \in [10, 300]\ \mathrm{Mpc}/h$, with the default ΛCDM cosmology.

First, make a copy of the default `settings.cfg` file, available here. The default settings file contains all of the descriptions of the various cosmology and precision parameters, and should be kept as a reference. Now, open it with some text editor, and locate the parameters `z_mean`, `mu`, `output_type`, and `correlation_contributions`. Then, edit them to match the below:

```
z_mean = 0.8
mu = [0, 0.5, 1]
output_type = 1
correlation_contributions = ["den"]
```

Make sure that the same parameter does not appear twice in the settings file. Note that if some parameters are missing, COFFE will most likely complain about a missing parameter value (but it will tell you which one is missing).

For convenience, you can also download the separations file from here, and save it to the same directory as the default settings file, so you can compute the 2PCF at more separations than the default ones, which are taken to be `[10., 20., 40., 100., 120., 150., 200., 250., 300., 350]` Mpc/h.

Now, if you haven't done so already during the installation, you can run COFFE (I will assume you have installed the Docker version):

```
coffe -s settings.cfg
```

The output of the above command should look something like the following:

```
   _____ ____  ______ ______ ______
  / ____/ __ \|  ____|  ____|  ____|
 | |   | |  | | |__  | |__  | |__
 | |   | |  | |  __| |  __| |  __|
 | |___| |__| | |    | |    | |____
  \_____\____/|_|    |_|    |______|
Parsing settings file "settings.cfg"...
Launching CLASS...
CLASS finished in 10.85 s
Settings file "settings.cfg" parsed in 10.85 s
```

```
Number of threads in use: 1
Initializing the background...
Background initialized in 0.32 s
Calculating integrals of Bessel functions...
Integrals of Bessel functions calculated in 0.16 s
Calculating multipoles...
Multipoles calculated in 0.04 s
Writing output to "results/2020-11-02-21-09-53_"...
Output finished in 0.03 s
Total program runtime is: 11.40 s
```

The following, or similar, may also show up in the above:

```
WARNING: maximum separation too high; cutting off list at the value 640.00
Mpc/h
```

This is caused by the variable `deltaz` overriding the maximum separation found in the separations file; this is done to more closely mimic what observers do, who perform redshift binning into bins of width Δz at some mean redshift $\bar{z}$.

By default, COFFE reports where the output will be saved, as well as the timings of each of the modules. This can be toggled on/off by changing the setting `verbose` to either 1 or 0, respectively. Additionally, in order to try to not overwrite any existing files, the settings file contains the variable `output_prefix`, which, if set to `$TIME`, sets the prefix of the out files to a timestamp of the form `YYYY-MM-DD-HH-mm-SS_` (with the trailing underscore).

There should also be following files in the `results/` directory (with the timestamp prefix):

- `background.dat` - this file contains the background quantities in the columns, such as the scale factor a, the comoving Hubble parameter $\mathcal{H}$, and various others, with their respective units written in the header (first line, indicated by `#`)
- `corrfunc0.dat`, `corrfunc1.dat`, `corrfunc2.dat` - these are the outputs we requested, i.e. the 2PCF, for the values of $\mu = [0, 0.5, 1]$, respectively, i.e. the output file names for the 2PCF don't use the value of μ, but just the index, starting from zero. If we requested the multipoles, say, $\ell = [0, 2, 4]$, however, the file names would be of the form `multipoles0.dat`, `multipoles2.dat`, `multipoles4.dat`, respectively, i.e. the actual multipole is indicated in the file name. The header of the 2PCF output is something like the following:

```
# mu = 0.000000
# z_mean = 1.000000
# correlation contributions: den rsd
# sep[Mpc/h]    result
```

and the two columns that follow are the separations (in units of Mpc/h) and the 2PCF (dimensionless), for the above fixed values of $\bar{z}$ and μ, with contributions from the terms written after

`correlation contributions`.

- `settings.cfg` - this is a copy of the input settings file (without the comments), which can be re-used to make another run of COFFE

(Optional): compute the 2PCF with the same configuration, but with additional contributions from redshift-space distortions (RSD). How does it compare to the 2PCF with only contributions from density, as we change the value of the angle μ?

Exercise 2 - full-sky vs. flat-sky multipoles

Next, compute the standard multipoles of the 2PCF, $\ell = \{0, 2, 4\}$, with contributions from density and redshift-space distortions (RSD), at the same redshift as before, $\bar{z} = 0.8$.

Compare the result for the multipoles with the one obtained by using the flat-sky approximation. The approximation can be toggled with the parameter `flatsky_local`.