N-body exercise with gevolution (Exercise #1)

Farbod Hassani
Simone Peirone
Mona Jalilvand
Basundhara Ghosh

Implementing the wCDM Model in *gevolution*

- Simple generalisation of ΛCDM
- $w \neq -1$, but constant
- No perturbations, only background

$$\rho_{\mathrm{fld}} \propto a^{-3(1+w)}$$

$$\texttt{Omega\_fld} = \frac{8\pi G \rho^0_{\mathrm{fld}}}{3H_0^2}$$

$$\texttt{w0\_fld} = w$$

Steps involved

- Add model parameters to the metadata structures (metadata.hpp)
- Allow parsing of model parameters from settings (parser.hpp)
- Modify background (background.hpp)

Metadata.hpp

- New model parameters are inserted in the structure called ‘cosmology’
- We add two double fields: Omega_fld and w0_fld

```
struct cosmology
{
  double Omega_fld;
  double w0_fld;
  double Omega_cdm;
  double Omega_b;
  double Omega_m;
  double Omega_Lambda;
  double Omega_g;
  double Omega_ur;
  double Omega_rad;
  double Omega_ncdm[MAX_PCL_SPECIES-2];
  double h;
  double m_ncdm[MAX_PCL_SPECIES-2];
  double T_ncdm[MAX_PCL_SPECIES-2];
  double deg_ncdm[MAX_PCL_SPECIES-2];
  int num_ncdm;
};
```

Parser.hpp

- Parsing the new model parameters from the settings file
- We use the function parseMetadata in parser.hpp
- We add new calls to parseParameter to read new parameters from settings file
  - ➢ Returns true if the parameter could be parsed
  - ➢ False otherwise : set variable to default value

```
if(parseParameter(params, numparam, "Omega_fld", cosmo.Omega_fld) )
{
}
else if(!parseParameter(params, numparam, "Omega_fld", cosmo.Omega_fld)){
  cosmo.Omega_fld = 0;
}
if(parseParameter(params, numparam, "w0_fld", cosmo.w0_fld) ){
}
else if(!parseParameter(params, numparam, "w0_fld", cosmo.w0_fld)){
  cosmo.w0_fld = -1;
}
```

Parser.hpp (contd.)

- Gevolution assumes curvatures is zero and never parse cosmological constant

$$\Omega_\Lambda = 1 - \sum_{i \neq \Lambda} \Omega_i$$

- We have to include Omega_fld in this equation

```
cosmo.Omega_Lambda = 1. - cosmo.Omega_m - cosmo.Omega_rad - cosmo.Omega_fld;
```

Background.hpp

- Implement the physical consequences of the model into the part of the code that deals with the background evolution
- change the function Hconf that computes the conformal Hubble rate

$$\mathcal{H}^2 = \frac{8\pi G}{3} a^2 \sum_i \rho_i = \frac{8\pi G}{3} a^2 \rho_{crit}^0 \sum_i \Omega_i a^{-3(1+w_i)}$$

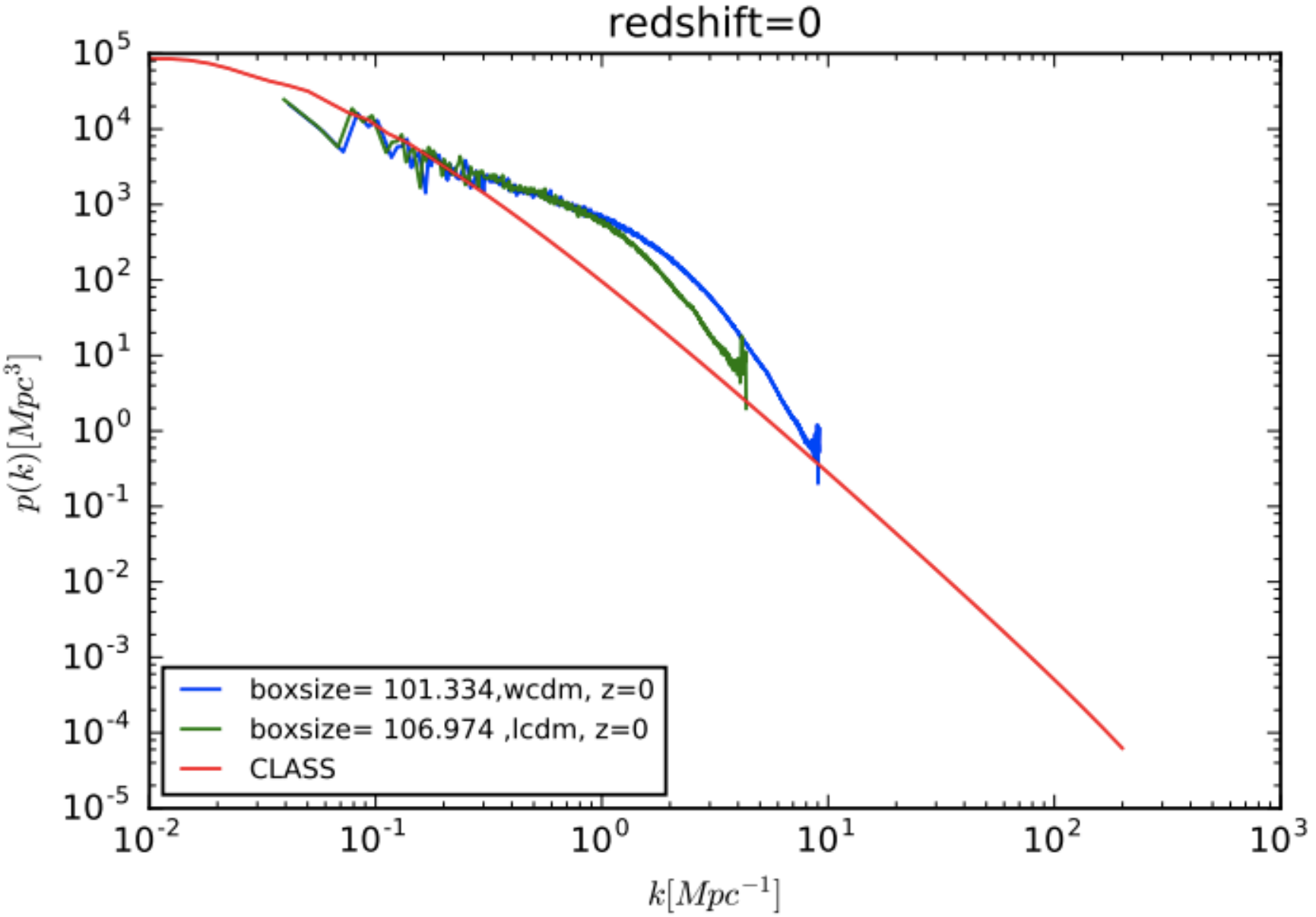
```
double Hconf(const double a, const double fourpiG, const cosmology cosmo)
{
  return sqrt((2. * fourpiG / 3.) * (((cosmo.Omega_cdm + cosmo.Omega_b + bg_ncdm(a, cosmo)) / a) +
  (cosmo.Omega_Lambda * a * a) + (cosmo.Omega_fld *pow(a,-1-3*(cosmo.w0_fld) ))+ (cosmo.Omega_rad / a / a)));
}
```

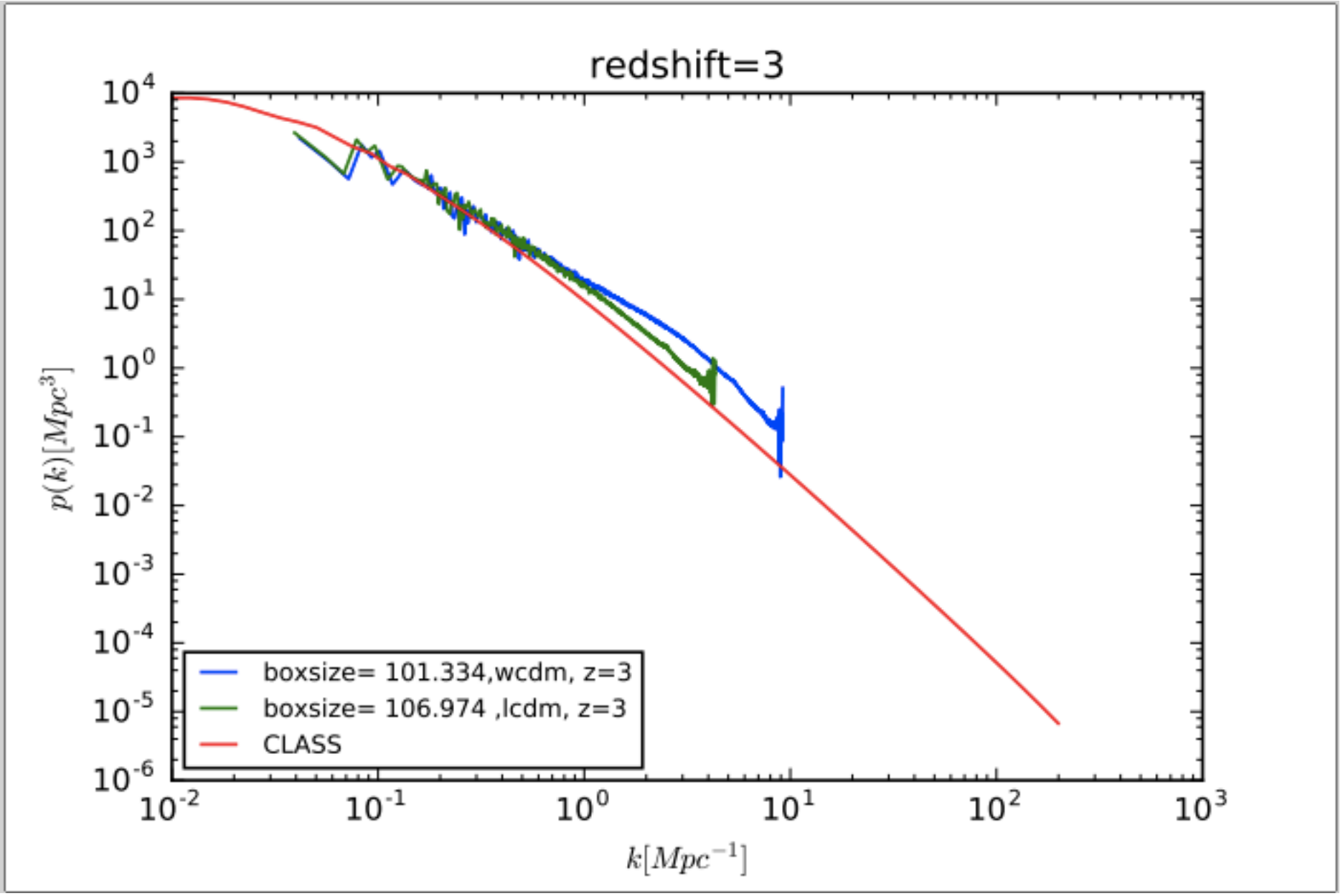
Background.hpp (contd.)

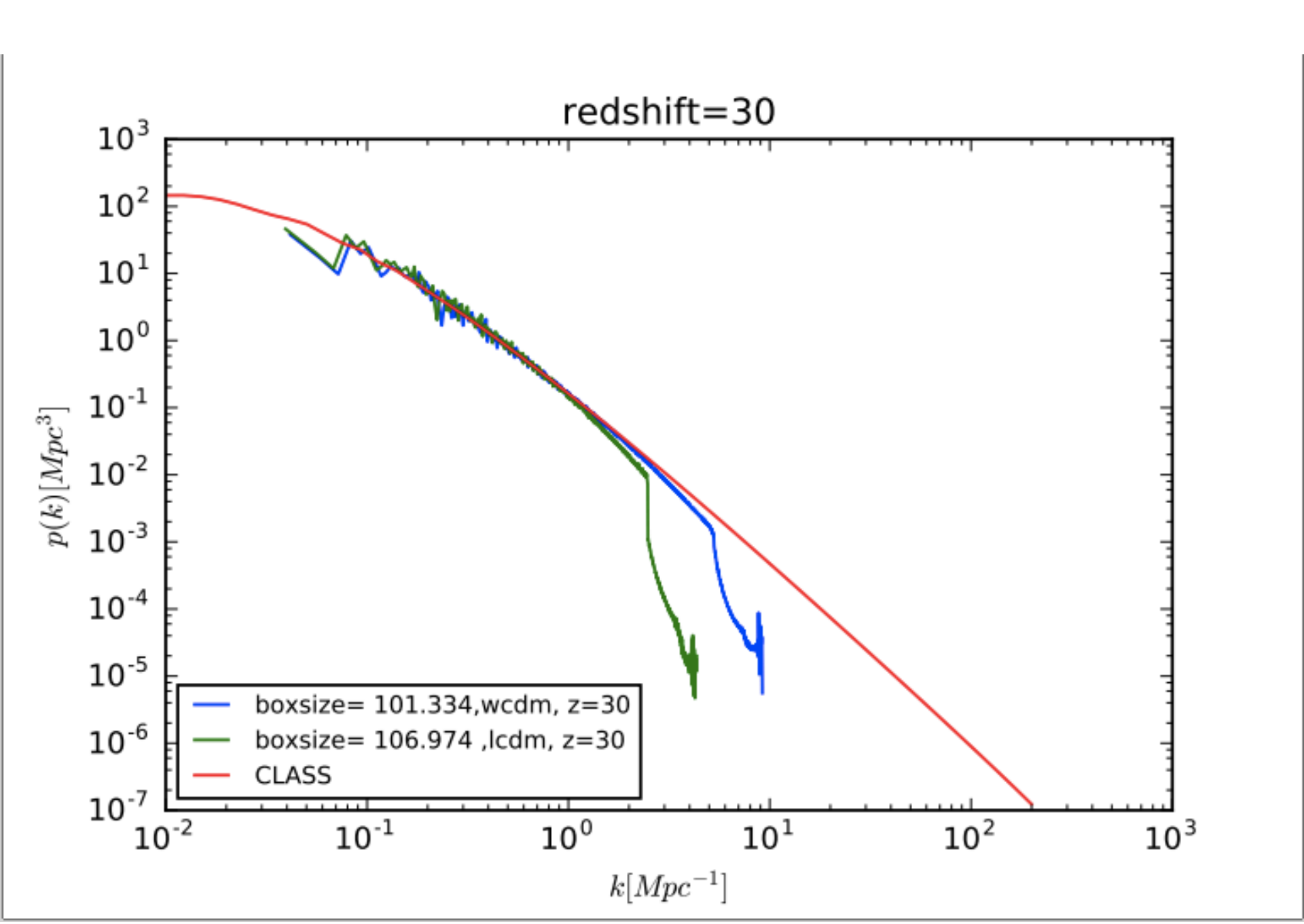
```
# cosmological parameters

h              = 0.71316
omega_b        = 0.022032
omega_cdm      = 0.12038
T_cmb          = 2.7255                  # in units of K
N_ur           = 3.046
Omega_fld      = 0.7199
w0_fld     = -1.1
```

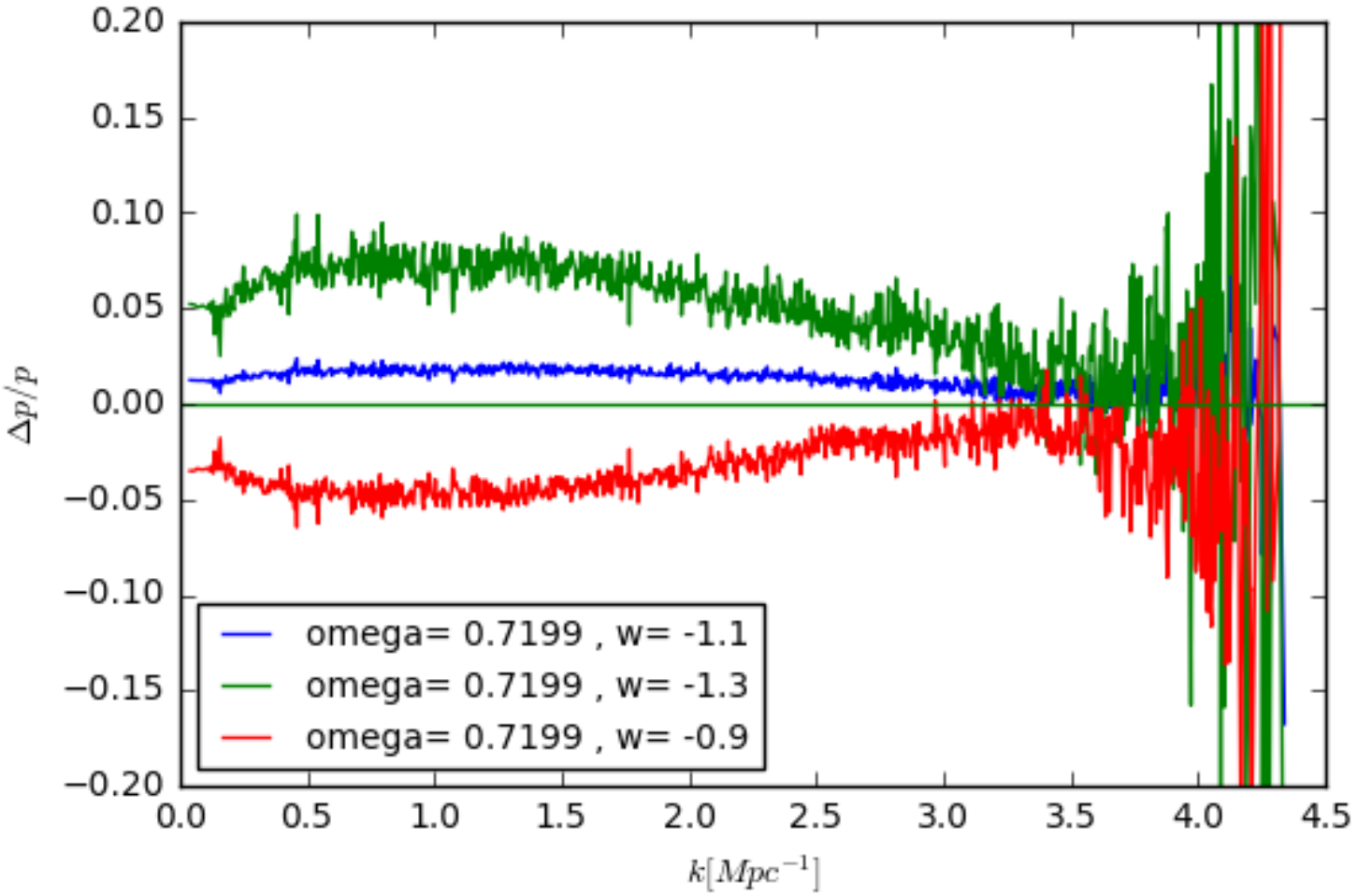
Power spectrums from Gevolution and CLASS




redshift=3
$p(k)[Mpc^3]$
$k[Mpc^{-1}]$
boxsize= 101.334,wcdm, z=3
boxsize= 106.974 ,lcdm, z=3
CLASS


redshift=30
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
$p(k)[Mpc^3]$
10^{-2}
10^{-1}
10^0
10^1
10^2
10^3
$k[Mpc^{-1}]$
boxsize= 101.334,wcdm, z=30
boxsize= 106.974 ,lcdm, z=30
CLASS

Power Spectrum for different values of w



Gracías por su atención