# A minicourse of CAMB Exercises

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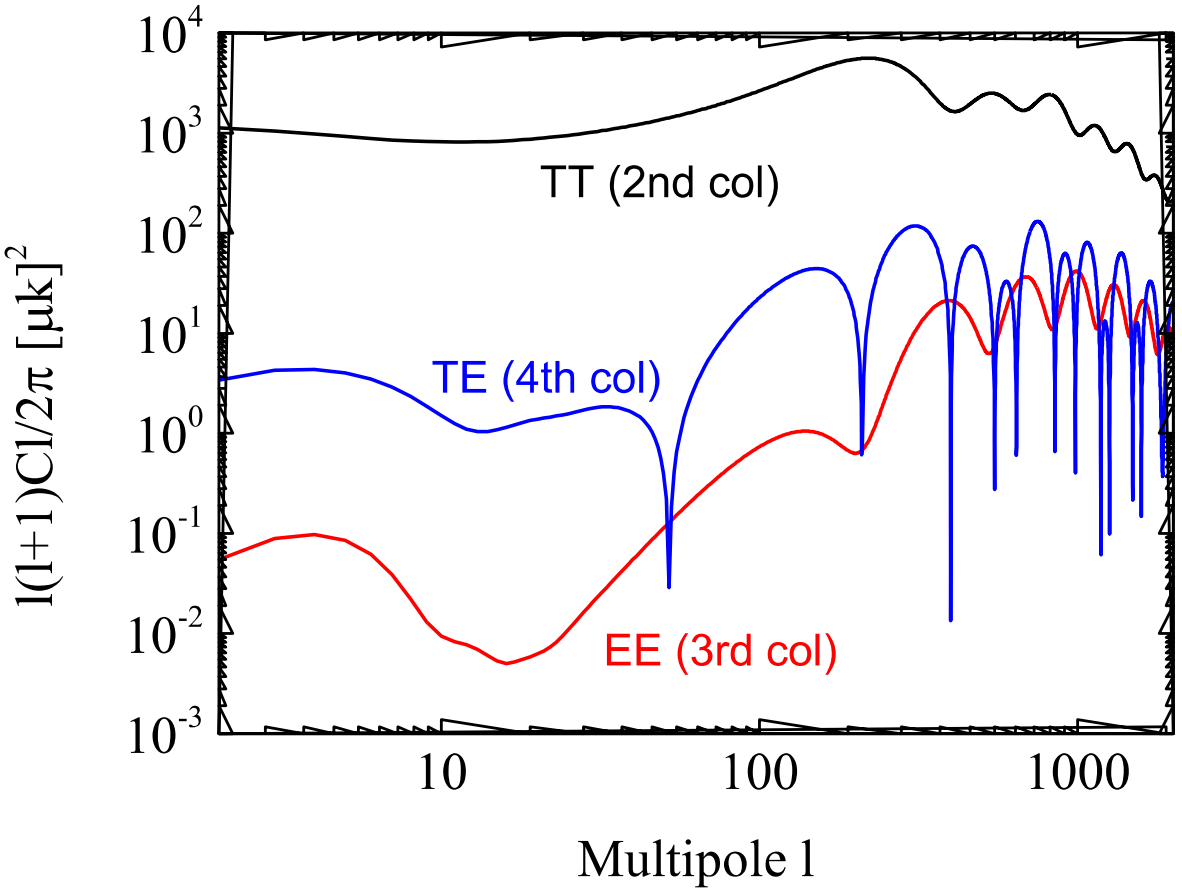
# Ex1: Getting and running default CAMB

Download, compile and run CAMB
camb.info
make clean; make all
./camb params.ini (the default parameter file)

```
Reion redshift       =  10.713
Om_b h^2             =  0.022600
Om_c h^2             =  0.112000
Om_nu h^2            =  0.000640
Om_Lambda            =  0.724000
Om_K                 =  0.000000
Om_m (1-Om_K-Om_L)   =  0.276000
100 theta (CosmoMC)  =  1.039532
N_eff (total)        =  3.046000
 1 nu, g= 1.0153 m_nu*c^2/k_B/T_nu0=    353.71 (m_nu=  0.060 eV)
Reion opt depth      =  0.0900
Age of universe/GYr  =  13.777
zstar                =  1088.72
r_s(zstar)/Mpc       =  146.38
100*theta            =  1.039841
zdrag                =  1059.70
r_s(zdrag)/Mpc       =  149.01
k_D(zstar) Mpc       =  0.1392
100*theta_D          =  0.160271
z_EQ (if v_nu=1)     =  3216.47
100*theta_EQ         =  0.847737
tau_recomb/Mpc       =  284.95  tau_now/Mpc =  14362.3
```

# xxx_scalCls.dat

l CTT CEE CTE [CΦ CΦT]



# xxx_scalCls.dat

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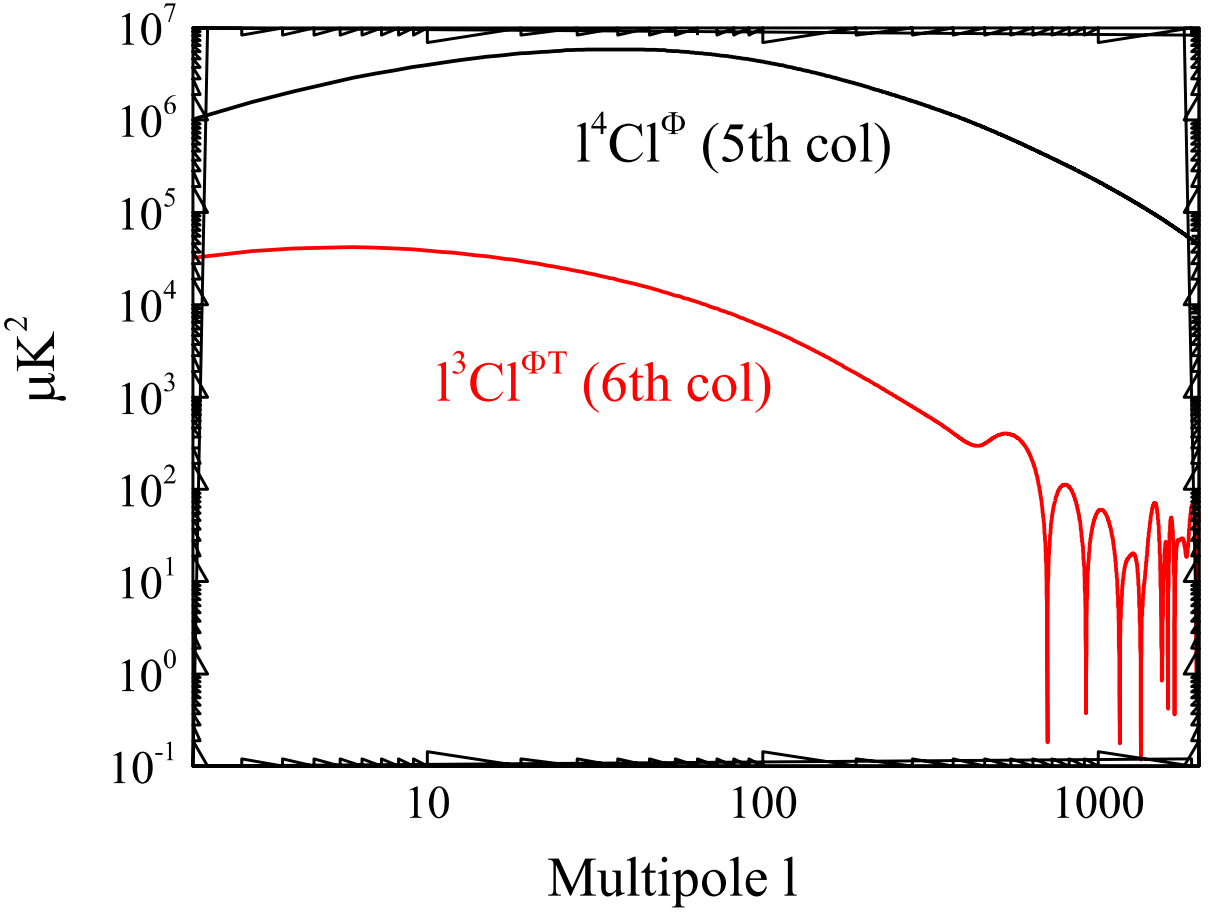
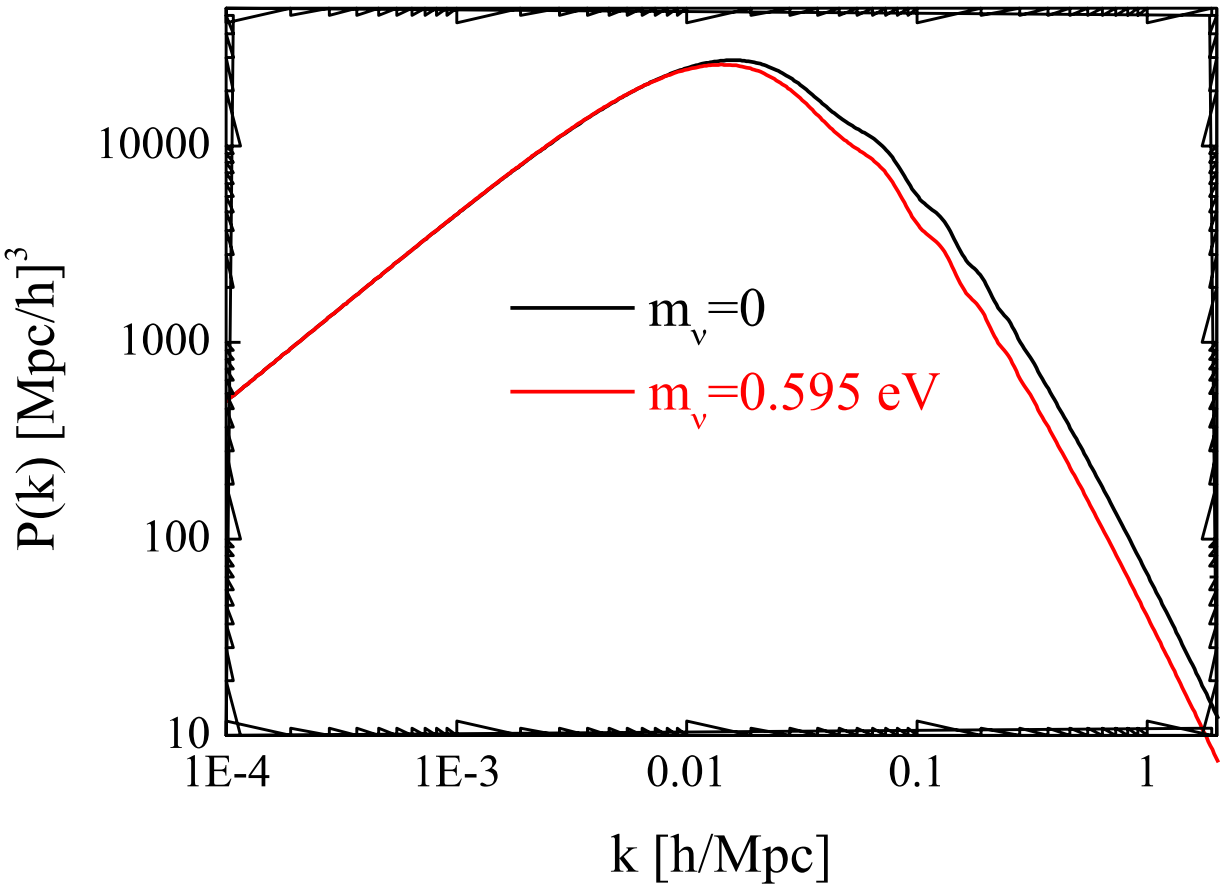


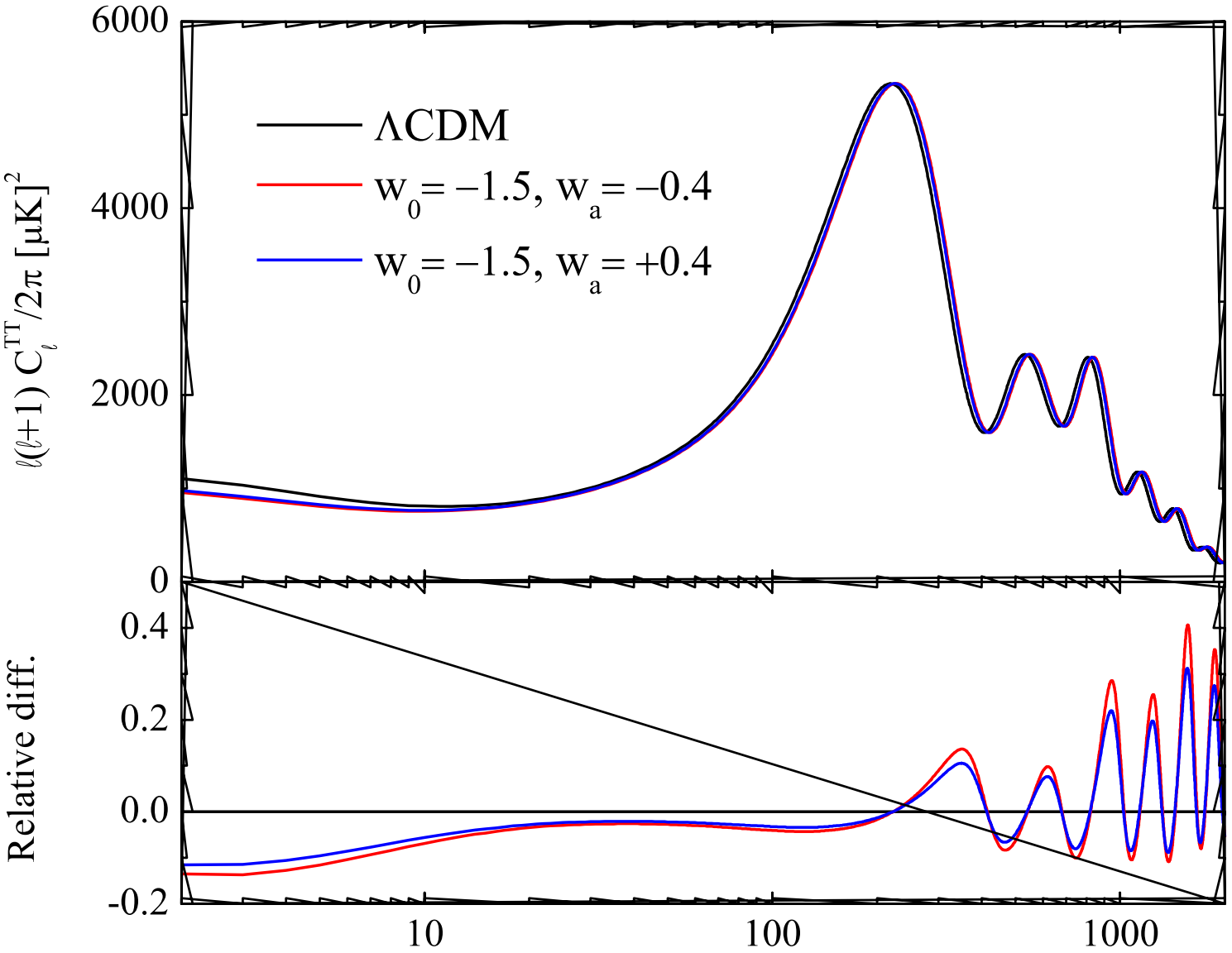
# Ex2: compare matter spectrum w/ and w/o neutrinos (\Omega\nu h2= 0.0064)

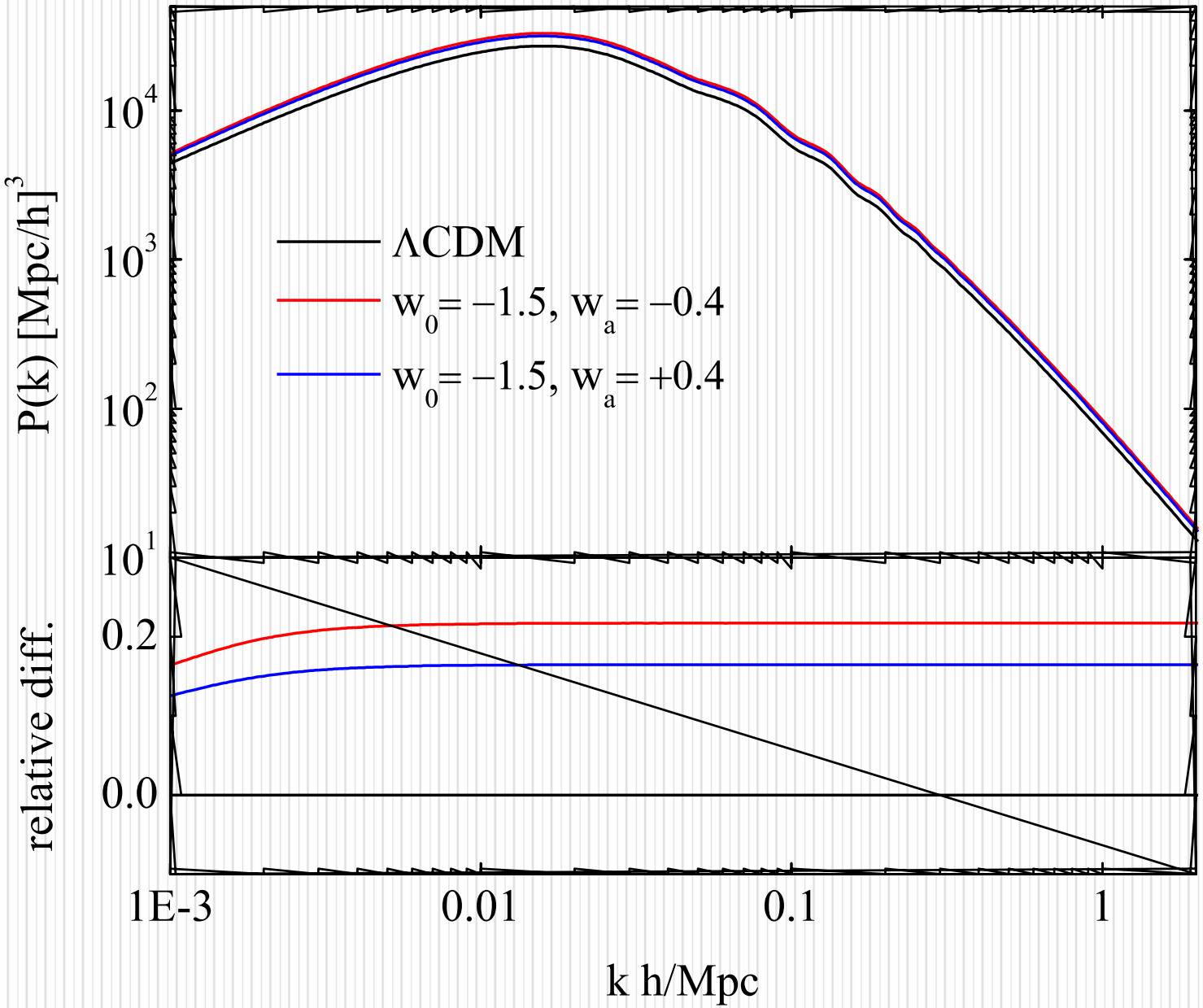
Trick: keep total omm unchanged!


10000
1000
100
10
P(k) [Mpc/h]$^3$
$m_\nu$=0
$m_\nu$=0.595 eV
1E-4
1E-3
0.01
0.1
1
k [h/Mpc]

# Ex3: w0-wa cosmology

Edit Makefile to use equations_ppf.f90, and recompile.
Overplot CMB TT and P(k) for
1.LCDM
2.$W_0$=-1.5, $w_a$=-0.4
3.$W_0$=-1.5, $w_a$=0.4


6000
4000
2000
0
ΛCDM
w0 = −1.5, wa = −0.4
w0 = −1.5, wa = +0.4
ℓ(ℓ+1) C_ℓ^TT/2π [μK]^2
0.4
0.2
0.0
-0.2
Relative diff.
10
100
1000
Multipole ℓ


P(k) [Mpc/h]^3
10^4
10^3
10^2
10^1
ΛCDM
w0 = −1.5, wa = −0.4
w0 = −1.5, wa = +0.4
relative diff.
0.2
0.0
1E-3
0.01
0.1
1
k h/Mpc

# Ex4: Output Dark Energy perturbation $\delta_{DE}(\eta)$, $v_{DE}(\eta)$ at $k=10^{-3}$ Mpc$^{-1}$

1. $w_0=-0.6$, $w_a=0$
2. $w_0=-1.5$, $w_a=-0.4$
3. $w_0=-1.5$, $w_a=0.4$

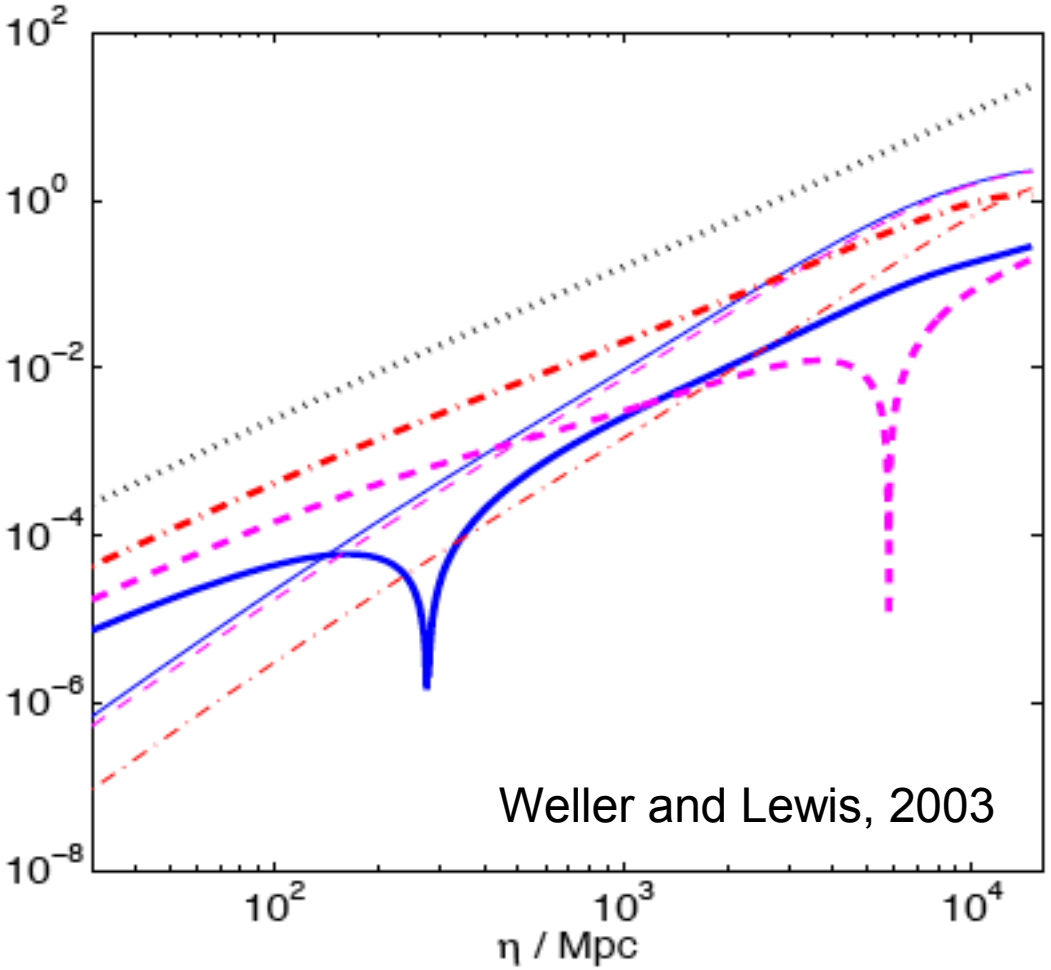



**Figure 4.** Evolution of $|\delta_{\rm de}|$ (thick) and $v_{\rm de}$ (thin) in the frame comoving with the dark matter perturbation (dotted line), for $w = -0.6$ and $\hat{c}_s^2 = \{1, 0.7, 0.1\}$ (solid, dashed and dash-dotted lines), and $k = 10^{-3}\mathrm{Mpc}^{-1}$. Note that we plot the absolute values of the fluctuations with amplitude normalized to unit initial curvature perturbation.

# Ex 4 Output Dark Energy perturbation $\delta_{DE}(\eta)$, $v_{DE}(\eta)$ at $k=10^{-3}$ Mpc$^{-1}$

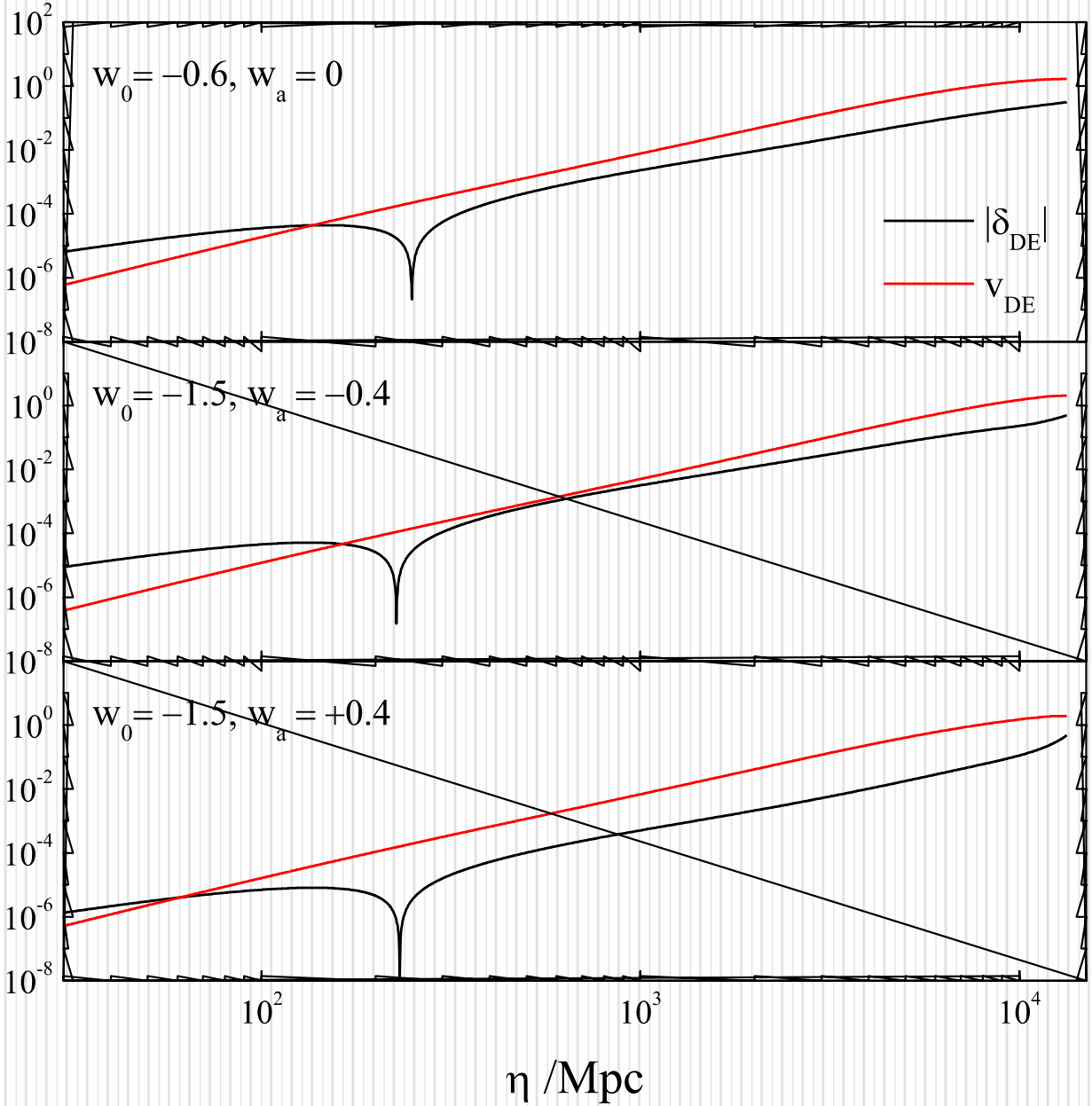
- Note that in CAMB language

$$\delta_{DE} = y(EV\%w\_ix)$$
$$v_{DE} = y(EV\%w\_ix+1)$$

- Uncomment the stuff in cmbmain.f90,

```
EV%q=1.d-3; EV%q2=EV%q**2
 tol1=tol/exp(AccuracyBoost-1)


   do j=1,6000
     tauend = taustart * exp(j/6000._dl*log(CP%tau0/taustart))
     call GaugeInterface_EvolveScal(EV,tau,y,tauend,tol1,ind,c,w)
     write (*,' (4E15.5)') tauend,1/y(1)-1, y(EV%w_ix) ,y(EV
%w_ix+1)
    end do
  stop
```


$10^2$
$10^0$
$10^{-2}$
$10^{-4}$
$10^{-6}$
$10^{-8}$
$w_0 = -0.6,\ w_a = 0$
$|\delta_{DE}|$
$v_{DE}$
$w_0 = -1.5,\ w_a = -0.4$
$w_0 = -1.5,\ w_a = +0.4$
$10^2$
$10^3$
$10^4$
η /Mpc

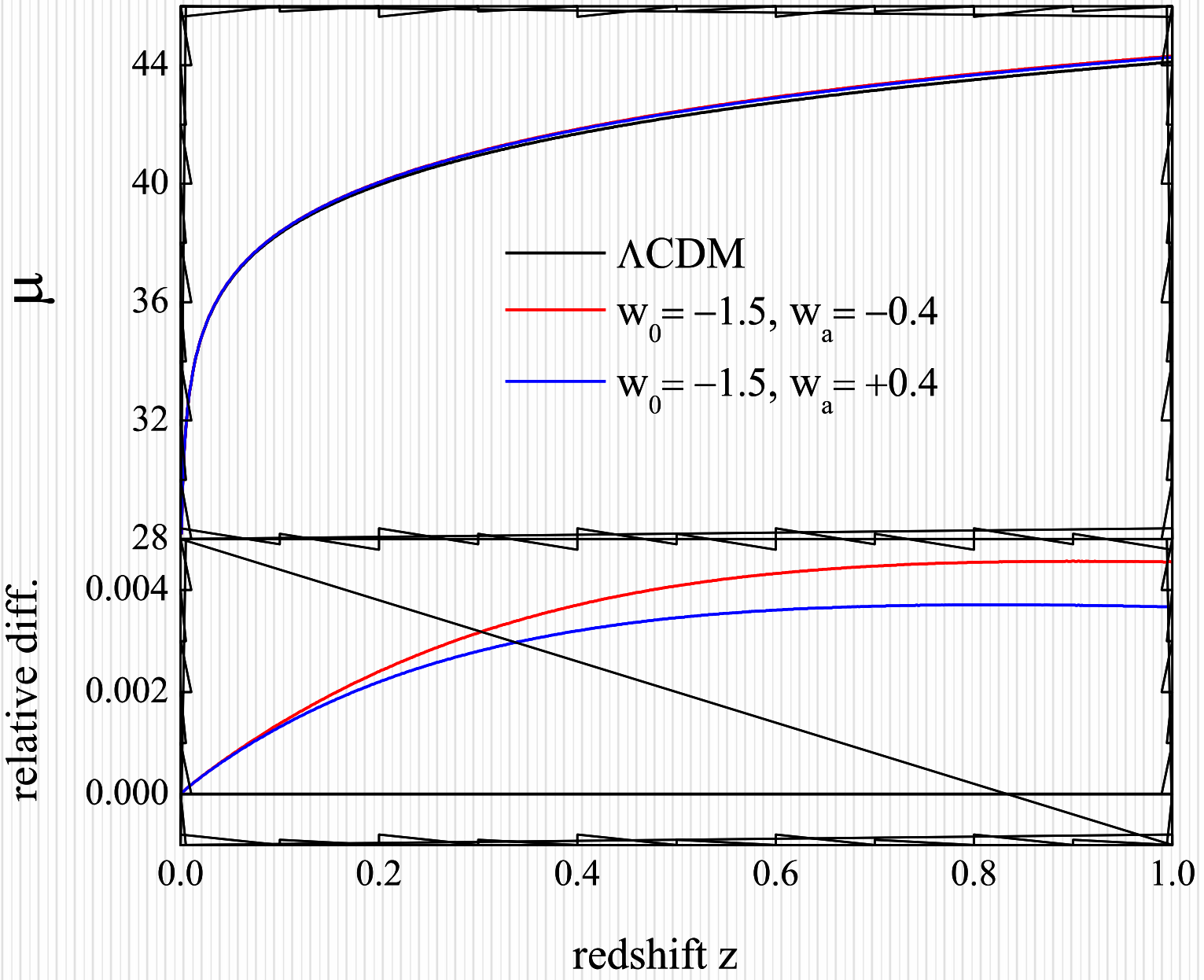
# Ex5: Output luminosity distance $D_L$ for

1. $w_0$=-1, $w_a$=0
2. $w_0$=-1.5, $w_a$=-0.4
3. $w_0$=-1.5, $w_a$=0.4

# Output m

In inidriver.F90

```
open(unit=50,file='dL_SN.dat')
   do i=1, 1000
      zz(i)=1.7d0+dble(i-1)/dble(1000-1)
      write(50,'(100e15.6)') zz(i),
   5*log10((1+zz(i)) &
      **2*AngularDiameterDistance(zz(i)))+25
   end do
close(50)
```


μ
44
40
36
32
28
ΛCDM
w0 = −1.5, wa = −0.4
w0 = −1.5, wa = +0.4
relative diff.
0.004
0.002
0.000
0.0
0.2
0.4
0.6
0.8
1.0
redshift z