

# Summary of decaying mode

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September 17, 2017

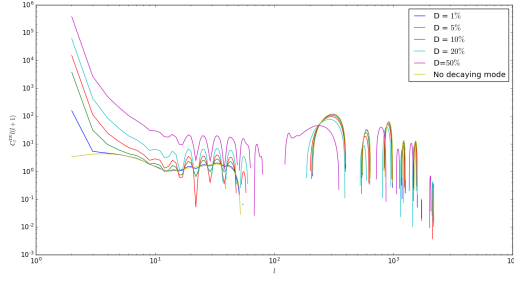
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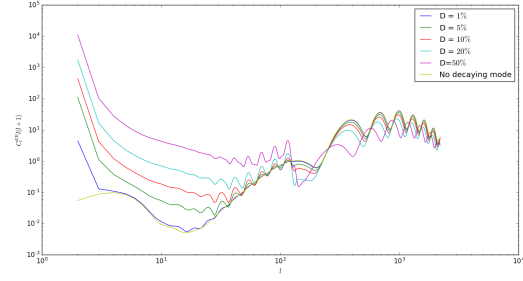
## 1 Introduction to decaying mode

## 2 Low $l$ divergence

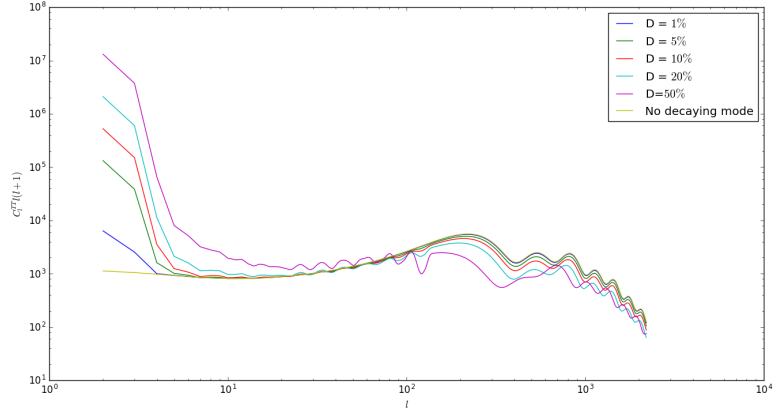
We look at the divergence at low  $l$  in CAMB and CLASS.



(a) TE Cl's



(b) EE Cl's



(c) TT Cl's

Figure 1: Decaying mode figures with  $n_s = 0.96$

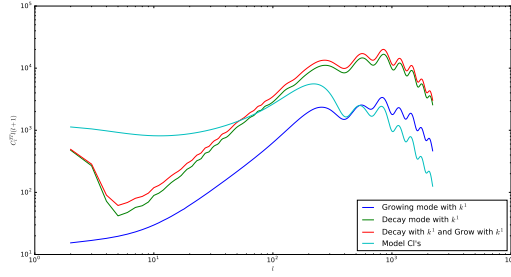
We now look at different spectral indices that are used in [1] in CAMB. The "Model" Cl's are for the canonical cosmology

We now present the same spectral indices as in [1] in CLASS. As Xin showed in class, the low  $l$  divergence goes away for  $n_s = 4$ , i.e the index is  $k^3$ . This suggests, as expected, that there are some rogue factors of  $k$  in the denominator for the decaying mode. There are also some differences in the decaying mode plots in class and camb as seen in figure 3. It might just be a difference in normalization (Multiplying the class Cl's by 4 makes them look similar at high  $l$ ) but I am not sure yet.

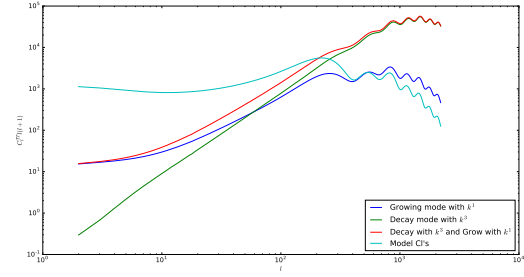
### 3 Solutions attempted

#### 3.1 Change of gauge

Changing the gauge from Synchronus (as is used in CAMB) to Newtonian in CLASS we see no real difference in the Cl's.



(a) TT decaying mode for tilt  $n_s = 1$



(b) TT decaying mode for tilt  $n_s = 3$

Figure 2: Decaying mode figures different tilts

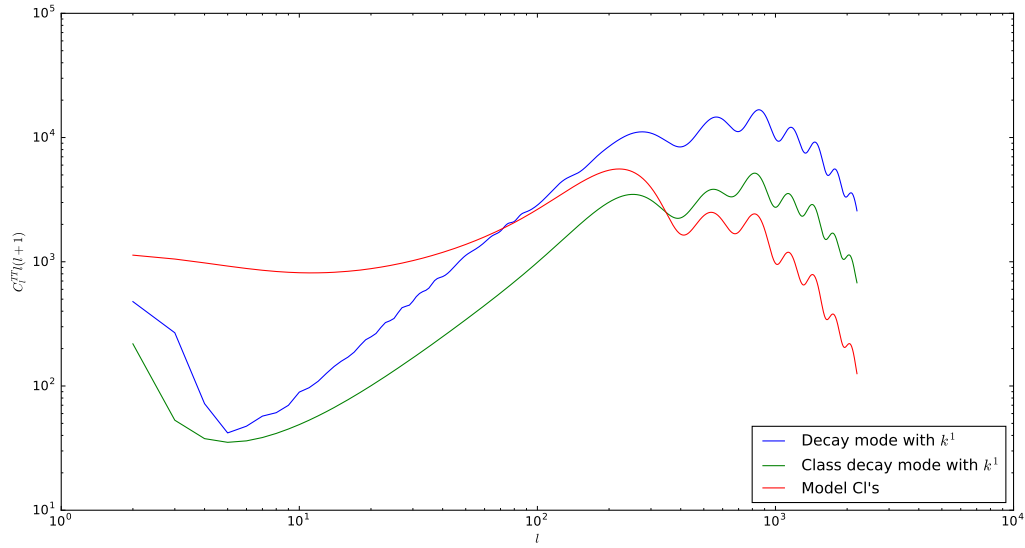


Figure 3: Comparing the CI's for the decaying mode for  $n_s = 1$  in class and camb along with the model CI's.

### 3.2 Try to normalize the transfer function on sub horizon scales

Various attempts have been made to normalize the decaying mode. In particular we have tried to use the high  $k$  transfer functions to find a function of  $ell$  to normalize the CI's by. It hasn't been successful yet.

As a comparison, we have the growing mode transfer function:

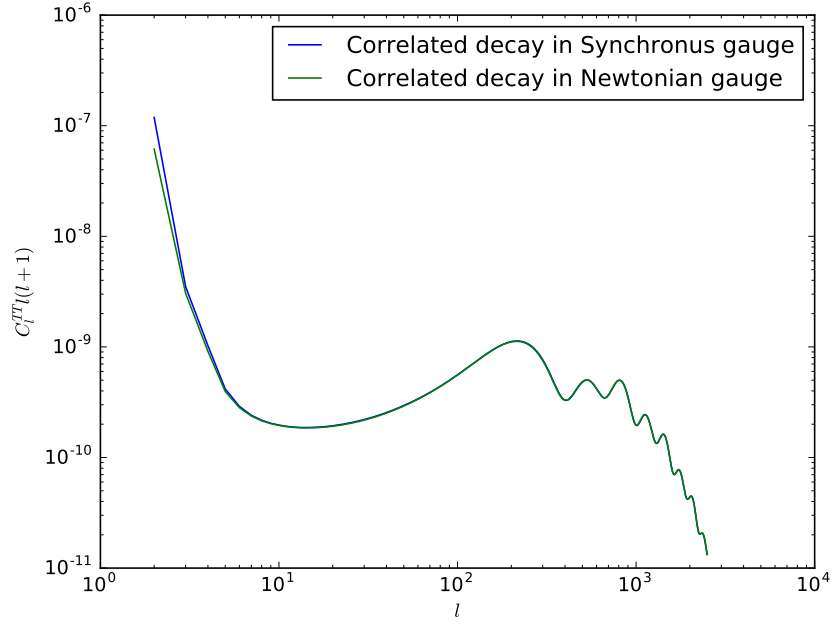


Figure 4: Cl's in Newtonian and Synchronous gauge.

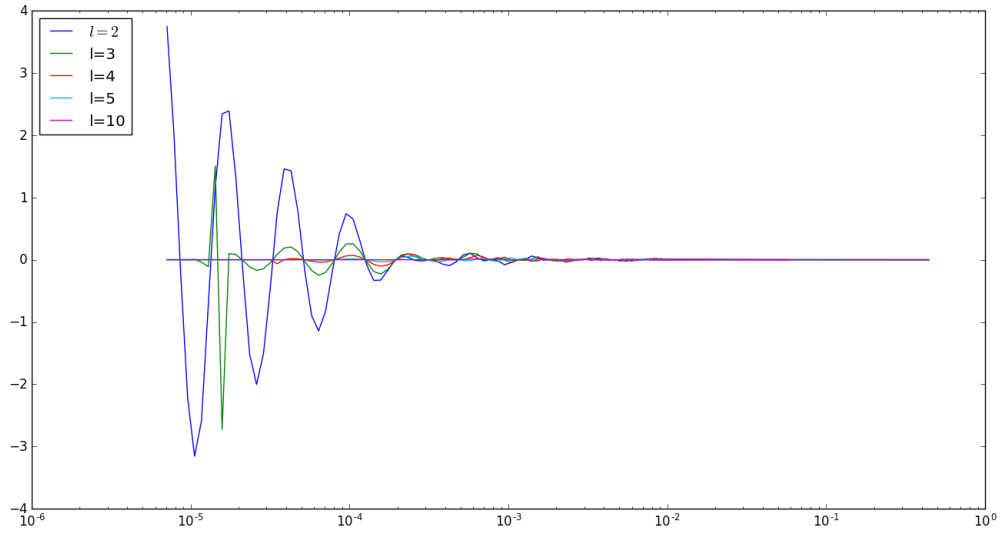


Figure 5: Transfer function for the decaying mode for various  $ell$ s.

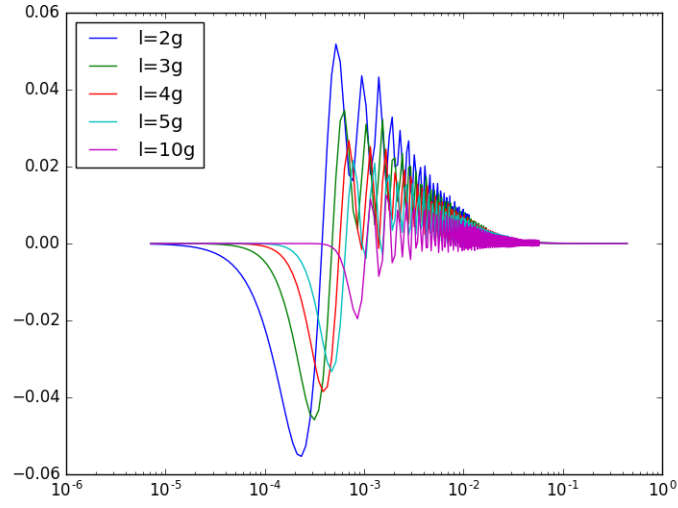


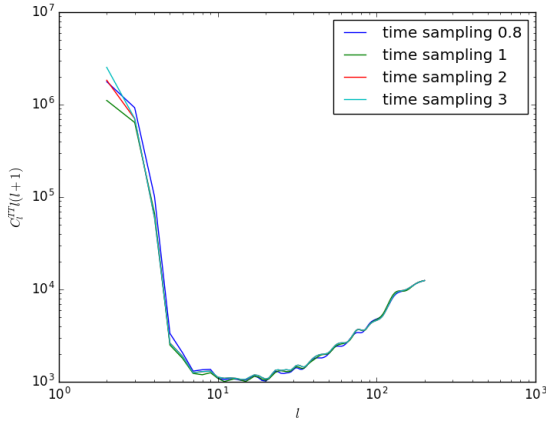
Figure 6: Transfer function for the growing mode for various  $l$ s.

### 3.3 Change accuracy settings

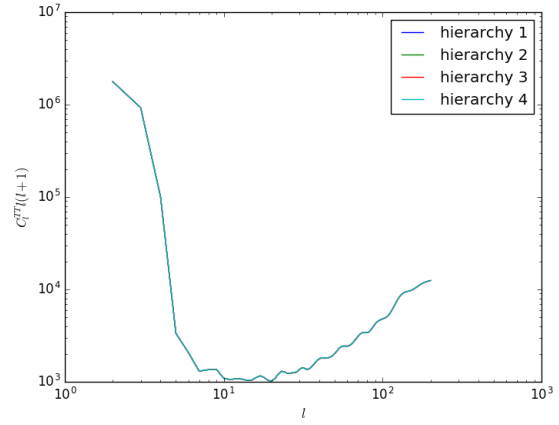
Changing the accuracy settings does not effect the divergence at low  $l$ .

### 3.4 The transfer functions for different redshifts

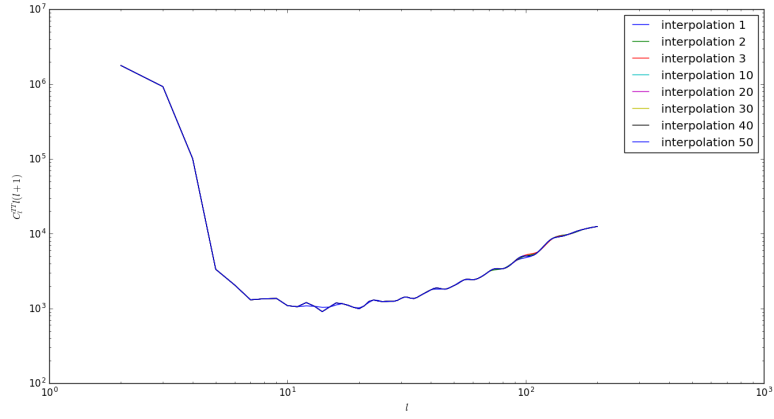
Currently working on it - Daan provided first plots.



(a) TE Cl's



(b) EE Cl's



(c) TT Cl's

Figure 7: Checking various accuracy settings in CAMB

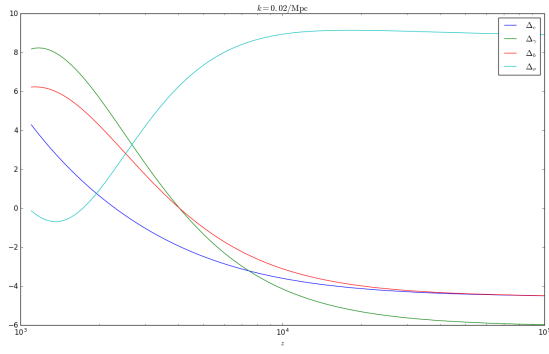
### 3.5 Radiation dominated universe

We see that the photon density  $\Delta_\gamma$  is effected by the decaying mode as seen in the density evolution plots. In particular the initial amplitude is much higher for the decaying mode.

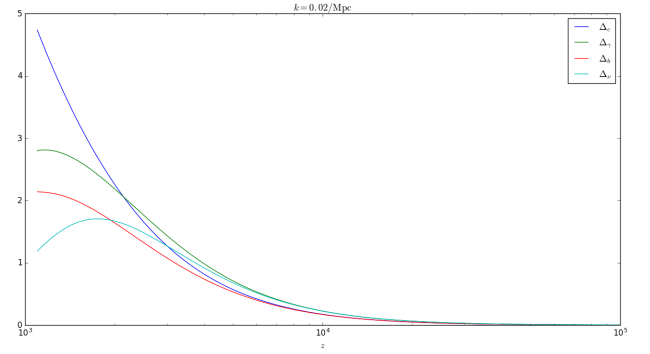
Furthermore we can look at the radiation dominated universe by increasing  $N_{eff}$ .

Doesn't effect the low  $l$  divergence.

Surprisingly it appears that the decaying and growing modes are in phase for  $\Delta_\gamma$ . One would expect the phase of the oscillation to be apparent in these modes.



(a) Decaying mode for  $k = 0.02$



(b) Growing mode  $k = 0.02$

Figure 8:  $\Delta_\gamma$  evolution for decaying and growing modes

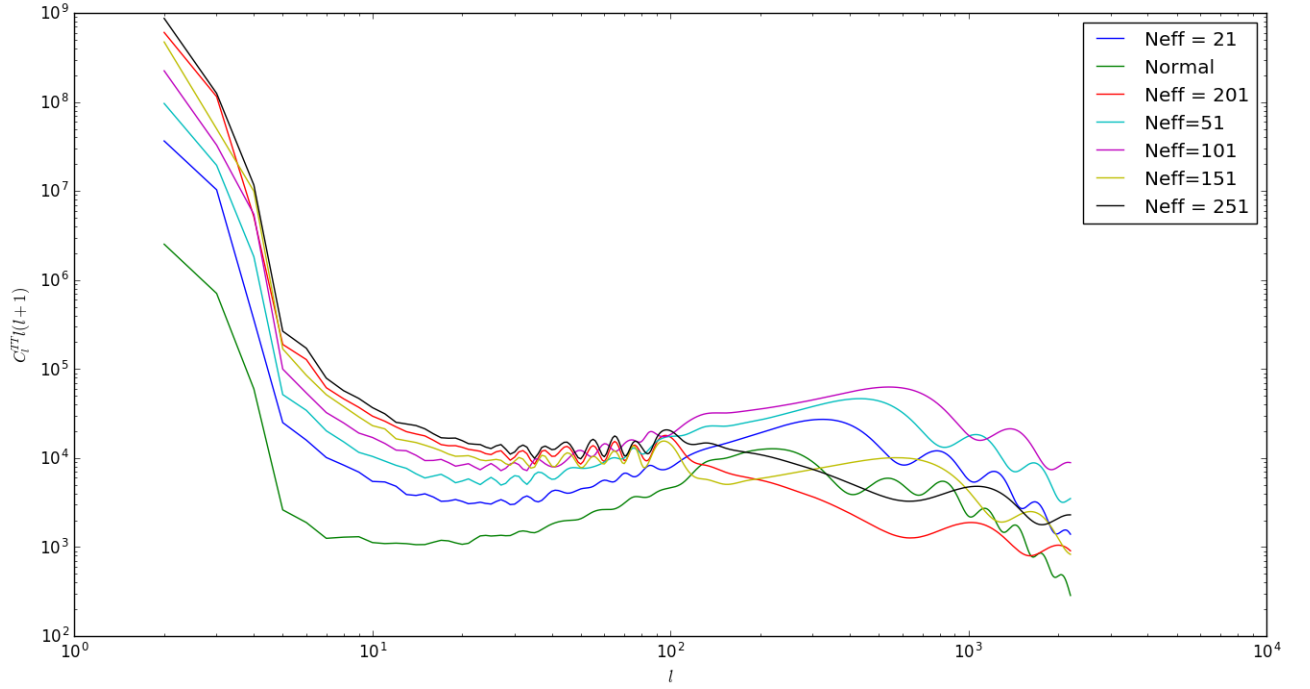


Figure 9:  $C_l$ 's for a range of  $N_{eff}$ .

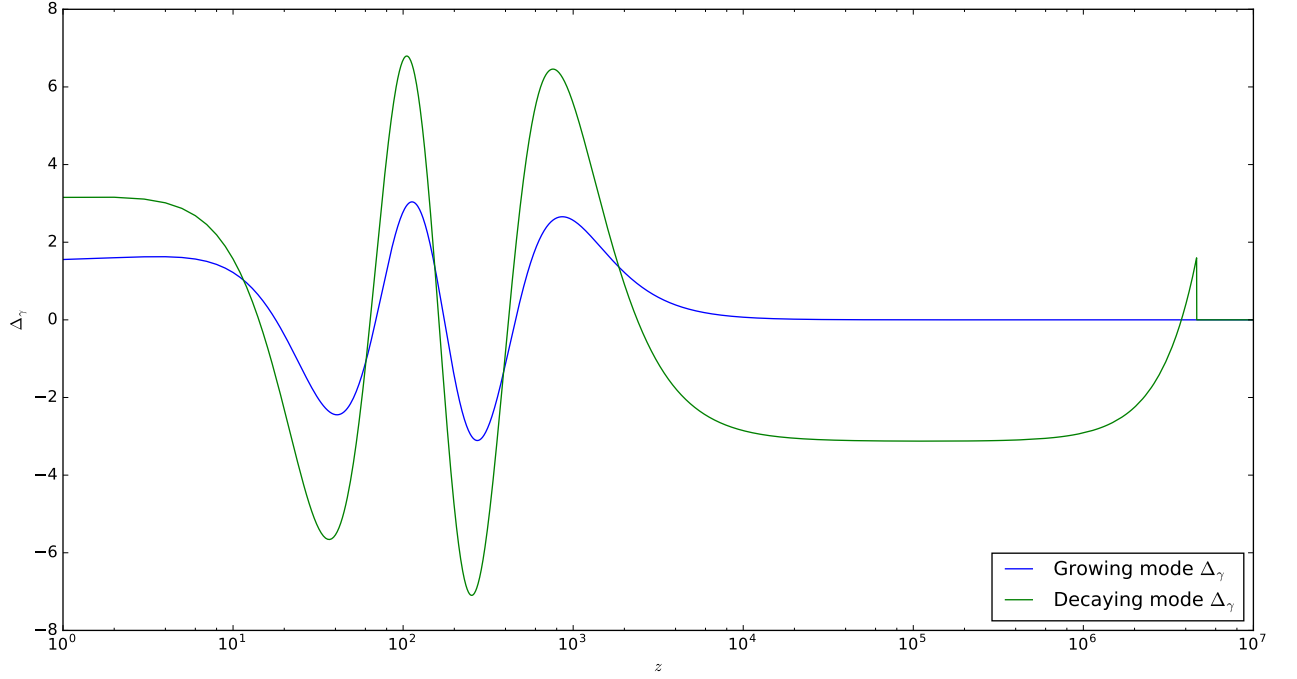


Figure 10: Comparing the evolution of  $\Delta_\gamma$  for decaying and growing modes for  $k = 0.1 \text{ Mpc}^{-1}$ .

### 3.6 More to follow...

## References

- [1] L. Amendola and F. Finelli, Phys. Rev. Lett. **94** (2005) 221303 doi:10.1103/PhysRevLett.94.221303 [astro-ph/0411273].