Assigned: Friday, January 14, 2022 **DMDE Exercise 5**
Due: 13:00, Wednesday, January 26, 2022 12 points + 24 bonus

Note that submitted solutions should be in PDF format and include the code that produced your plots. Send any questions to hannah.mccall@uni-bonn.de, or attend office hours on January 21st!

Problem 1: Type Ia Supernovae (7 points)

Use the data from `SN_z_mV.txt` on eCampus for this problem.

a) Assuming the absolute magnitude of a Type Ia supernova is $M_V = -19.6$, plot the observed distance modulus $\mu = m_V - M_V = 5\,log_{10}\left(\frac{d_L}{10pc}\right)$ of all the SNIa as a function of redshift. (2 points)

b) Choose at least three different combinations of cosmological parameters and plot the distance moduli for each of these cosmologies on top of the previous plot. Python users may find the `astropy.cosmology` package useful here. (3 points)

c) Explain what you see in your plot. (2 points)

Problem 2: The CMB (5 points + 24 bonus)

For this question, use the online CAMB solver. Uncheck the "Do Lensing" option in *Actions to Perform*. The options you now see will be referred to as **our defaults**. Do NOT simply paste the figures from the online results for your answers.

a) Download the data (*Scalar Output*) and plot TT, EE, and TE on a single plot with the multipole moment l on the x-axis. Note that the columns in the downloaded .dat file correspond to l, TT, EE and TE respectively. Make sure to note the units of power. (3 points)

b) With our defaults, plot the temperature and polarization power spectra on their own plots. (2 points)

c) Modify only the values of $\Omega_b h^2$ to be in the range from 0.01 to 0.1. Take three values other than the default value. Plot the resultant spectra for temperature and polarization together with the default value results. Explain the differences that you see. (BONUS 8 points)

d) Repeat everything from part (c), but this time change $\Omega_b h^2$ back to the default and change only $\Omega_c h^2$ to any three other values between 0.05 and 0.2. (BONUS 8 points)

e) Change all values back to defaults, and then modify the Hubble constant first to $h = 0.45$ and then to $h = 0.95$. In each of these cases, for what values of Ω_K can we approximately reproduce the acoustic peaks as seen in the default plots? Also note down Ω_m and Ω_Λ in these cases and comment on their values. (BONUS 8 points)