Using CAMB to Change Cosmological Values in the Universe

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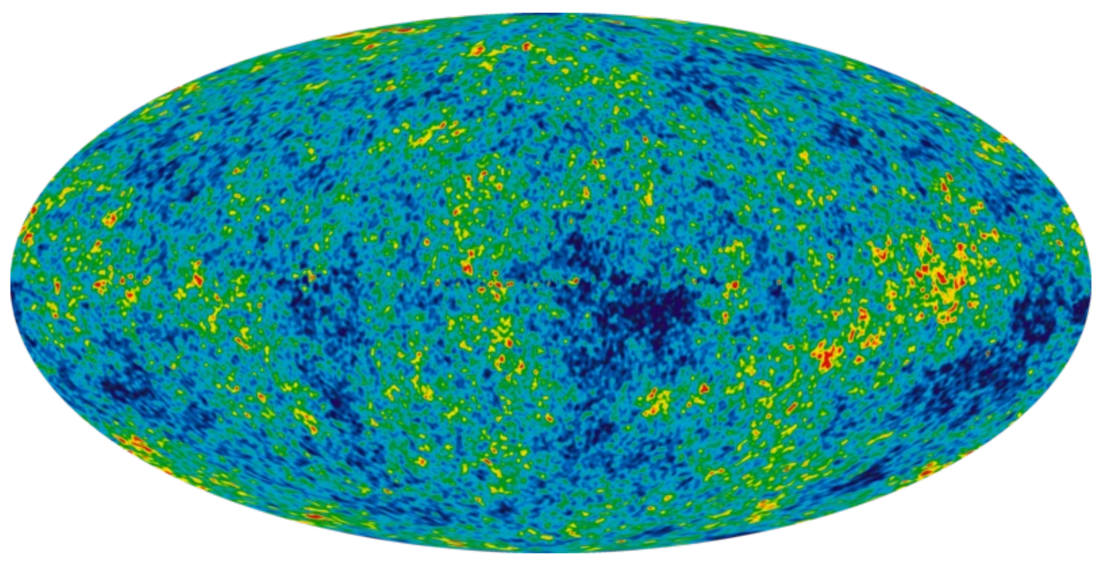
CMB and CAMB

The cosmic microwave background (CMB) is the remnant of the first light that could ever travel freely throughout the universe. It consists of the blackbody photons produced by the early universe and the density fluctuations of this hot, dense early universe can be seen within it.

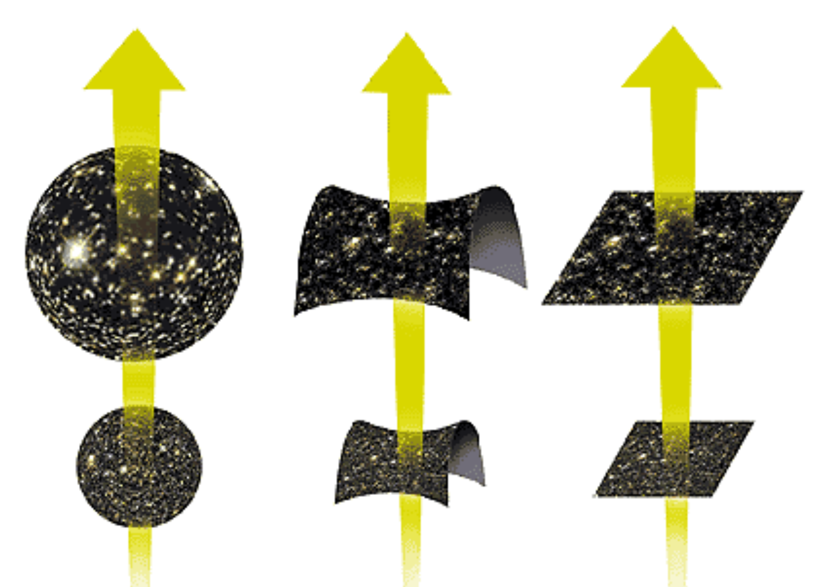
The Code for Anisotropies in the Microwave Background (CAMB) is an application that computes cosmic microwave background (CMB) spectra given a set of input cosmological parameters. Parameters such as baryon density, the Hubble Constant, and CMB temperature were changed to see how this would affect the CMB map as we know it today.



(Fig. 1)

Closed, Open, or Flat Universe

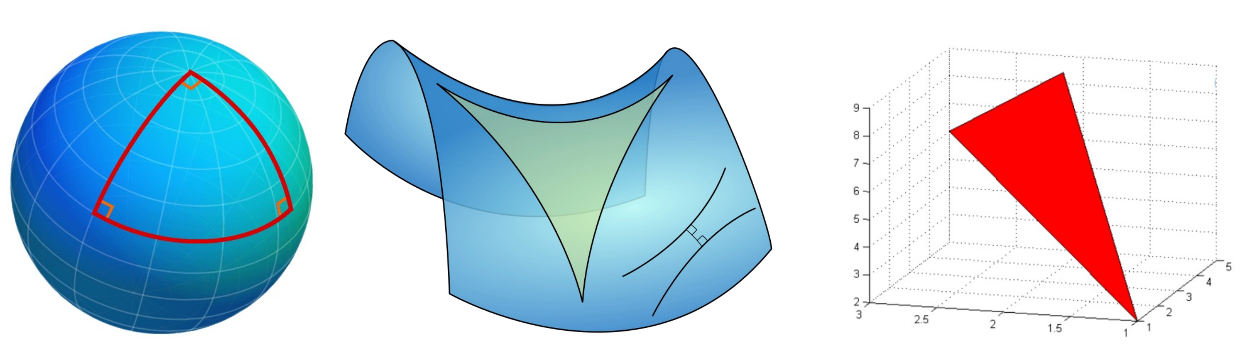
There are three possibilities for the shape of the universe, aka the curvature of spacetime: closed, open, and flat. While these are impossible to picture in 3D, in 2D a closed universe would resemble a sphere, an open universe would resemble a saddle, and a flat universe would be like a sheet of paper.



Closed Universe Open Universe Flat Universe

(Fig. 2)

As can be seen below, angles in a closed universe are slightly greater than those in a flat universe while angles in an open universe are slightly less than those in a flat universe.



Closed Universe Open Universe Flat Universe

(Fig. 3)

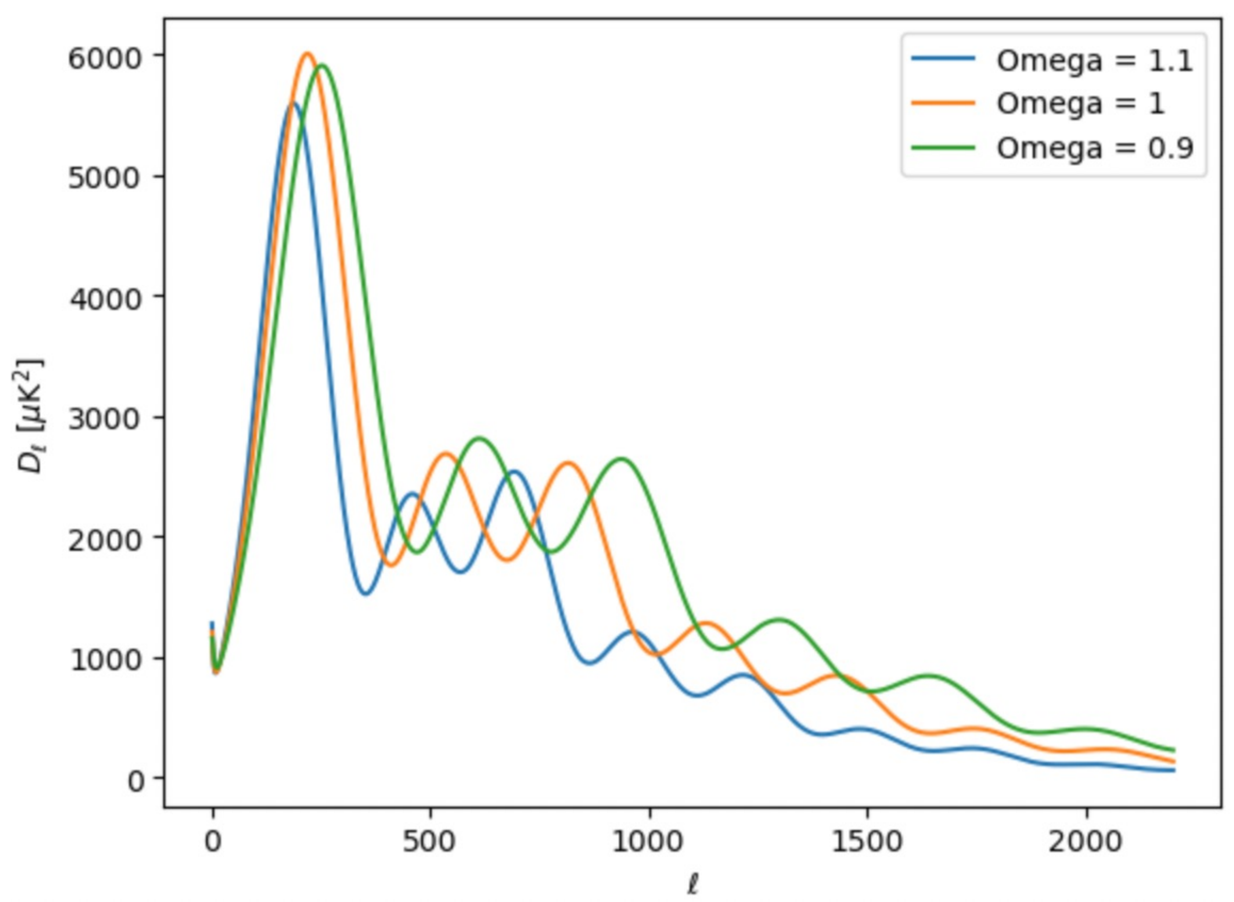
Changing Omega (Ω)

The average density of the universe determines if it's closed, open, or flat, and also ultimately determines the fate of the universe (i.e. if it will expand forever or eventually re-collapse). The value of average density describing the boundary between these two possibilities is called the critical density.

Ω (omega) represents the fraction of the actual density of the universe compared to the critical density.
If $\Omega > 1$, then the universe is closed and will eventually re-collapse.
If $\Omega < 1$, then the universe is open and will expand forever.
If $\Omega = 1$, then the universe is flat and has critical density.

Many independent observations indicate that the universe is in fact flat and has an omega value of 1.

In CAMB, there are a few different parameters of omega which can be changed, including baryon density, cold dark matter density, etc., their sum being 1. In order to change the total value of Ω, each of these values was scaled either up or down by the same amount, which resulted in the power spectrum map below.

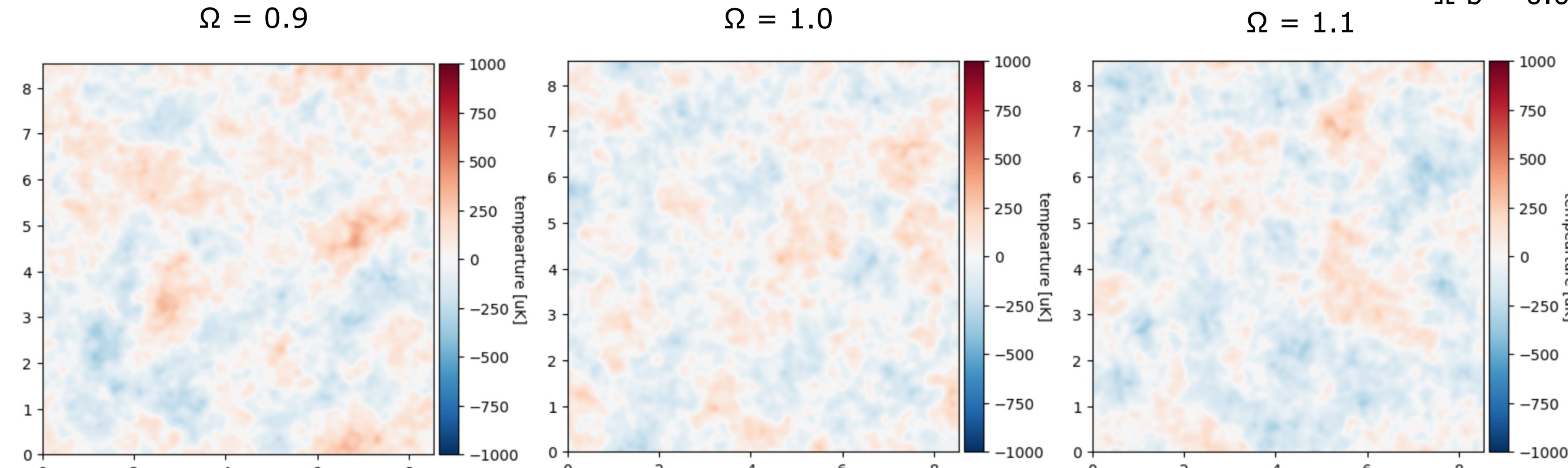


(Fig. 4)

As can be seen in this graph, a lower omega value shifts the power spectrum to the right while a higher omega value shifts it to the left. This is because the x-axis corresponds to the inverse of angular degrees (the higher the l value, the smaller the angular degree). Looking at figure 3, this makes sense since angles are bigger in a closed universe and smaller in an open one.

Below are the CMB maps for the power spectra depicted above. Unfortunately, there isn't enough of a difference in the spectra for there to be a visible pattern in these maps.

$\Omega = 0.9$ $\Omega = 1.0$ $\Omega = 1.1$



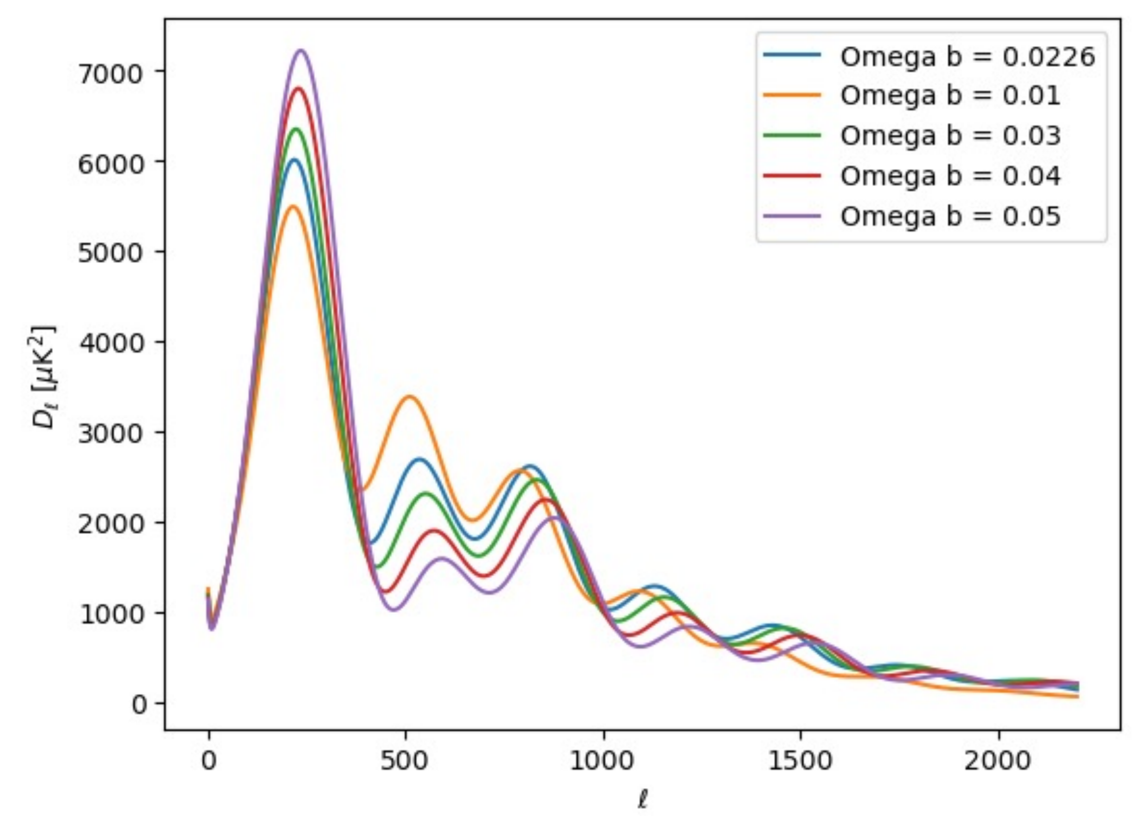
(Fig. 5)

Changing baryon/ordinary matter density ($\Omega_b h^2$)

The baryon density tells us how many baryons, which consist of protons and neutrons, there are in the universe. Various objects are made up of baryons including planets, black holes, stars, and other objects.

The CMB power spectrum and Big Bang Nucleosynthesis (BBN) theory along with deuterium abundance (D/H) measurements determine that today's universe is made up of about 4-5% of baryons, making the baryonic density equal to about $\Omega_b h^2 = 2.239$.

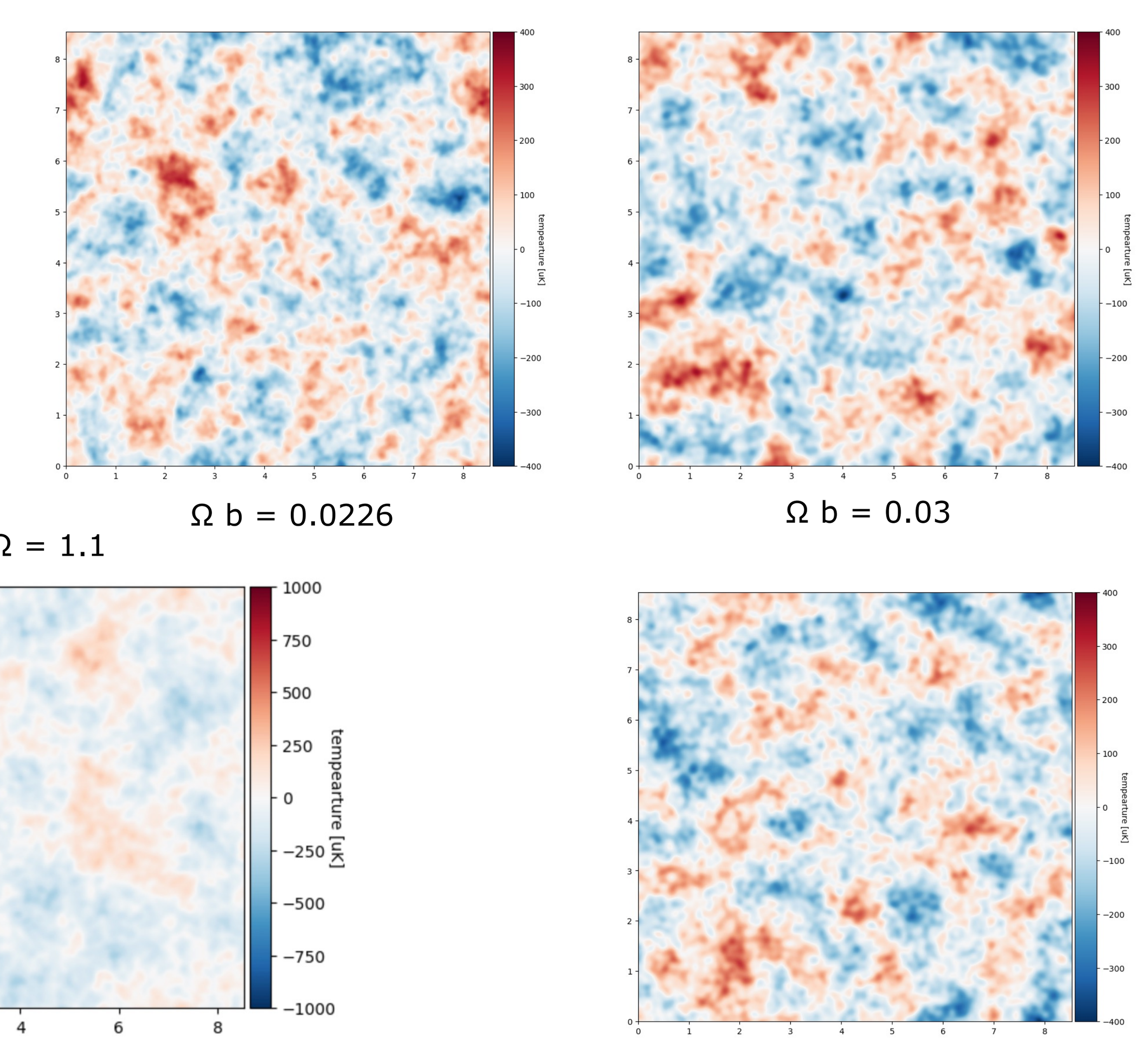
The power spectrum experiences a rise in the odd numbered peaks above the even numbered peaks. This is demonstrated in the graph below as the omega b value is changed between the range of 1-5% within the simulation.



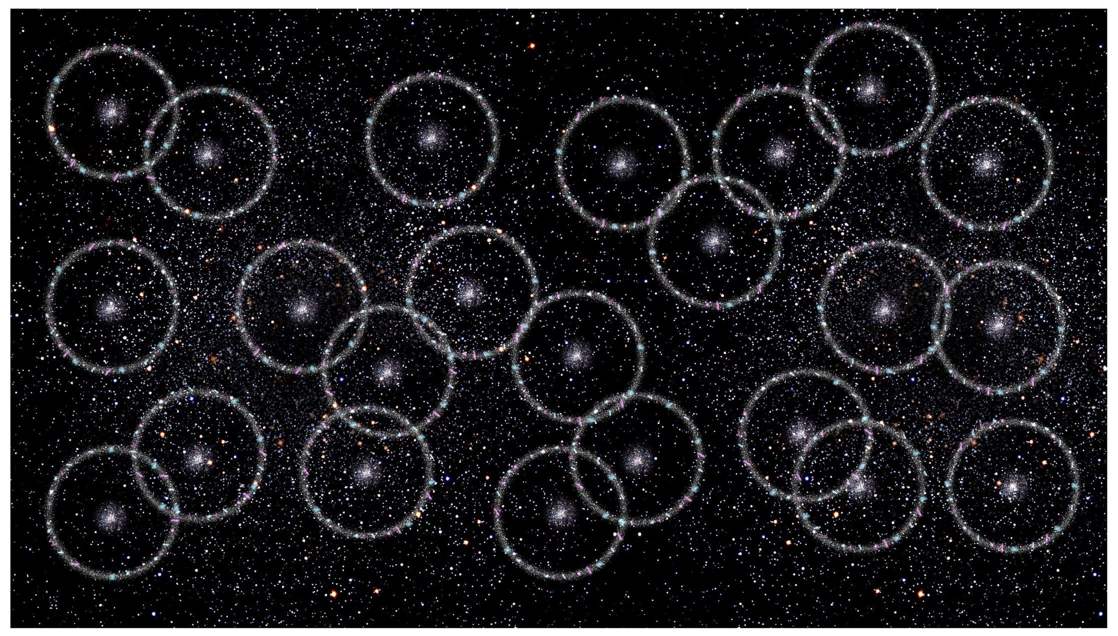
(Fig. 6)

The CMB temperature maps below do not appear to include a pattern as the baryon density decreases or increases.

(Fig. 7)



Baryon acoustic oscillations



(Fig. 8)

Conclusion

The CMB also known as the cosmic microwave background the leftover of the first light which is made up of blackbody photons from the Early universe. The CAMB also known as the Code for Anisotropies in the Microwave Background is used to find the CMB spectra using cosmological parameters like the baryon density, and Hubble constant.

Three possibilities for the shape of the universe are determined using the average density of the universe also known as Omega. An omega value that is less than 1 means it is a closed universe that will re-collapse. An omega value greater than 1 means the universe is open and will expand forever and an Omega value equal to 1 means the universe is flat with a critical density. Observations suggest that the universe has an omega value equal to 1.

Baryons are made up of protons and neutrons; the number of baryons determines the baryon density. The universe is made up of about four to five percent of baryons with a baryon density of about 2.239.

References

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