17.6: Wrapping It Up 17 - Cosmological Parameter Estimation

Scientists working with supernova, CMB, and large-scale structure data have determined to high precision the ingredients making up the Universe. From these data, scientists have constructed a pie chart depicting the matter and energy budget of the Universe (Figure A.17.9).

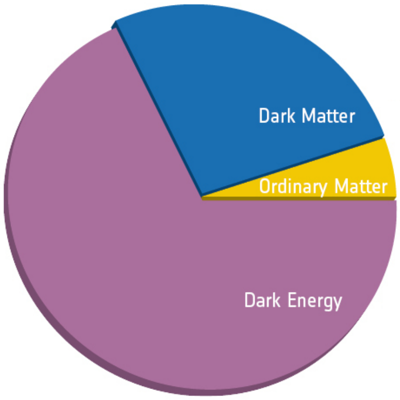

Figure A.17.9: Ordinary matter represents only a small portion of the total mass-energy inventory of the Universe. Dark energy, which is responsible for accelerating the expansion of space, accounts for the majority of the budget. Credit: ESA/Planck

In this activity, you will use data from various cosmological measurements in order to determine the values of several cosmological values: the amount of matter (Ω_m), which is comprised of regular baryonic matter and cold dark matter, and the amount of dark energy (Ω_{DE}).

You should notice that there are constraints on Ω_m and Ω_{DE} from three different measurements:

- Supernovae (SNe, blue region)
- The cosmic microwave background (CMB, orange region)
- Large-scale structure baryon acoustic oscillations (BAO, green region)

Click on each cosmological source to pull up confidence regions for the measurement.

For a given source, the combination of Ω_m and Ω_{DE} has a 68% chance of falling within the smallest region, 95% chance of falling within the next larger region, and a 99% chance of falling within the entire shaded region. A 99% confidence region means that the true value will lie outside the region only 1% of the time. In other words, we are 99% confident that the true value lies inside the region bounded by the contour.

Play Activity

Part I: Individual Measurements

1. Plot the BAO measurement. With 99% confidence, what is the range of values for Ω_m?

Cannot determine from this data

0.15 – 0.30

0.15 – 0.45

0.20 – 0.40

0.25 – 0.45

2. With 68% confidence, what is the range of values for Ω_m from BAO alone?

Cannot determine from this data

0.15 – 0.30

0.15 – 0.45

0.20 – 0.40

0.25 – 0.45

3. Within 68% confidence, what is the range of values for Ω_{DE} from BAO alone?

Cannot determine from this data

0.15 – 0.45

0.20 – 0.40

0.60 – 0.80

4. Overall, with 99% accuracy, do measurements from BAO alone constrain Ω_m, Ω_{DE}, or both?

m"> constrains only Ω_m

DE"> constrains only Ω_{DE}

constrains both

5. Now click the measurements from the CMB only to constrain the region of possible values for Ω_m and Ω_{DE}. Overall, with 99% accuracy, does this measurement alone constrain Ω_m, Ω_{DE}, or both?

m"> constrains only Ω_m

DE"> constrains only Ω_{DE}

constrains both

6. Now click the measurements from the supernovae (SNe) only to constrain the region of possible values for Ω_m and Ω_{DE}. Overall, with 99% accuracy, does this measurement alone constrain Ω_m, Ω_{DE}, or both?

m"> constrains only Ω_m

DE"> constrains only Ω_{DE}

constrains both

Part II: Combining measurements

1. As you click to add additional cosmological measurement sources, the size of the overlapping region

increases

decreases

stays the same

2. Combing the confidence regions of both the BAO and CMB, with 68% confidence, what is the range of values for Ω_m?

cannot determine from this data

0.22 – 0.39

0.29 – 0.32

3. Combing the confidence regions of both the BAO and CMB measurement, are Ω_m and Ω_{DE} constrained to within 99% confidence?

m"> constrains only Ω_m

DE"> constrains only Ω_{DE}

constrains both

4. Click on various combinations of BAO, CMB, and SNe. Which pair of measurements gives the smallest range of values for Ω_m?

BAO+CMB

BAO+SNe

CMB+SNe

5. Which pair of measurements gives the smallest range of values for Ω_{DE}?

BAO+CMB

BAO+SNe

CMB+SNe

6. With all three measurements checked, you should see a set of gray/black confidence regions. What is your best estimate of the matter density fraction, Ω_m from all measurements combined?

7. What is the best estimate of the dark energy density fraction, Ω_{DE} from all measurements combined?

8. You should also see a line labeled “flat,” which denotes the region of this plot where the total density, Ω, is equal to 1. In other words, $\Omega_m + \Omega_{DE} = 1$. If the combined values of Ω_m and Ω_{DE} fall below and to the left of this line, what type of Universe would that indicate?

a flat universe

one that will expand forever

one that will collapse eventually

9. The gray region indicates that the best fit for the geometry of the Universe is:

flat ($\Omega = 1$)

1)"> spherical ($\Omega > 1$)

saddle-shaped ($\Omega < 1$)