

Week 6 Notes

Astro 2 (Discussion Section 102)

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Administrative Tasks

Sargazing

Remember that our stargazing night will take place **this** Monday. We'll meet at 9:00 in front of the elevators in Broida. The even should last no more than an hour and is not for extra credit.

Homework and Midterm 2 reminder

Homework 3 is on the way. Remember that homework 5 isn't due this Friday, but the next Friday. Also recall that midterm 2 is scheduled for Monday, May 17, so next week will be another review session. Come with questions!

Midterm 1 is back!

I'll hand Midterm 1 back to students and explain the curve at the end of class.

Review

A Quick Note on Problem 1

I'll mention a quick hint on homework problem 1 for those who attend section.

Expansion of the Universe

We know from Hubble's Law that the Universe is expanding but what does that mean for what we observe in the universe? When we look far away, we are looking back in time, so will we see things denser or sparser than they actually are today? Is space hotter or colder than it is today?

Recall the definition of redshift:

$$z = \frac{\lambda - \lambda_0}{\lambda_0}$$

Simplifying the fraction, we get

$$z = \frac{\lambda}{\lambda_0} - 1 \Rightarrow z + 1 = \frac{\lambda}{\lambda_0}$$

So $z+1$ gives us our "stretching factor" wavelengths are stretched to a length $z+1$ times what they originally were. As it turns out, this factor, $z+1$ pretty much uniquely scales all dimensions when looking back in time. For instance, if we observe a chunk of space that was 1 meter long in our telescope at redshift $z=1$, it is currently

$$L = (z+1)L' = 2(1 \text{ m}) = 2 \text{ m}$$

so in its own reference frame right now, that chunk of space is now 2 meters long. When doing calculations like this, be sure that you put the factors of $(z+1)$ in the right places. Remember, the dimensions we measure in our telescope are always the dimensions from the *past*, which I denote with primed variables. The *actual* dimensions right *now* cannot be measured. I denote these with unprimed variables (you can make up your own system, there is no standard to my knowledge). Note also that in this example I didn't say we were observing a meter stick. A meter stick would not expand in time (why?) the way space would. This is because electromagnetic forces hold the stick together, causing it to not expand with the Hubble flow.

Example Suppose we observe a square of space with sides of length 1 pc at a $z = 3$. How much bigger is the area now than it was when the light we are receiving was first emitted?

Letting A be the area now and A' be the original area, we see that we observe a measured area of $A' = 1 \text{ pc}^2$. Since we know individual lengths scale as $(1 + z)$ we may scale each side of the square:

$$s = (z + 1)s'$$

To get the area being

$$A = (z + 1)^2 s'^2 = (z + 1)^2 A' = 16A'$$

So the current area of space is $A/A' = 16$ times larger than how we currently view it. Note that this process works for volume as well, meaning that

$$V = (z + 1)^3 V'$$

Discussion: Universal Geometries

In class today we talked about three possibilities for geometries of the universe and their analogues in two dimensions:

- Positive curvature / Closed, finite (surface of sphere)
- Zero curvature / Flat, infinite (infinite plane)
- Negative curvature / Open, infinite (saddle-shaped)

In the closed universe, initially parallel light beams must converge, where as in an open universe they must diverge (go away from each other). In the infinite models, the universe has always been infinite, but it is also expanding. Current tests show that the universe is probably flat, or at least very close. Questions?

Midterm Returns and Grade Discussion