MITOCW | Investigation 6, Part 4

PROFESSOR: Write in your notes the Doppler effect is this-- the observed wavelength minus the emitted wavelength divided by the emitted wavelength is equal to the change in wavelength divided by the emitted wavelength, which we said was equal to the velocity that is moving-- the object is moving-- divided by the speed of light, which is "Z," which we call the "redshift." The Doppler effect relates a change in the wavelength-- or if you're thinking about photons, a change in the energy. So this is change in energy of the photons, and it--

AUDIENCE: What does that "C" stand for?

PROFESSOR: What's that?

AUDIENCE: What does that "C" stand for?

PROFESSOR: "C?" Oh, I'm sorry. I should make this clear.

So, "V" stands for the velocity. And if it's positive velocity, that means it's moving away. So if velocity greater than zero, that means moving away. Velocity is less than zero, that means moving toward you. And we saw that if something's moving across your line of sight, we don't get a Doppler shift. We don't get any change.

"C" is the speed of light, which is equal to 3 times 10 to the 8th, meters per second. So we're saying the amount of wavelength change is equal to the speed that the object is moving divided by the speed of light. The speed of light is like the total amount that you could change. Nothing can go faster than the speed of light.

AUDIENCE: Nothing?

PROFESSOR: Nothing. No information can go faster than the speed of light. Two things can move apart from each other faster than the speed of light, so long as you're not trying to talk to that other person.

So the Doppler effect relates the change in the energy of photons, which is this part to the speed of the motion-- actually, it's speed and direction of motion. So on one side we've got this-- change in energy of photons is related to the speed of the motion and the direction. It says nothing about distance-- nothing. What does Hubble's law say-- or Hubble's observation?

"Law" is just a fancy word for super observation.

AUDIENCE: It has to be the distance in space.

PROFESSOR: Hubble's observation. And before we get to that, what did we do where we learned about the Doppler effect? What did we use in class here?

AUDIENCE: [INAUDIBLE]

PROFESSOR: We used the what? The animation, that applet, that application online where we moved the emitting source around and we measured the different wavelengths? But then we looked at Hubble's observation. How do we describe that?

AUDIENCE: [INAUDIBLE]

PROFESSOR: Say it again?

AUDIENCE: [INAUDIBLE]

PROFESSOR: What did we do? What do we look at when we observed Hubble's observation? What were we doing yesterday? Peter?

AUDIENCE: [INAUDIBLE]

PROFESSOR: OK, that's when we applied the model of the expanding universe, but what did we do before that? [? Jalen? ?]

AUDIENCE: Wait, before we did the paper?

PROFESSOR: Before we did the paper expanding, what did we look at?

AUDIENCE: Oh, we looked at the distance between the two galaxies.

PROFESSOR: No. It's all on your desk.

AUDIENCE: The spectrum of the [INAUDIBLE]?

PROFESSOR: The spectrum--

AUDIENCE: Of the galaxies?

PROFESSOR: Of the galaxies. What else did we look at?

AUDIENCE: The spectrum of hydrogen?

PROFESSOR: The spectrum of hydrogen. And what else did we look at?

AUDIENCE: The LAMP.

PROFESSOR: The what?

AUDIENCE: The LAMP.

PROFESSOR: The spectrum of the LAMP. And what was the thing that we compared to?

AUDIENCE: Images of the galaxies.

PROFESSOR: Images of the galaxies. So think about it. This is why I always ask you how did you learn these things. We learned this by playing with the applet. We learned this by playing-- so this was from the applet. We learned this by observing the images and the spectra of different galaxies.

It's in that little plastic bag that's still on your table. We looked at images and spectra. And what did we find out?

AUDIENCE: That the bigger ones-- though they're all the same linear size, but the one that larger angular sizes were closer.

PROFESSOR: OK, so the closer ones. What did we find out about their motion using the Doppler effect?

AUDIENCE: They were [INAUDIBLE].

PROFESSOR: OK, we found that the velocity of a receding galaxy-- and when I say "receding," that means getting further away from us-- the velocity was equal to Hubble's constant times the distance to the galaxy. Because we saw that the ones that looked big when we looked at the images were also moving away slower.

So what are we relating here? Here we're relating speed-- well, let's just say speed. Keep it simple. Here we're relating speed to distance. Velocity of a receding galaxy equals h naught times the distance to that galaxy.

Now, the Doppler effect happens anywhere. Anytime something is moving away from you or towards you and it's emitting waves, you're going to get a change in the energy of those waves, a change in the energy of those photons. Hubble's observation only holds for galaxies in the expanding universe.

This is more general. This is more specific. We can't always say that if an object is farther away from us it must be moving faster. [? Shakib ?] is farther away from me than Bianca is, so he must be moving faster.

AUDIENCE: Well, of course.

PROFESSOR: That doesn't work, right?

AUDIENCE: [INAUDIBLE]

[LAUGHS]

AUDIENCE: How can you say that if they're not moving?

PROFESSOR: Say that again?

AUDIENCE: How you can say that if they are not moving?

PROFESSOR: Well, I'm just saying that this relationship doesn't apply, because [? Shakib ?] is not a galaxy far away from me. But if [? Shakib ?] had a LAMP and he was running away from me, I could take a picture, take a spectrum of that LAMP, and I would see that the wavelength, or the energy of those photons, would have shifted a little bit. So that would happen here in this room, all right?