

On the Big Bang—4 Nov

- Announcements
 - Open house at the MSU Observatory, Fri & Sat, 9:00-11:00
 - Homework 8 will be due on 11 Nov.
 - Is Missouri Club wanted today?
- Outline
 - What does not obey Hubble's Law and why?
 - Expansion is encoded in the wavelength of light.
 - Examples of distant objects.

Why do most galaxies move away, but a few move toward us?

- Andromeda & two companions are moving toward us at 200km/s. The distance is 0.7Mpc.
- 1. What is very strange about Andromeda's motion?
 - A. It is going too fast.
 - B. It is going in the wrong direction.
- Why does A not obey H's Law?
 1. Assume early in the history of the universe, A did obey Hubble's Law. What caused it to change direction and move toward us?



Andromeda M31, M32, & M33
www.noao.edu/image_gallery/images/d6/m31y.jpg

Why does Andromeda not obey H's Law?

1. Assume early in the history of the universe, A did obey Hubble's Law. What caused it to change direction and move toward us?
 - Imagine a history
 - Immediately after Big Bang, material follows Hubble's Law strictly.
 - Our local group of galaxies was slightly more dense than the surroundings.
 - Gravity overcame motion, and caused A to reverse direction and come toward us.



Andromeda M31, M32, & M33
www.noao.edu/image_gallery/images/d6/m31y.jpg

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Ast 207

How much universe has expanded

- A distant galaxy emits some light. The light travels billions of years, and an astronomer at the SOAR telescope records the light. She asks, "How much has the universe expanded during that time?" As her colleague, you say, "Interesting question. I will think about it."
1. Is it possible to answer her question? Explain your hunch. All answers will be counted as correct.
 - A. Y
 - B. N

Expansion is encoded in the wavelength of light

- The hydrogen in a distant galaxy emits some spectral line at wavelength λ_{rest} . The astronomer observes it with wavelength λ_{obs} . wavelength of a spectral line. Between the emission and reception of the light, the universe expanded by a factor

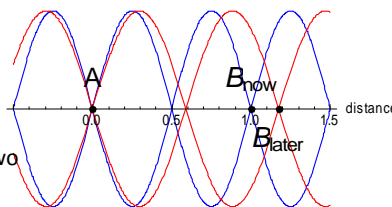
$$\lambda_{\text{obs}}/\lambda_{\text{rest}}$$

- The universe and the light expanded by the same factor.

Expansion stretches wavelength of light

- Principle: Wavelength of light stretches by the same factor as the universe expands.
- Fundamental observation: Universe is observed to be the same in all directions.
- Why?

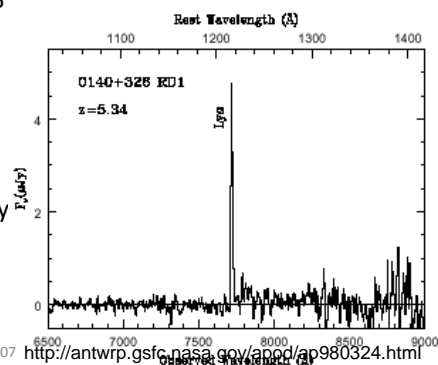
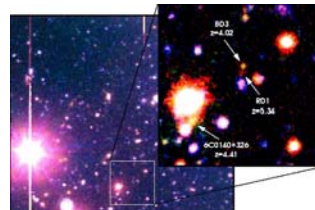
- A standing wave permeates the U. (Two waves going left & right add up to a standing wave.)
- At the present time, galaxies A and B sit on nodes of the standing wave.
- Later, galaxy B has moved farther away.
- B must remain on a node. If it is to the left of the node, then the direction toward A is special.
- Therefore wavelength stretches by the same factor that the universe expands.



Example: Very distant galaxy

- Galaxy found by looking for red objects
- Key idea: Universe expands the same factor as wavelength of light.
- 1. When the light that we see left Galaxy 0140+326 RD1, its wavelength was 1215 Å (121.5nm). We see its wavelength to be 7710Å. By what factor has the universe gotten bigger?
 - between 2 & 3 times bigger
 - between 3 & 4
 - between 4 & 5
 - between 5 & 6
 - between 6 & 7
- U has expanded by a factor of 6.35 since the time the light left that galaxy

$$\frac{D_{\text{now}}}{D_{\text{lightEmitted}}} = \frac{\lambda_{\text{received}}}{\lambda_{\text{emitted}}} = \frac{7710}{1215} = 6.35.$$



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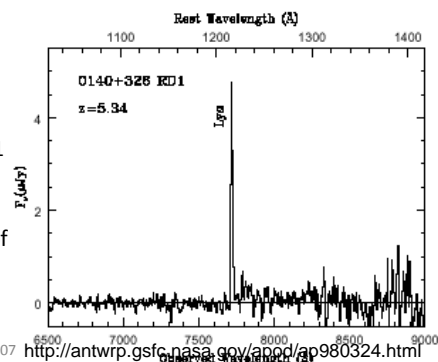
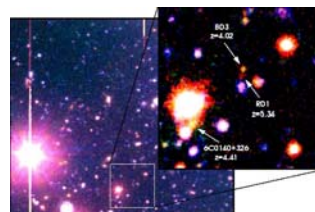
Example: Very distant galaxy. Redshift

- U has expanded by a factor of 6.35 since the time the light left that galaxy.

$$\frac{D_{\text{now}}}{D_{\text{lightEmitted}}} = \frac{\lambda_{\text{received}}}{\lambda_{\text{emitted}}} = \frac{7710}{1215} = 6.35.$$

- Redshift $z = \frac{\lambda_{\text{received}}}{\lambda_{\text{emitted}}} - 1$
- $\frac{D_{\text{now}}}{D_{\text{lightEmitted}}} = 1 + z$
- For galaxy 0140+326 RD1,
 $z = \frac{7710}{1215} - 1 = 6.34 - 1 = 5.34$

- How to say it
 - Galaxy 0140+326 RD1 is at redshift 5.34
 - The redshift of galaxy 0140+326 RD1 is 5.34
- How to think
 - The universe expanded by a factor of 6.34 since the light from the galaxy was emitted.
 - The redshift of Coma is $\frac{6000 \text{ km/s}}{(300000 \text{ km/s})} = 0.02$.



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