Monday, Nov. 10

Syllabus, class notes, and homeworks are at:
www.as.utexas.edu → courses → AST 301, Lacy

Reading for this week: chapter 13.1, 13.2, 15

The help session this week (only) is in WEL 3.260 at 6:00 on Wednesday. (Note the unusual place and time.)

Topics for this week

How does the big bang theory explain Hubble's law?

How does the big bang theory explain the microwave background radiation?

Describe some of the events that occurred in the first few minutes after the big bang.

Describe how supernovae are used to measure the rate of expansion of the Universe in the past.

Describe how matter and energy cause the expansion of the Universe to accelerate or decelerate.

Do we think the Universe is finite or infinite?

Do we think the Universe will eventually collapse or expand forever?

Motions of Galaxies

In 1920s Vesto Slipher measured spectra of galaxies.

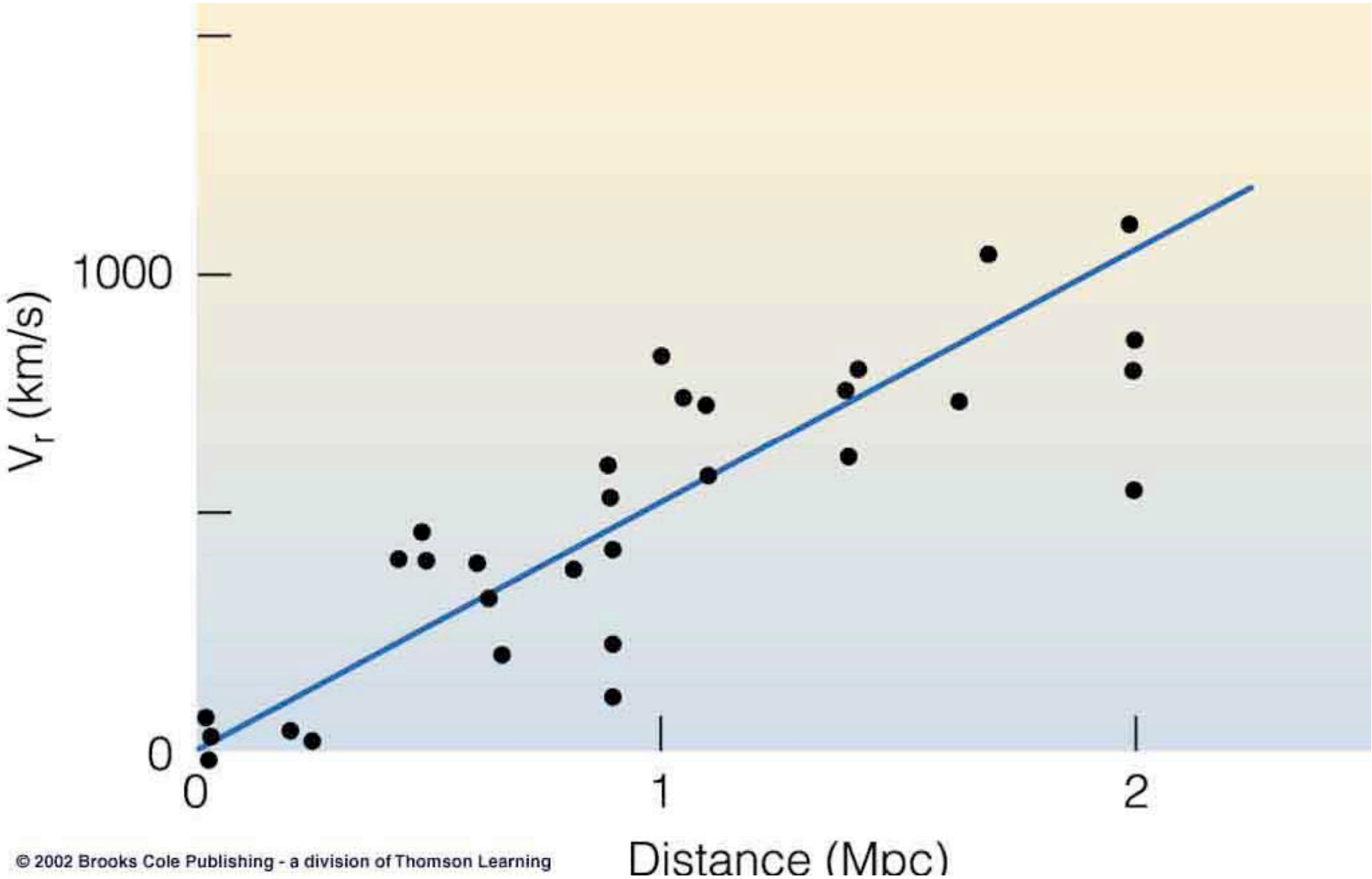
He found that most galaxies are redshifted, that is they are moving away from us.

Soon after that Edwin Hubble measured the distances to galaxies.

He found that in general more distant galaxies are moving away from us faster than closer galaxies are.

This is Hubble's law: $v = H\,d$ or $v \alpha d$

The Hubble diagram is like the H-R diagram, but each dot is a galaxy (instead of a star) and the axes are distance and speed (instead of temperature and luminosity).



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How are distance and speed measured?

Speed is measured with the Doppler shift – the faster a galaxy moves away from us, the more the spectrum is shifted to longer wavelengths.

Distance is more difficult.

No galaxy is close enough for us to measure its parallax.

The measurement used to require a difficult chain of measurements, but with the Hubble Space Telescope we can see Cepheid variable stars in many galaxies.

From the periods of their variation we know the luminosities of these stars, and then by measuring their apparent brightnesses (fluxes) we can calculate their distances.

Hubble's Law

Hubble found that a galaxy's speed away from us is proportional to its distance from us.

$$v = H\,d$$

What does this mean?

If galaxies are objects like the Milky Way, why would they all be moving away from the Milky Way?

And are they accelerating, so they move faster as they move away? What would cause this?

The wrong explanation

We could explain Hubble's law if galaxies accelerated as they went away from us.

Then they would be going faster when they are farther from us.

But then our galaxy (the Milky Way) would have to be special, since all other galaxies would be accelerating away from it.

Besides, what force could cause the galaxies to accelerate away from us?

We don't think this is the right explanation for Hubble's law.

Big Bang explanation for Hubble's law

The galaxies don't have to accelerate as they move away from us.

If different galaxies started out moving away from us faster than others did, and they all started at the same time, the ones moving away faster would have gotten farther by now.

The explosion that started everything is called the Big Bang.

This still sounds like it means that the big bang occurred here, and we are at a special place in the Universe.

That is wrong.

No matter where the explosion occurred, an observer on any galaxy would see other galaxies moving away from him.

The age of the Universe

We can calculate when the big bang occurred by asking how long it would have taken distant galaxies to get to where they are.

If different galaxies started out moving away from us faster than others did, and they all started at the same time, the ones moving away faster would have gotten farther by now.

If the galaxies' speeds have not changed we can calculate how long ago they started moving.

The time to travel a distance d at speed v is given by

time = distance / speed

If we use Hubble's law that speed = H x distance, we get

time = distance / (H x distance) = 1 / H

Using our best number for H, we get the time since the big bang = 13 billion years.

Turning Hubble's law around

Once we know that more distant galaxies have greater redshifts, we can use a galaxy's redshift to estimate its distance.

speed = Hubble's constant x distance, so

distance = speed / Hubble's constant

From their redshifts, we know that most of the galaxies in the Hubble (Space Telescope) "Deep Field" picture are very distant.

Since light took a long time to get to us we are seeing them as they were long ago.