

Week 11

Expanding Universe & Big Bang

December 2, 2016

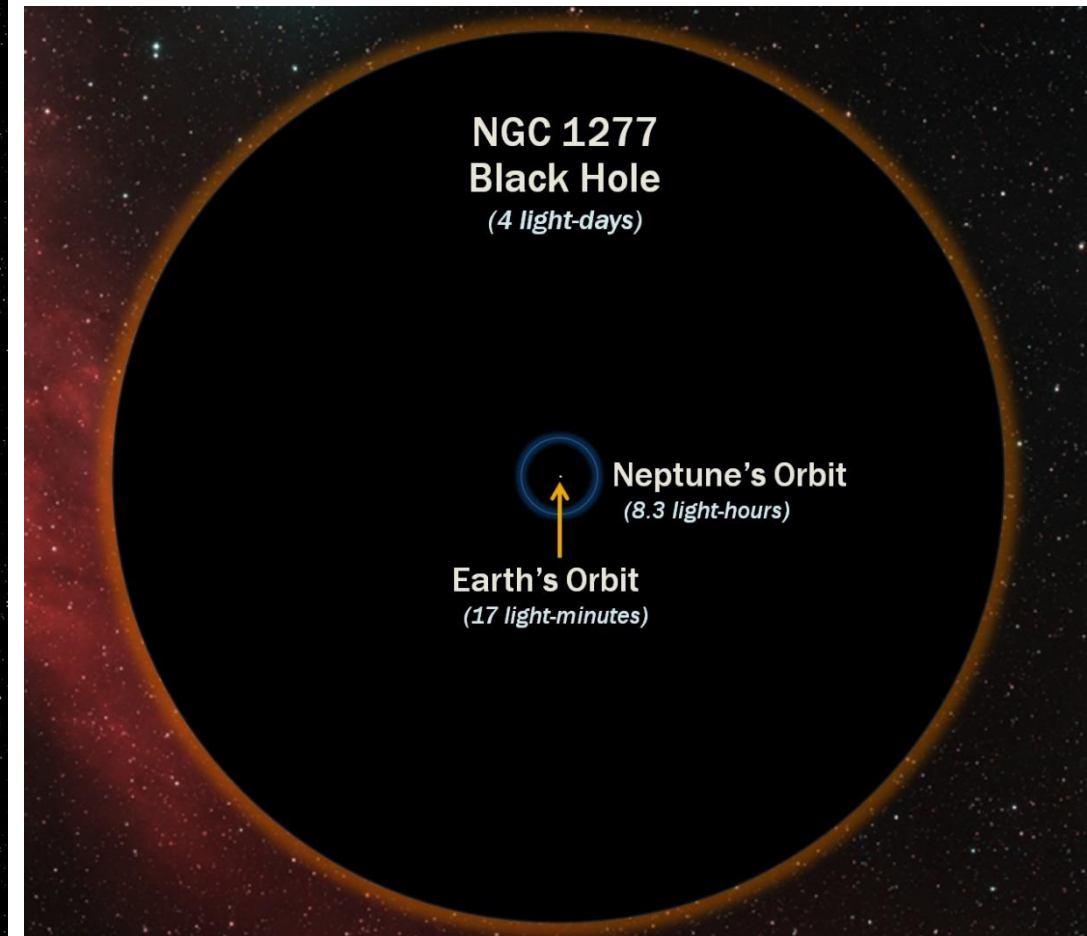
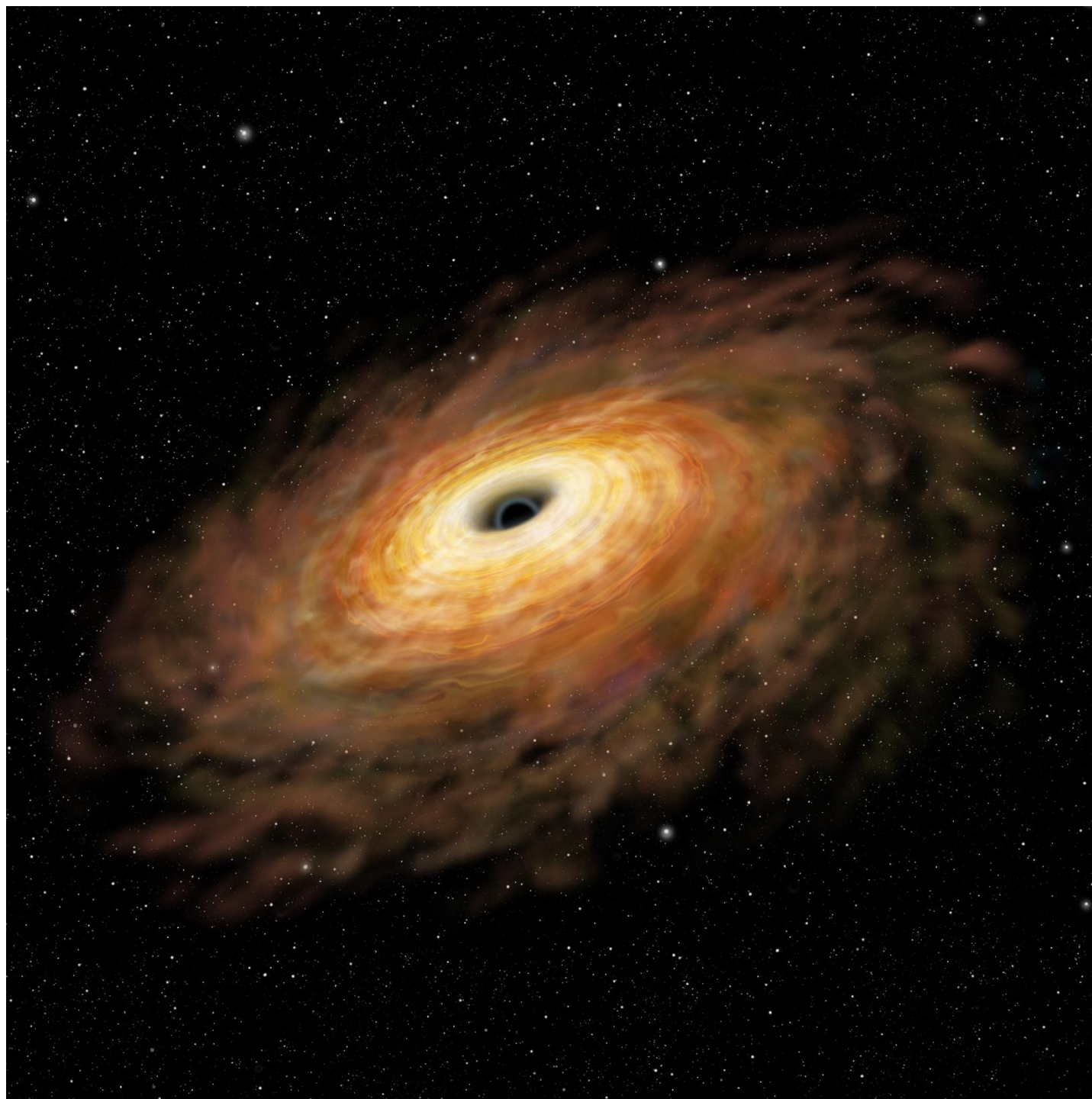
This Week

- Friday: Cosmic Web, expanding universe, dark energy and the Big Bang
- Final Exam on Tuesday, December 6, 8-10 AM
 - *Cumulative: ~25% material from each midterm exam and 25% new material*
- **2nd Review session**: CF 115 – TODAY 1-2pm

Today: Learning objectives

- Know what mass make up the centers of galaxies
- Describe the basic structure of the universe in terms of the Cosmic Web
- Explain how we know the universe is expanding
- Describe what the Big Bang explains and what it does not explain
- List the evidence for the Big Bang

Super massive black holes at the centers of galaxies



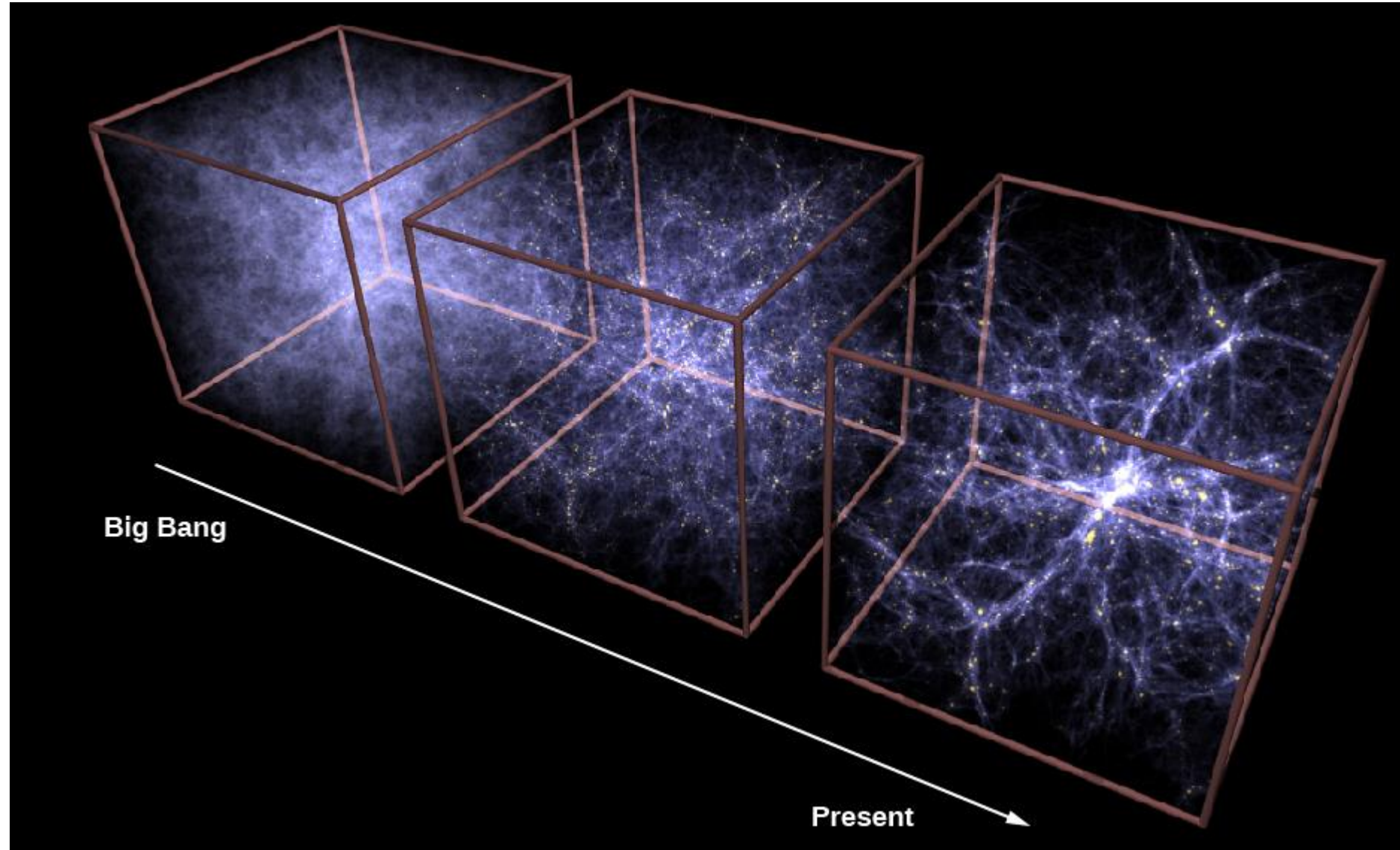
Observing Galaxies

- Astronomers have mapped locations and distances of galaxies
 - *Using Type IA supernovae*
- *Find galaxies organized into groups and super groups*
- Astronomers have determined the movements of galaxies
 - *Using redshift*
- *Find galaxies moving away from each other*



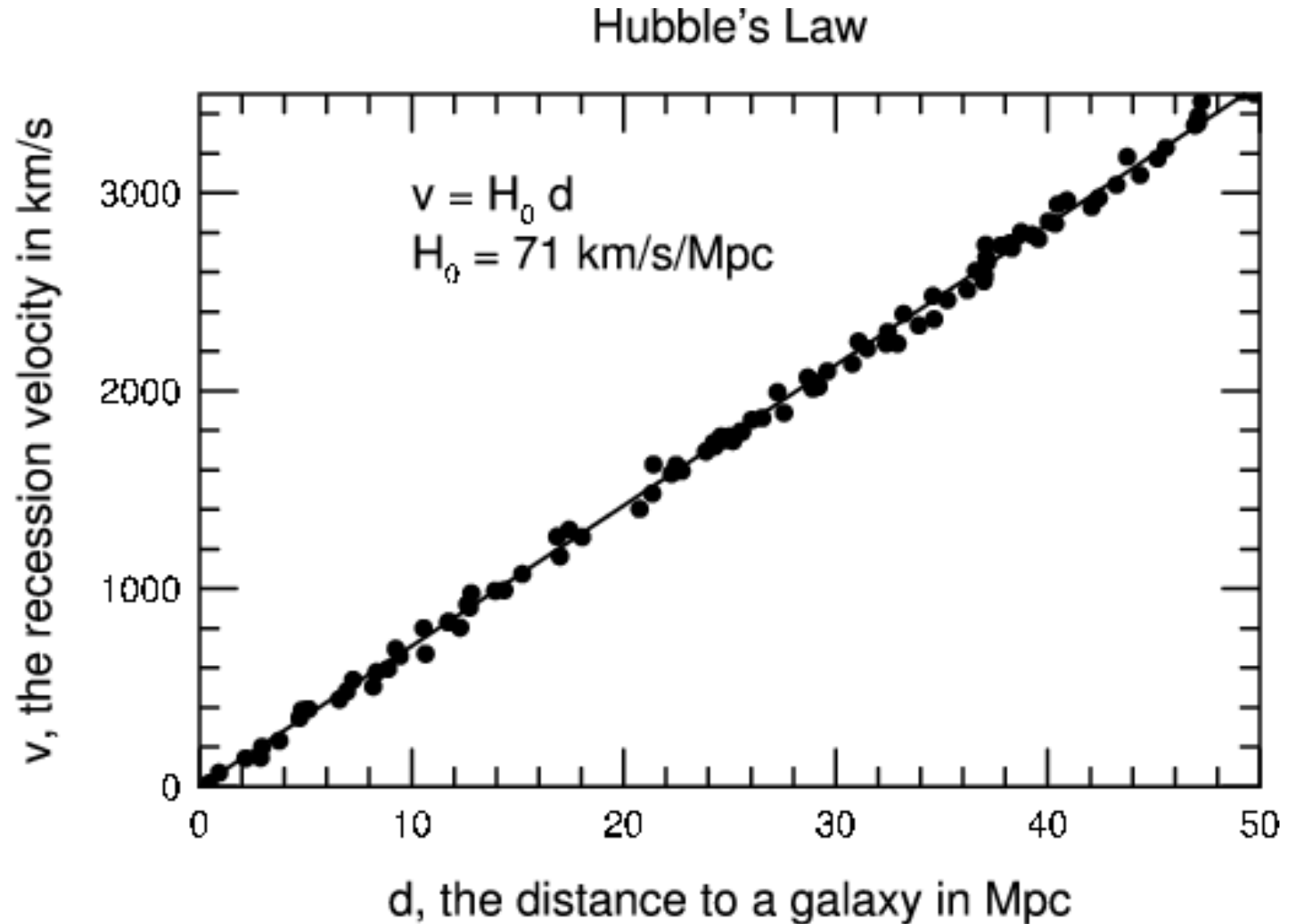
Cosmic Web: Distribution of Galaxies

- Galaxies organized into groups and super groups
- Over time, universe has organized into a web of galaxies
- Web is “rivers” of galaxies separated by vast, empty space between



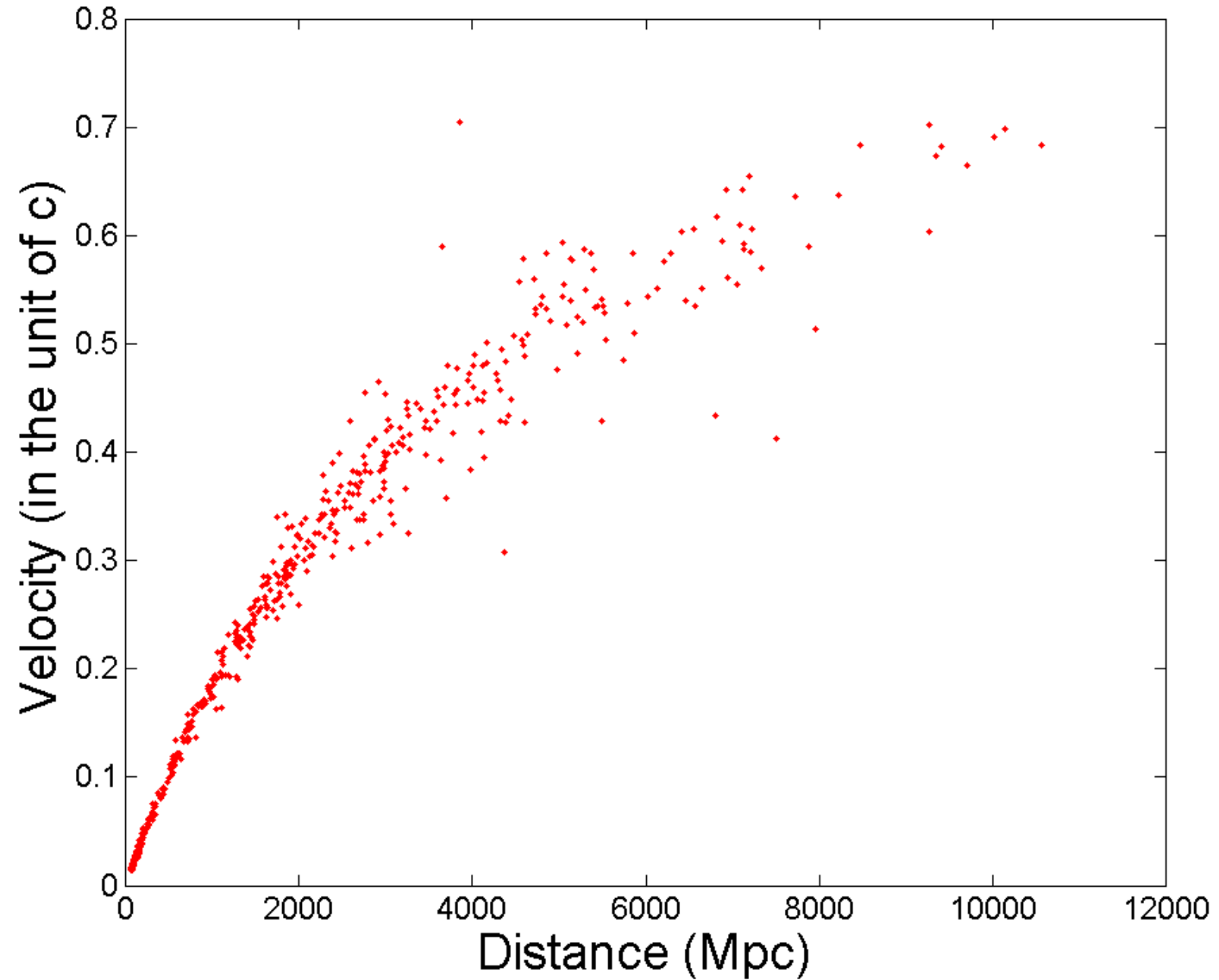
Expanding Universe

- The more distant the galaxy, the greater its redshift
- Greater redshift means it is moving away from us at a faster rate
- Hubble calculated velocity galaxies moved away vs. their distance derive the Hubble constant, H_0



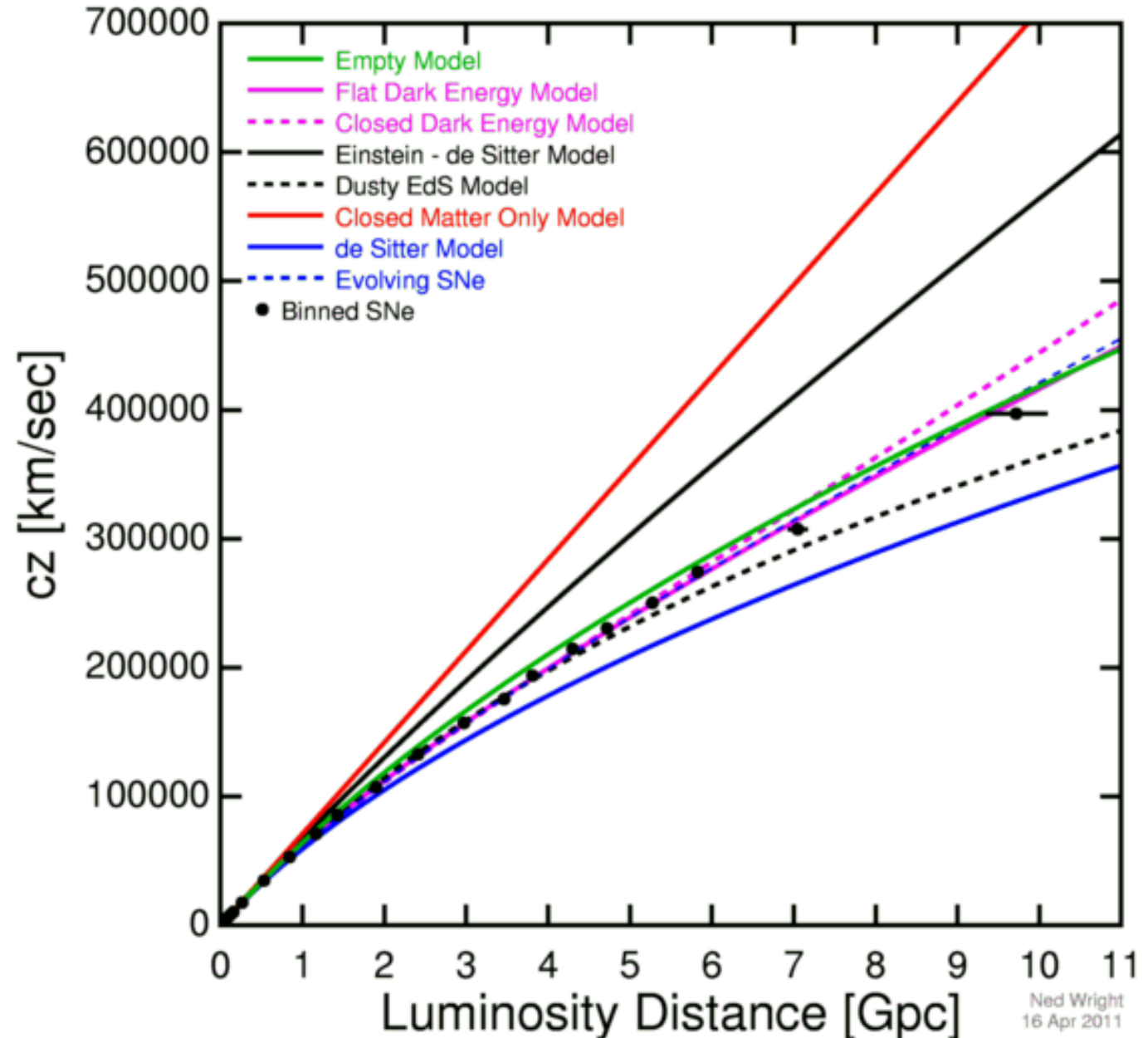
Expanding Universe

- Expanding our volume to 10,000 Mpc, we find a Hubble constant that is $\sim 7\%$ smaller than what we measure in the nearest 50 Mpc.



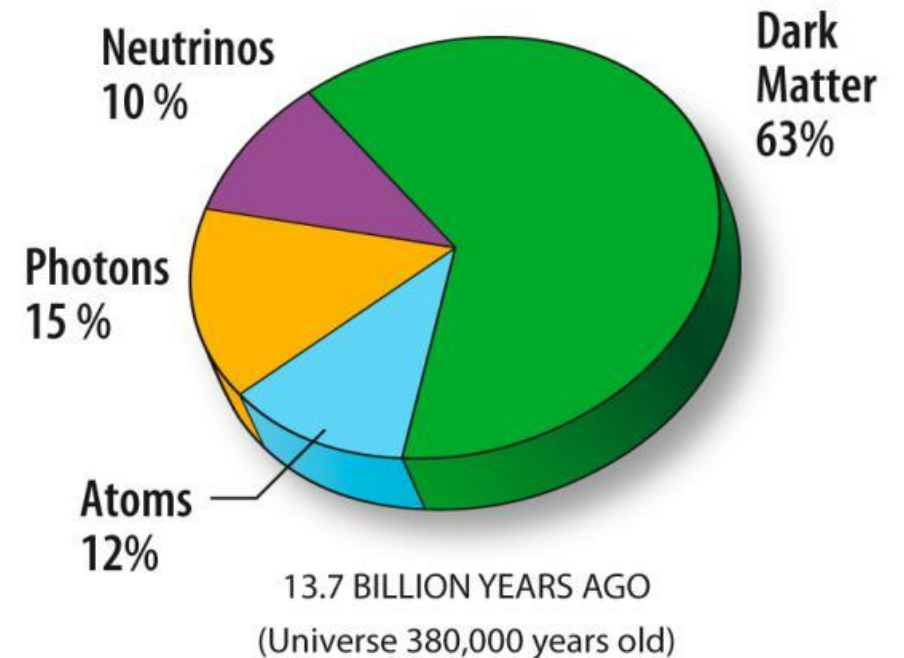
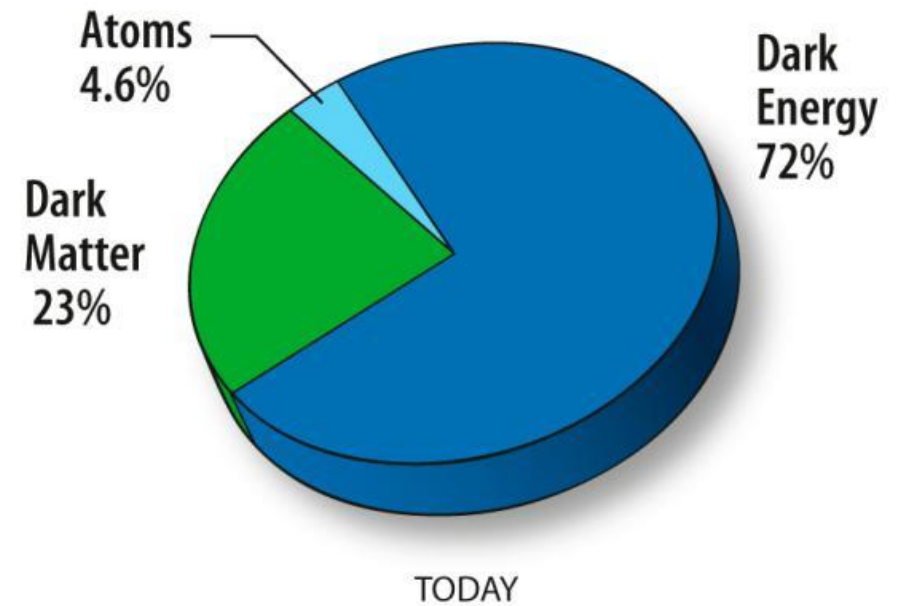
Expanding Universe

- A shallower Hubble Law for distant galaxies, whose light was emitted when the universe was younger than it is today, imply the **expansion of the universe is speeding up** as the universe ages
- The best explanation for this accelerating expansion is the so-called 'dark energy' that permeates empty space, and drives its expansion faster and faster as more space is created.



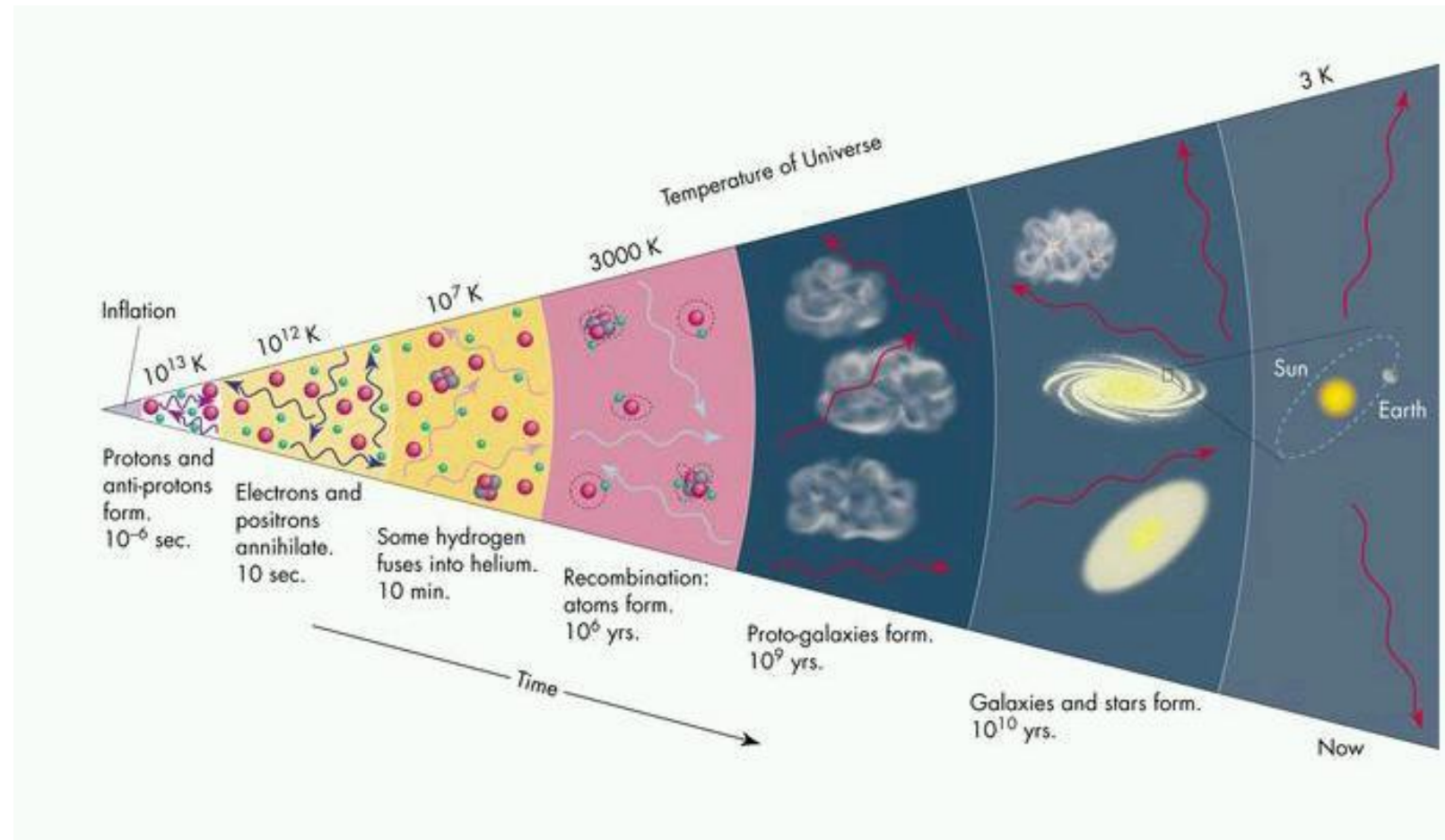
Dark Energy

- The amount of matter in the universe isn't changing with time, but dark energy is.
- Dark energy seems to be a property of empty space, so as the universe expands, the amount of dark energy increases.
- We 'recently' (about 4-5 billion years ago) tipped over from a universe dominated by matter to a universe dominated by dark energy.
- The Universe's expansion now seems unstoppable.



Big Bang

- Theory to explain the development of the universe as we know it
- Beginning of space-time, and matter and energy we see in the universe



Evidence for Big Bang

- Expansion of the universe
- Know it was dense enough for fusion of deuterium, helium and lithium (we see remnants of this earliest fusion)
- Cosmic Microwave Background Radiation (CMBR) = left over radiation from a hot early universe

<http://kcts9.pbslearningmedia.org/resource/ess05.sci.ess.eiu.microwave/evidence-for-the-big-bang-theory/>

