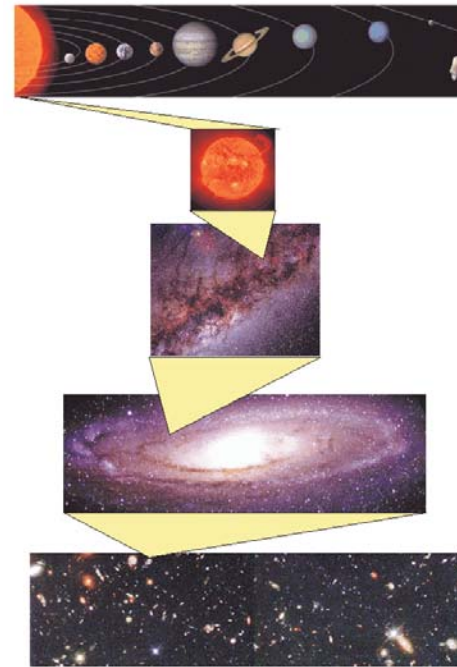




- Last Homework is due next Friday– 11:50 am
- Honor credit– need to have those papers soon!
- THE FINAL IS DECEMBER 15th: 7-10pm!

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Astronomy: The Big Picture



Arguably, the biggest fish of all: *Cosmology*

- What is the Universe made of?
- How big is it?
- How old is it?
- How did it form?
- What will happen to it?

Outline



- Galaxies are the building block of the Universe
- Homogenous Universe
- Isotropic Universe
- Hubble's Law
- The Universe is expanding.
- The early Universe was dense.
- The early Universe was hot.
- The Big Bang may explain the Early Universe.

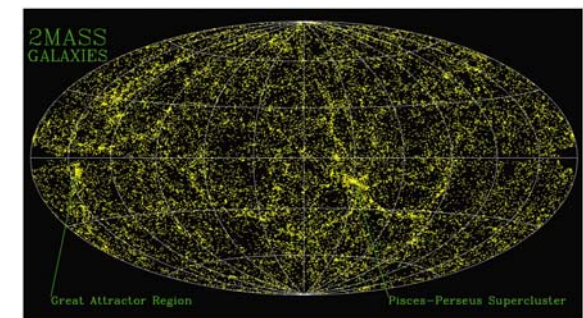
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Galaxies: Building Blocks of the Universe



- On the large scale, the universe is homogenous (galaxies are evenly spread)
- On the large scale, the universe is isotropic (looks the same in all directions)



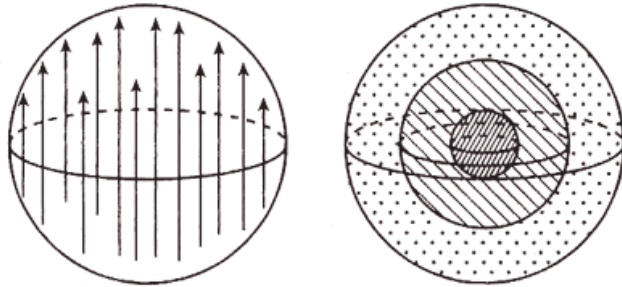
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What the...



- Isotropy: There is no preferred direction in the Universe.
- Homogeneity: No preferred location in the Universe.



Overhead Demo.

Homogeneous
Not isotropic

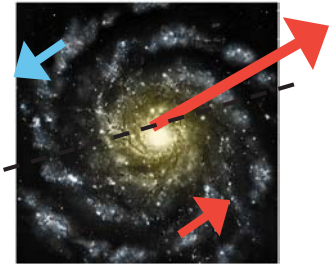
Isotropic
Not homogeneous

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Redshift of Galaxies



- Most galaxies are moving away from us.
- The farther away, the faster they are moving away.
- Or $V = H_0 \times D$
 - $H_0 = 72 \text{ km/s / Mpc}$
- What does this mean?
- Key to understanding the Universe!



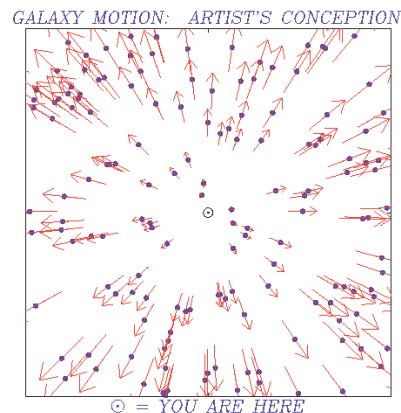
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What does that mean?



- In a homogenous Universe, what does the farther away the faster they move away mean?
- Draw it.



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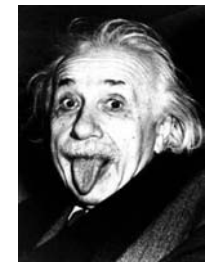
Interpretation: View of the Universe



Egoist view– We are at the center of the Universe.



Einstein's view– The Universe is expanding, and there is no center!



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The Expanding Universe

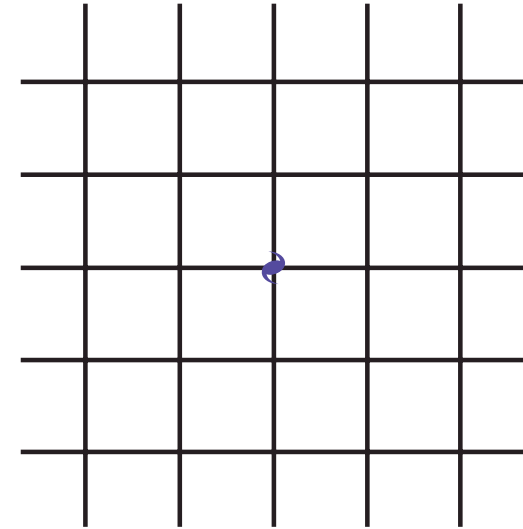


- To describe the motion of all the galaxies in the Universe, we must use General Relativity (due to the gravity effects)
- General Relativity + homogeneity + isotropy = *expanding Universe*.
- In other words, space is stretching in all directions. This completely explains Hubble's Law.
- Overhead demo.

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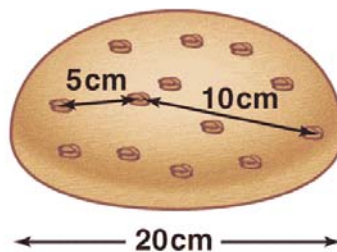
Dude, The Universe is Expanding.



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Analogy– Raisin Bread



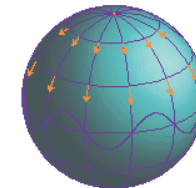
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Raisins stay the same size.

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Analogy– Balloon



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<http://background.uchicago.edu/~whu/beginners/expansion.html>

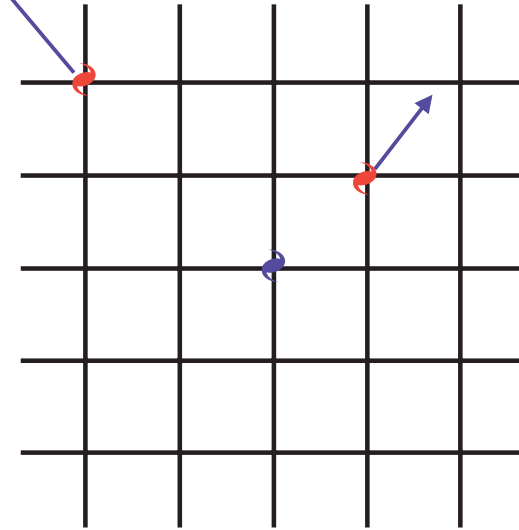


~~Expanding into What?~~

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Wow. The Universe is Expanding.



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Reality



- The analogies are just to help us visualize, don't get stuck in the specifics.
- The Universe has no center
- The Universe has no edge
- Concept of time and space began with the Universe, can not apply the concepts so easily.
- The Doppler Effect is not the real reason that galaxies are redshifted. As space expands, it stretches the light.

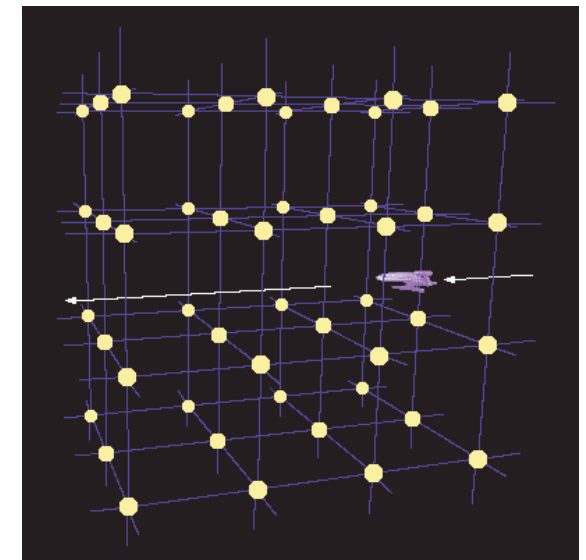
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The Edge of the Universe?



- If the Universe consisted of only 48 stars?
- The spaceship, would never really see the edge of the Universe.



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<http://www.answers.org/free/universe/bigbang.html>

The 3rd Revolution



1. Copernicus and others: We are not the center of the solar system. The Earth is a typical planet.
2. Shapley and others: We are not the center of the Galaxy. The Sun is a typical star.
3. Hubble and others: We are not in the center of the Universes. The Milkyway is a typical galaxy.

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Living in an Expanding Universe



Consider a large "box" containing many galaxies

- Total mass in box today: M
- Total volume in box today: V_{today}
- **Density today** = M/V_{today}

How does the density of the Universe change with time? As Universe expands:

- M stays the same
- V becomes larger
- Density M/V **smaller**

Density changes with time!

- Universe was denser the past
- Universe will be less dense in future

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Living in an Expanding Universe



We know that galaxy spectra show redshifts

- Spectral lines shifted to red: longer wavelengths

but: galaxy recession due to expansion of space

- "Doppler shift" not correct



Better to say that expansion stretches lengths

- Then, redshift comes from **stretching of wavelength!**

What does this mean for photon energy?

- Since wavelength increases
- And photon energy decreases with longer wavelength
- Photons lose energy as universe expands

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Putting it all together:



1. Earlier Universe was more dense
2. Earlier Universe was hotter.
3. The Universe is expanding.

The origin of the Universe can be described by the idea of the Big Bang.

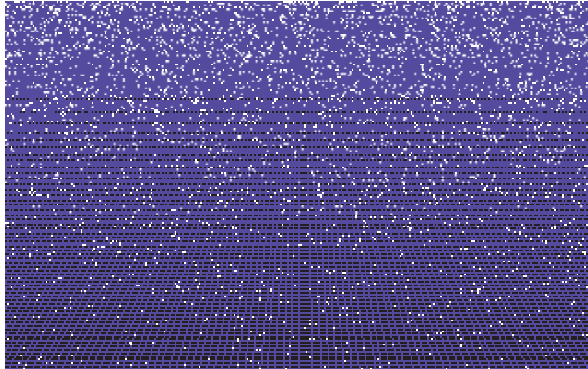
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The Big Bang



- Occurred everywhere at once.
- Not an explosion into empty space.
- The Universe was suddenly filled with matter—hot and dense.
- A point, or infinite.
- The beginning of time and space.
- Expanding and cooling, eventually forming the stars and galaxies we see today.

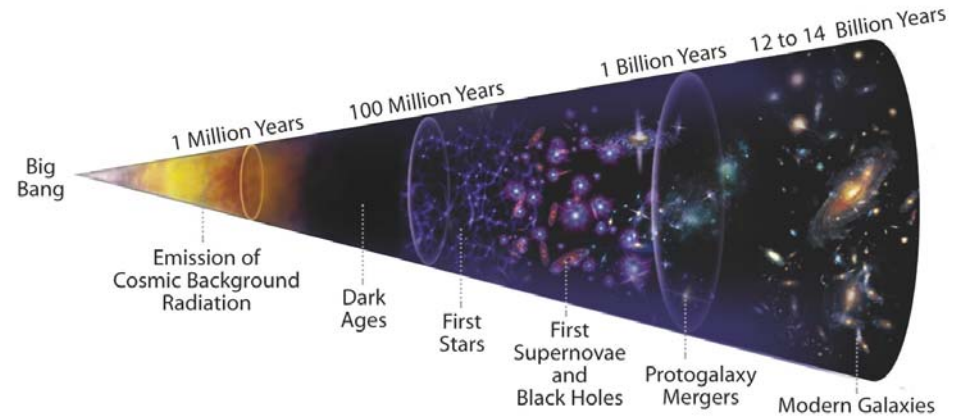


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<http://www.answers.org/free/universe/bigbang.html>

The Backward Ride



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