THE MEL PROJECT

Origins of the Universe

How did we get here?

Model A **Space, time, and matter came into existence a finite time ago in a hot dense state. It has been expanding and cooling ever since.**	→	Current observations show that the universe is expanding and cooling. If you rewind the current expansion backwards, the Universe would have been an incredibly small point. It was extremely dense and hot. Over time space itself has been growing.
Model B **The Universe has always existed in its current state and always will. Matter is created in some places and destroyed in other places at different times.**	→	What we see in the Universe today is basically the same as what has always existed. Although there might be small-scale changes in certain locations, overall everything stays the same. It will continue to be like this forever.
Model C **The Universe began a finite time ago when a small ball of matter exploded. The matter then spread out throughout space .**	→	Everything that we currently see in the Universe used to be located in a tightly packed ball of matter. Billions of years ago, this ball exploded and distributed that matter across space. This resulted in the distribution of galaxies we see today.

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Plausibility Ratings

- Read the three models carefully and quietly.
- They each provide explanations for a specific scientific phenomenon.
- Discuss with partners to clarify each model.

Circle the plausibility of each model. [Make three circles, one for each model.]

	Greatly implausible (or even impossible)									Highly plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10
Model C	1	2	3	4	5	6	7	8	9	10

Plausibility Ratings

What are some factors that you considered when determining the plausibility of the models?

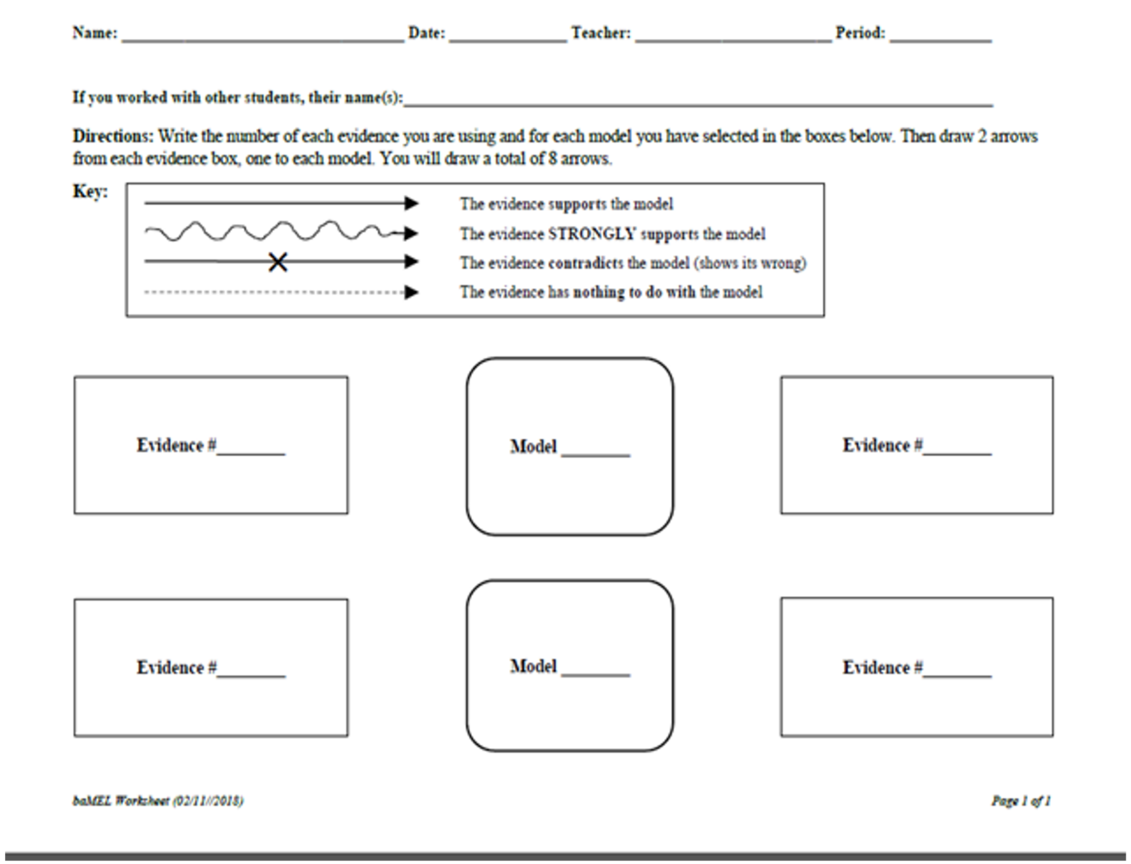
Model Selection

In your work group:

Choose two of the three models to use in the MEL activity.

Place the model card on your worksheet. It will be super helpful if you put them on the sheet in alphabetical order, from top to bottom.

Write the model letter on the line.


Name: ______ Date: ______ Teacher: ______ Period: ______

If you worked with other students, their name(s): ______

Directions: Write the number of each evidence you are using and for each model you have selected in the boxes below. Then draw 2 arrows from each evidence box, one to each model. You will draw a total of 8 arrows.

Key:
The evidence supports the model
The evidence STRONGLY supports the model
The evidence contradicts the model (shows its wrong)
The evidence has nothing to do with the model

Evidence #______
Model ______
Evidence #______

Evidence #______
Model ______
Evidence #______

baMEL Worksheet (02/11/2018)
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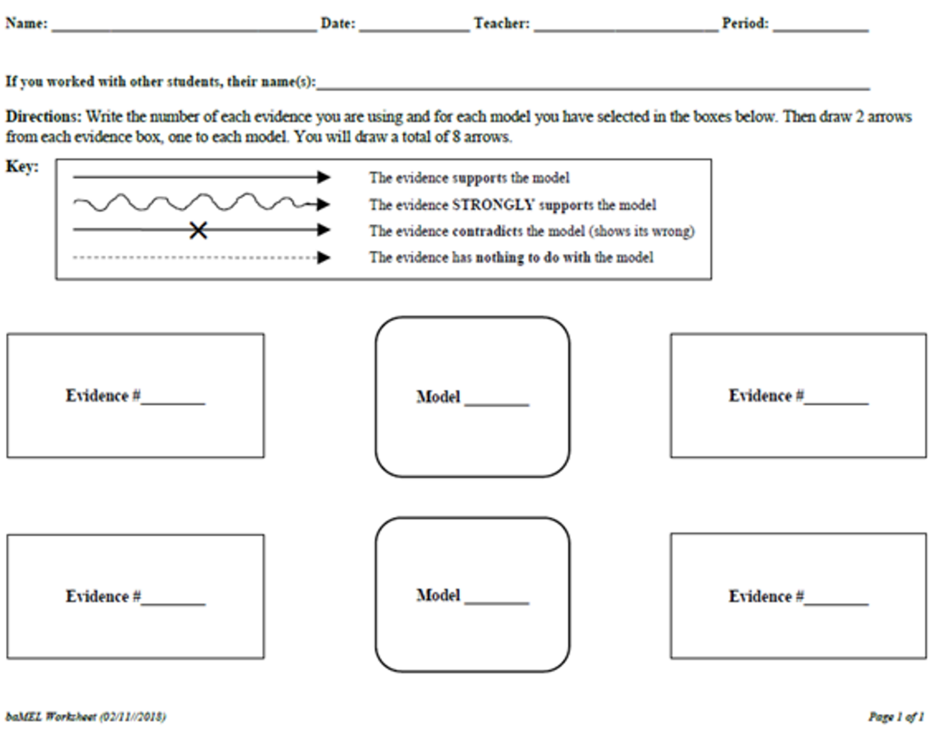
Model Selection

Which models did you choose?		Why did you choose those two models?	Why did you exclude the one that you did?
A vs B			
A vs C			
B vs C			

Evidence Selection


Name: ______________________ Date: __________ Teacher: ________________ Period: __________

If you worked with other students, their name(s): ______________________________

Directions: Write the number of each evidence you are using and for each model you have selected in the boxes below. Then draw 2 arrows from each evidence box, one to each model. You will draw a total of 8 arrows.

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Evidence #______

Model ______

Evidence #______

Evidence #______

Model ______

Evidence #______

baMEL Worksheet (02/11/2018)

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Choose 4 lines and your evidence cards on your worksheet in numerical order, from top to bottom, then left to right.

Go through and carefully read each of the 8 lines of evidence and the supporting texts. Think about each question as you read:

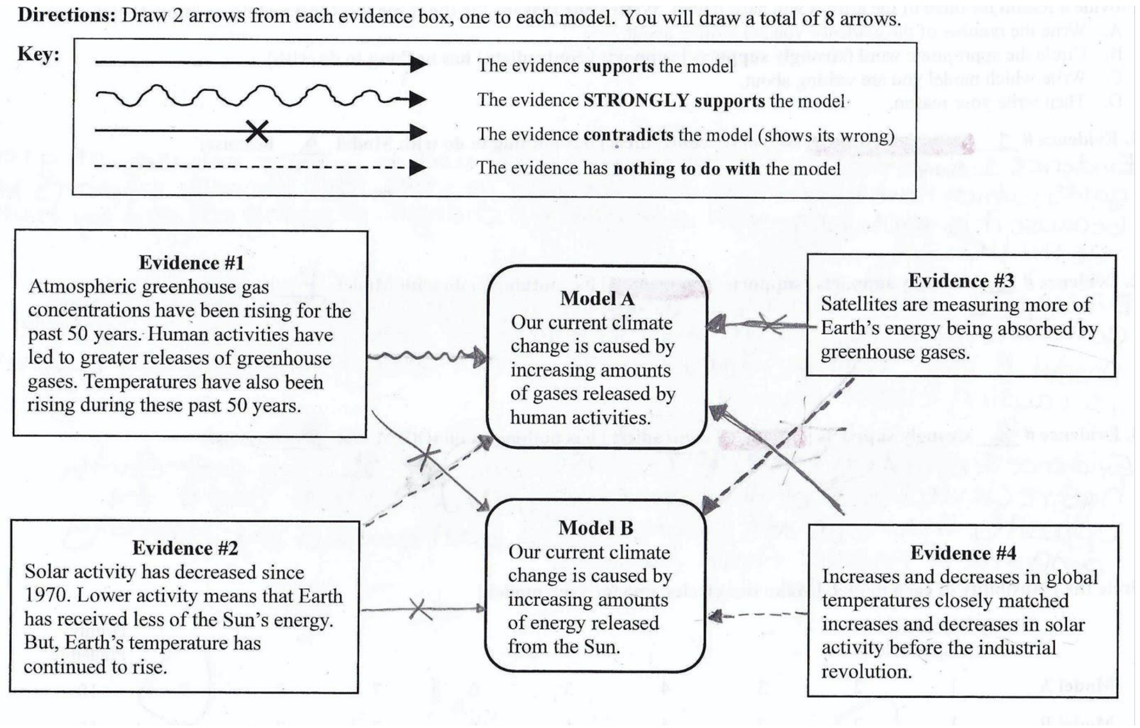
Does the evidence *strongly* support the model(s)?

Does the evidence support the model(s)?

Does the evidence contradict the model(s)?

Does the evidence have nothing to do with the model(s)?

MEL Construction



- Use the additional information for your evidences to help you evaluate the relationship between them and each model.
- Draw 2 arrows from each evidence box, one to each model (totaling 8 arrows).
- Use the key to show how each evidence relates to the model.

Explanation Worksheet

Name________________________________Date________Teacher________________________Period_______ Topic______________

1. Compare and contrast two (or three) models.

2. Please work on this part individually after you complete your diagram. Now that you have completed the diagram, reconsider the plausibility of Models A and B (and C, if there is one). Circle the plausibility of each model. [Make one circle for each model.]

	Greatly implausible (or even impossible)									Highly plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10
Model C (if there is one)	1	2	3	4	5	6	7	8	9	10

What were your previous ratings? Model A: ____________ Model B: ____________ Model C (if there is one): ____________

3. For the model you selected as most plausible, explain why you think so.

4. Which arrows changed your plausibility judgments about the models? If your plausibility judgment did not change, which arrows supported your original plausibility judgments? Consider 2 lines of evidence. For each line, does it support, strongly support, or contradict one of the models? Why? When writing your explanation, consider the following:

- Use the specific information from the evidence text and figures to support your response. Ex: when looking at graphs or figures, be sure to describe the patterns in the data
- Describe any cause and effect relationships found in the text.

Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

5. In your final ranking, did you rank either Model as "1" or "10?" Yes or No [Circle One] Why? Why not?

- The final task is for you to individually re-rank the plausibility of each model and choose one of your compelling link to explain.
- Select the two most interesting or important arrows that you feel is the best one.
- Justify your thinking for choosing the link between the evidence and model in the space provided on the sheet.

This task is very important so please explain thoroughly.

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Explanation Worksheet

Name________________ **Date**________ **Teacher**________________ **Period**________ **Topic**______________

1. Compare and contrast two (or three) models.

2. Please work on this part individually after you complete your diagram. Now that you have completed the diagram, reconsider the plausibility of Models A and B (and C, if there is one). Circle the plausibility of each model. [Make one circle for each model.]

	Greatly implausible (or even impossible)									Highly plausible
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What were your previous ratings? Model A: ____________ Model B: ____________ Model C (if there is one): ____________

3. For the model you selected as most plausible, explain why you think so.

4. Which arrows changed your plausibility judgments about the models? If your plausibility judgment did not change, which arrows supported your original plausibility judgments? Consider 2 lines of evidence. For each line, does it support, strongly support, or contradict one of the models? Why? When writing your explanation, consider the following:

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Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

5. In your final ranking, did you rank either Model as "1" or "10?" Yes or No [Circle One] Why? Why not?

- Which evidences were most compelling for you? Why?
- Did your plausibility scores change?
- What about the score for the model you did not select?
- Which arrows affected your plausibility judgment about a model?
- How do you think differently about the topics surrounding origins of the universe?
- Did you rank any Model as '1' or '10'?

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NSF

Evidence #1

Scientists expect that the scientific principles we use on and around Earth also work elsewhere in the Universe. Observations of phenomena around the Universe show that this is true.

One example of how scientific principles work everywhere in the Universe is looking at spectra. In a lab, we see that different elements each give off a unique pattern of light, or spectra. These spectra can be used to identify unknown substances. For example, Figure 1 shows the spectra created by helium and neon. We can see these same patterns of lines when we look at stars and galaxies. This means that helium and neon are present in those objects as well. Scientists use the spectra of the objects they observe to determine what the objects are made of.

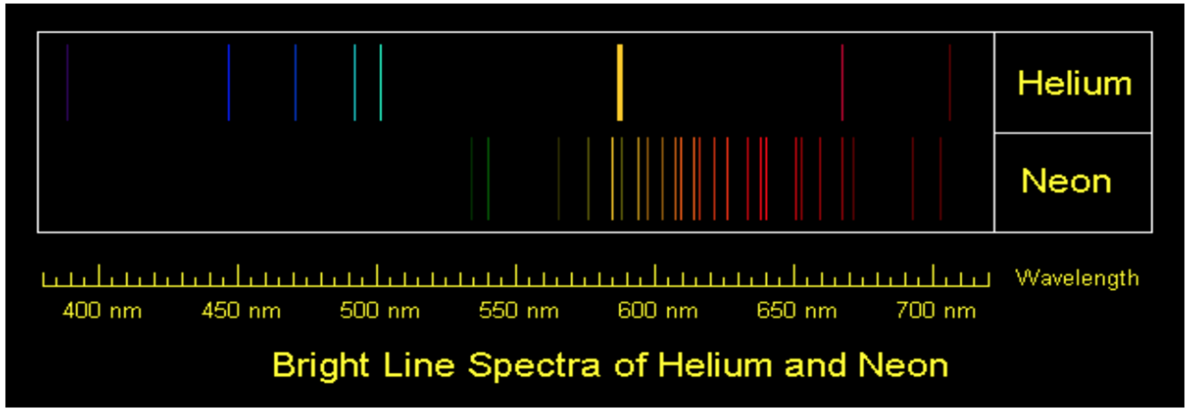


Figure 1. Spectra given off by helium and neon
(http://www.mtholyoke.edu/~mpeterso/classes/phys301/projects/mktrias/spectrum.html)

Evidence #2

Stars convert light elements into heavier ones inside their cores. When stars die, the heavier elements are sent outward into space. These elements then become part of new stars and planets. The oldest stars contain mostly lighter elements. Younger stars contain larger amounts of heavier elements.

A star has nuclear fusion at its core. The strong gravitational forces inside the core causes lighter elements to combine to form heavier elements. When stars die, elements are released into space and the elements become part of the next generations of stars. These stars also fuse elements inside their cores. Over several cycles stars make even heavier elements. As part of this process, the oldest stars contain mostly lighter elements. Younger stars contain larger amounts of heavier elements. Because there are more older stars than younger ones, there will be a greater abundance of lighter elements in the Universe compared to heavier elements. Figure 1 shows how much of each type of element is present in the Universe.

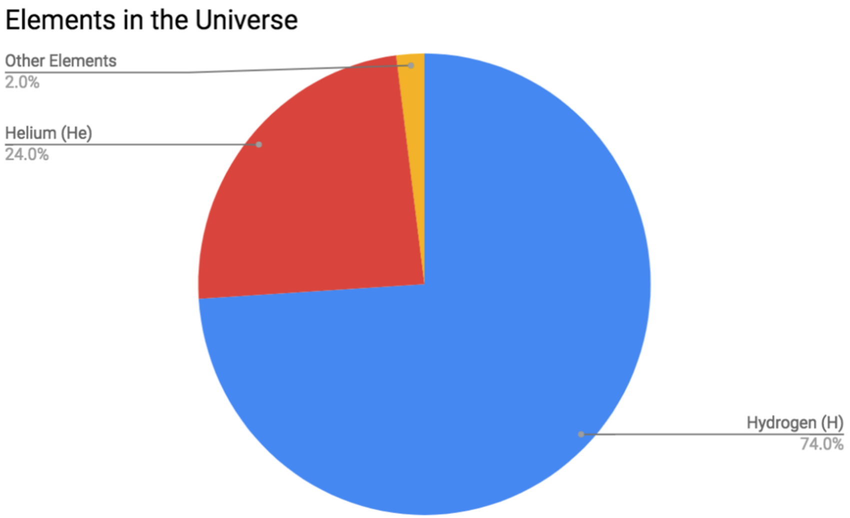


Figure 1. The composition of the Universe by element. (Figure by Scott; data from http://periodictable.com/Properties/A/UniverseAbundance.html)

Evidence #3

On average we observe about the same distribution of galaxies in any area of space. We would also make this observation from different galaxies elsewhere in space.

Images have been taken of random areas of the night sky past the stars. The figures below were taken by the Hubble Space Telescope. We can see galaxies in these pictures. When comparing the images, the number of galaxies in each image is about the same. This means that no matter which direction outward from our own galaxy you look, the Universe contains an evenly distributed number of galaxies.

Hubble Deep Field South in infrared

Hubble Ultra Deep Field in infrared (2004)

Hubble Ultra Deep Field in infrared (2009)

Figure 1. Three deep field images taken at different times and at different areas of the sky. The objects in the photographs are galaxies. (http://www.spacetelescope.org/science/deep_fields/)

Evidence #4

Astronomers observe a uniform glow in the background of the sky no matter where we look.

Astronomers have observed a background noise, or glow, everywhere in the sky. It does not appear to come from a single source like a star or a galaxy. The glow is strongest in the microwave region of the electromagnetic spectrum. Microwaves are a form of invisible light. Figure 1 shows measurements of this background, indicated by red crosses.

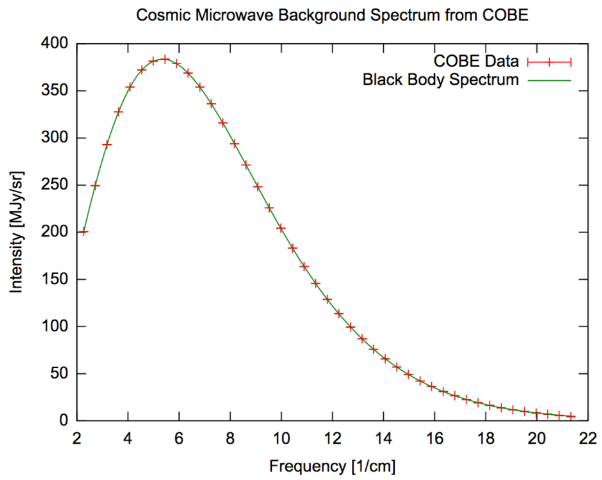
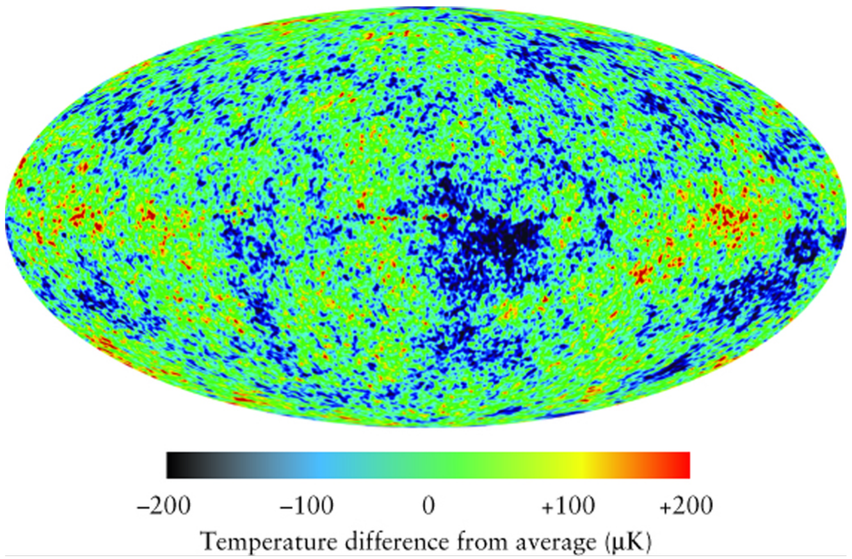


Figure 1. A graph of the intensity of the cosmic microwave background versus frequency. (Credit: Quantum Doughnut / Wikimedia Commons)



Evidence #5

All galaxies are moving through space. Galaxies that are farther from Earth are moving faster than galaxies closer to Earth. Most galaxies are moving away from each other.

Astronomers have measured the movement of galaxies by looking at their spectra. Most of them appear to move away from Earth. Only a handful of very close galaxies appear to be moving toward Earth. Edwin Hubble first noticed that there is a relationship between how far away a galaxy is and how fast it is moving. Figure 1 shows this relationship, now called Hubble's Law.

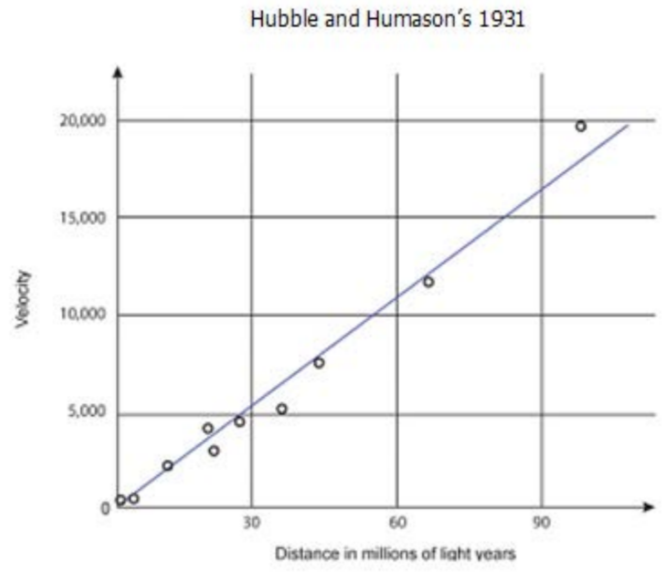


Figure 1. Circles in the figure represent galaxies, with their distance plotted on the x-axis and their velocity on the y-axis. (Figure from *The Big Ideas in Cosmology* based on original data by Hubble and Humason)

Evidence #6

The light of most galaxies appears more red than it really is. This means most galaxies are moving away from Earth.

All galaxies give off light, which can be analyzed by looking at spectra. Spectra are created when you take light and break it up into its component parts. Different chemicals give off distinct spectra--each one is unique, much like a person's fingerprints. The top picture in Figure 1 shows the visible light spectrum for iron. As a galaxy moves through space, the light in the spectrum is shifted to appear more blue or more red. Figure 1 (bottom) shows iron's spectrum redshifted. The black lines, caused by the absorption of light, are now farther into the red portion of the spectrum than they were. This is the same idea as how sound seems to shift in pitch as a source (such as a train or a car honking its horn) passes by you. For light, blueshifts occur if the galaxy is moving toward Earth, while redshifts occur if the galaxy is moving away from Earth. The greater the shift of the lines, the faster the galaxy is moving.

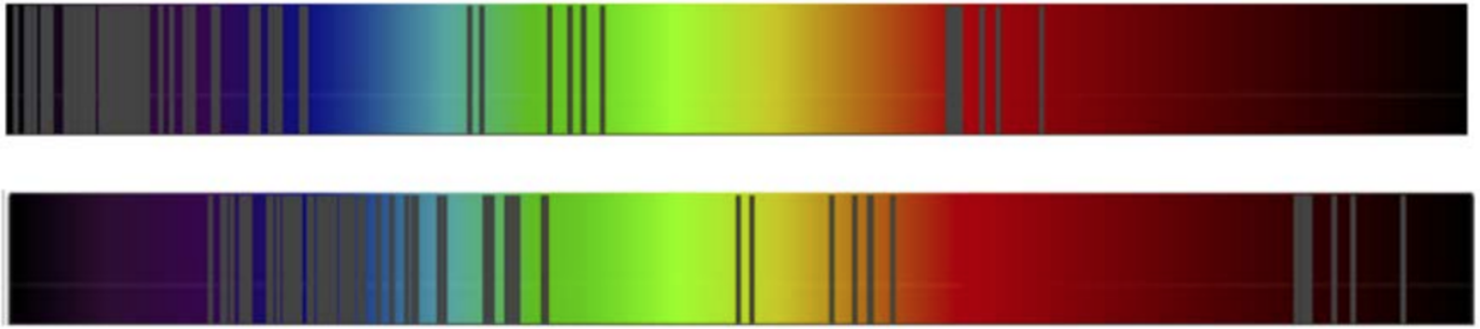
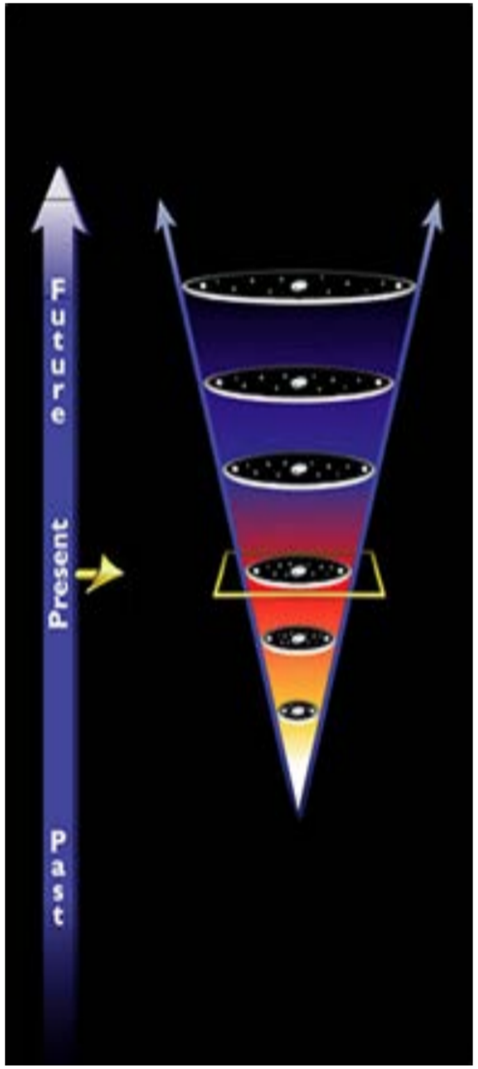


Figure 1. Iron gives off this spectrum when it is at rest (top) and moving away from us (bottom). (Figure from *The Big Ideas in Cosmology*)

Evidence #7

The Universe has a predictable age based on its rate of expansion. Nothing in the Universe is older than that age.

Astronomers have observed that almost all galaxies are moving away from each other. This means there is no central point of space special to the Universe and that the Universe is expanding. Figure 1 shows how astronomers have modeled the expansion of Universe over time. These models suggest that the early Universe was much smaller and hotter than it is now. In the future, these models suggest it will be larger and cooler.



Evidence #8

The Universe was once extremely hot and allowed for matter and energy to spontaneously convert back and forth into each other. Today, the Universe is far cooler than it once was.

When high densities of matter or energy are exposed to extremely high temperatures, they can convert between one another. These conditions existed during the beginning of the Universe. Not long after, the conditions changed. The Universe expanded and cooled and became less dense as well. Figure 1 shows the temperature of the Universe over time, with the present at the far right.