Test Re-test and Verify & The Big Bang Boom

The Hot Potato Universe

By Rocky Alvey & Dr. William K. Teets

The Big Bang Boom

Rocky Alvey/Beth Nielsen Chapman/Annie Roboff

The Universe is the strangest place
Started with the big bang boom
Created time and also space
Way back in the big bang boom
No galaxies or stars to see
Way back in the big bang boom
An expanding singularity
Way back in the big bang boom

The big bang boom, the big bang boom
Started with the big bang boom
All the Universe's room
All came from the big bang boom

At first no atoms could be found
Way back in the big bang boom
They all were formed when it all cooled down
Way back in the big bang boom

The big bang boom, the big bang boom
Started with the big bang boom
All the Universe's room
All came from the big bang boom

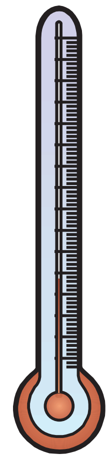
You can see the first light shine
Telescopes look back in time
The Universe was oh so very small
The galaxies they fly apart
Closer at the very start
And in your hand you could have held it all….

The big bang boom, the big bang boom
Started with the big bang boom
All the Universe's room
Created from the big bang boom
Started with the big bang boom
It all came from the big bang boom

Test Retest and Verify

Rocky Alvey/Beth Nielsen Chapman

Well humanity was in the dark for several thousand years
They based their fortunes good and bad, plus all their hopes and fears
On omens in the Earth and sky, and superstitious rot
But now we have a better way to understand our lot

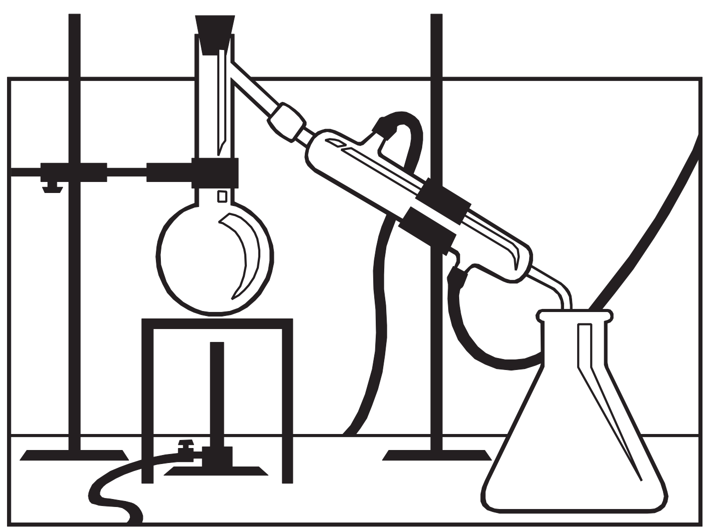


Test retest and verify, test retest and verify
The scientific method gets us closer to the truth
Test retest and verify, test retest and verify
Test retest and verify and then you'll have your proof

Physics run our universe so have a skeptic mind
It's good that one does not accept each notion that they find
The science isn't science if the rules do not exist
But if you don't know of what I speak, it goes a lot like this

Test retest and verify, test retest and verify
The scientific method gets us closer to the truth
Test retest and verify, test retest and verify
Test retest and verify and then you'll have your proof

Retest and verify, retest and verify
Some things just aren't what they seem
Retest and verify, retest and verify
Let your theories gleam



This activity addresses two songs on The Mighty Sky album, The Big Bang Boom and Test Retest and Verify.

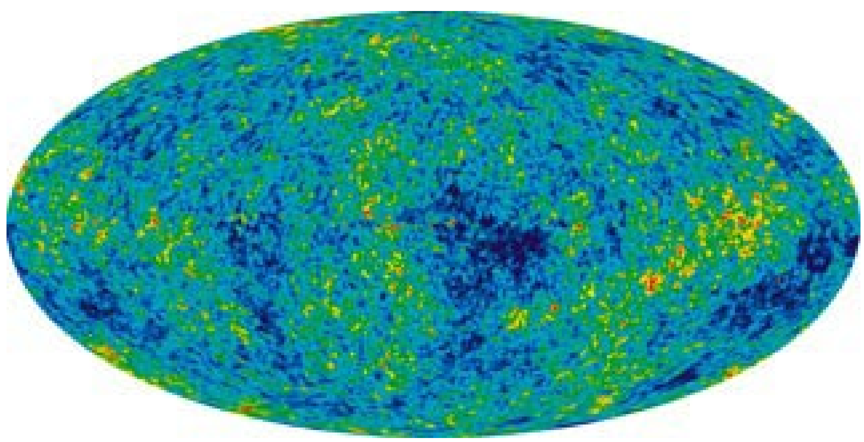
Play both songs before each Day's session. Highlight the pertinient words.

The Big Bang Boom

Did you know that one important key to understanding the universe is temperature?

Scientists are able to determine amazing things by knowing the temperature of an object and how it changes over time. One method that astronomers use to determine the age of the universe utilizes the temperature measurement of stars known as white dwarfs. These stars are really celestial embers that have gone through their life cycles. By finding the age of old white dwarf stars, one can determine a lower limit to the age of the universe.

Another method of determining the universe's age is through careful inspection of the Wilkinson Microwave Anisotropy Probe (WMAP) data. These data are essentially a temperature map of the cosmic microwave background of the sky. This information has been very important in determining the age of the universe. By measuring the temperature of the background of the sky (the universe that is, not the Earth's atmosphere), scientists were able to estimate how long it took for the universe to cool down to its present temperature.

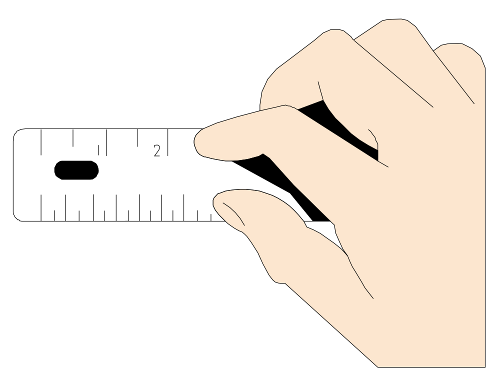


WMAP data of the infant universe. Credit: NASA

The potato experiment described below is an introduction to making measurements, recording data, observing how temperatures of objects change over time, and utilizing these cooling trends to make predictions. In this experiment, the potato will represent the universe.

Key Words for The Big Bang Boom

"At first no atoms could be found
Way back in the big bang boom
They all were formed when it all cooled down"



The Scientific Method

If Earth's scientific knowledge suddenly disappeared and only one important concept could be passed on to future generations, the scientific method is perhaps humankind's most important idea. Although scientists don't strictly follow a multi-step method, all science is accomplished using some form of this principle:

- •Observe and ask a question
- •Predict an outcome based on your observation: make a hypothesis as to why the observed phenomena occurs
- •Test your hypothesis: conduct experiments to confirm your predictions. Retest and analyze the results
- •Publish your conclusions so that others can examine your results and repeat the same experiment

Key Words for Test, Retest and Verify

"Test, retest and verify, the scientific method gets us closer to the truth"

Objective

The objective of this exercise is to observe the change temperature over time, reaching thermal equilibrium, and to make predictions about the rate of change.

Duration

2 sessions, 1.5 hours each

Caution

Due to the temperature of the baked potato and use of a microwave oven, this experiment is to be done with the oversight of an adult.

NEVER PUT METAL IN A MICROWAVE OVEN! This includes the cooking thermometer and aluminum foil.

Supplies

-A clock or timer
-Baking mitts
-1 baking thermometer
-3 similar size baking potatoes (Ideally you would obtain several potatoes and weigh each, finding the two that are the most similar in shape and weight)
-A microwave oven
-Aluminum foil
-Sharpie or black marker
-Data sheets, graph sheets,
-1, #2 graphite pencil
-2 different color pencils (The colored pencils are used in graphing the data in order to differentiate each experiment's data)

The Experiment

In our experiment, the potato will represent the a white dwarf star.

1. Start by measuring the room-temperature potato. Place the thermometer probe as close to its center as you can.

2. With your marker, draw a small circle on the potato around the probe. This will allow you to reinsert the probe in the same place after the potato is cooked. Allow three minutes for the thermometer to stabilize,

and then record the precooked temperature in your data sheet with the #2 pencil.
REMOVE THE THERMOMETER PROBE BEFORE COOKING!

3. Place the raw potato in a microwave oven, set the control to the timer for cooking one potato, and turn on the oven. Note: the cooking time will vary with each oven. Most microwave ovens have a digital or dial setting for a single potato.

4. When finished cooking, safely remove the potato with oven mitts, wrap it in aluminum foil, and place it on a plate or cutting board. Allow it to sit for five minutes. This will allow the potato to thermally stabilize and cook through.

5. After five minutes, completely unwrap the potato and stick the food thermometer into its center. Try to use the same hole that you created earlier when measuring room temperature.

6. When the probe is fully inserted, start the timer. After one minute has passed, record the temperature.

7. At the five-minute mark, record the temperature again and repeat every five minutes for a total of 30 minutes. Do not remove the thermometer after the first 30 minutes.

8. After one hour has passed, record a final measurement.

9. Fill in your data of measured temperatures on the attached graph with one of the colored pencils. Plot your data points to see the shape of the temperature curve. Remember, on the first part of this experiment there will be no data from 35 minutes to 55 minutes.

Day 2
Before repeating the experiment, discuss whether the temperature decline over time can be predicted accurately. Ask participants how similar they expect the new data points to be to the earlier experiment. Explain that in this experiment they will take data for one hour. Have students discuss their predictions for the shape of the temperature curve for the missing 35-60 minutes. Have them draw their predicted data points on the graph with the regular #2 pencil.
Repeat the process of the previous experiment using the second potato; this time you will include measurements until the 60-minute mark. Plot the second set of data on the graph using the other colored pencil. You should now have two sets of actual data on your graph along with the predicted 35-60 minutes in #2 pencil.

Overview
Compare the results of both experiments.

- •Were they similar? If so, would you expect others who do the same experiments in different places to have the same results?
- •How did the results of the experiment from the second day compare with the predicted result? If the results are not consistent, how could anyone depend on a standard cookbook recipe? Chefs would never be able to repeat a meal with any confidence.

If there are large discrepancies in the data, what factors could have influenced the differences? Some factors to think about include

-Different type and efficiency of microwave ovens
-Different type and size of potatoes

-Altitude and temperature of the laboratory
-Errors by those doing the experiment
-The internal temperature of the potato is not consistent

Using What We Have Learned

If you have time and enough supplies, you can then put what you have learned to good use. Your students have now discovered a cooling trend for the potatoes. Now let's make use of the cooling trend.
1. Prepare the third similar-sized potato in the same manner as the previous two; however, prepare this potato ahead of time so that it will have time to cool somewhat. Once you have cooked the potato, allow it thermally stabilize. After you have removed it from the aluminum foil, start your timer.

2. Present your students with the potato a set time after you have started your timer (25 minutes may be a good time to select). Be sure that they do not know when you finished cooking the potato or started your timer!

3. Have your students measure the current temperature of the potato with the thermometer.

4. With this temperature, have the students determine how long it has been since the potato was removed from the foil by matching their observed temperature to their cooling rate graph. Have them read off the corresponding time from their graph.

5. Check their time with your timer – if everything is done correctly, then the two times should be similar.

6. Discuss what could possibly cause differences in the two times.

Bringing It All Together

So what does a baked potato's cooling rate have to do with determining an age for the universe? In our experiment, the baked potato represented a white dwarf star. White dwarf stars are rather unique objects. They are made up of mostly carbon and oxygen, which are in a degenerate state (don't worry about what all that means, just know that it means that the white dwarf will not shrink as it cools – it will always remain the same diameter). Astronomers have found numerous white dwarfs in our galaxy, and

1.Through various methods, astronomers have determined the temperatures and true luminosities (as opposed to just how bright they appear to be in a telescope) of many of these objects.

2. With this knowledge, they have deduced the diameter and masses of the white dwarfs.

3. Using current theoretical models, which are supported through observations, astronomers know fairly well how hot white dwarfs are when they are first formed and how long their parent stars (from which they formed) existed before the white dwarfs were created in their deaths.

4. Finally, with a working theoretical knowledge of the rate of cooling for a large mass of carbon and oxygen, astronomers have determined how long it has been since a white dwarf was created. This is basically like running the clock backwards – they know the white dwarf's current temperature, they know how fast it cools, so they work backwards to determine how long it has been since the dwarf formed.

In summary, we know how fast a white dwarf cools. We can observe white dwarfs, measure their current temperatures and masses, and figure out (from the cooling rates) how long they have been around in order to get to their observed temperatures from their original temperatures. By adding this result to the length of time the parent star existed, we get a minimum age for the universe – the universe has to be at least this old for the parent star to have formed, lived, and died and for the white dwarf (which was created during the death of the parent star) to have existed long enough to cool from its original temperature to the temperature we observe today.

Once you have explained how the potato experiment is analogous to determining the age of the universe with white dwarfs, you may want to discuss with your students some of the issues astronomers may have in determining very accurate ages with this method. Some topics include

1. Very slight errors in the measurements of the white dwarfs can drastically affect the derived masses and temperatures of the stars.
2. Theoretical computer models are very good but they are not perfect, so we have a really good, but not perfect, idea of how fast white dwarfs cool based on their composition and size, how long the parent stars live, how hot the white dwarfs are when they first form, and so on.

Web Resources

NASA, WMAP
http://map.gsfc.nasa.gov/

The Scientific Method
http://www.sciencemadesimple.com/scientific_method.html

A very special thanks to Vanderbilt University's Dr. David Weintraub for the cooling-potato idea, taken from his excellent book "How Old Is The Universe?"