Slacker Astronomy Presents

Monologues on Monolithic Ideas

Ep. 1: The Big Bang

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Welcome to Slacker Astronomy's first ever Monologue on a Monolithic Idea. Periodically Aaron, Travis or I will get a wild hair to talk to you about some concept in astronomy that we like talking about. These monologues generally won't be on some new discovery that just happened this week, but instead they're going to be more about some big idea that has been around for a long time and that has shaped how we view some or all of astronomy.

In this first monolog I'm going to talk about the Big Bang. It just somehow seems fitting to start at the moment that everything started.

Today, as an astronomer, I can say with surety that the universe is 13.7 billion years old give or take about 200 million years. I can tell you that our universe appears to be accelerating apart, and that its geometry is flat, like we learned how to deal with in geometry class. But sitting here saying these things, I'm just giving you facts, I'm not really helping you to understand how I know any of these neat sounding bits of trivia.

The truth is, the search for the Big Bang has been a long one. Man has known for a while that something weird was going on out there in the stars, but it's only be in the past 200 years or so that our scientific abilities, and our philosophical and religious freedoms have allowed us to work toward understanding the Big Bang and cosmology in general.

It may sound a bit odd to hear me say that philosophy and religion have anything to do with science. The truth is, when a scientist comes face to face with an idea that goes against his or her worldview, they must either change their worldview, or throw out their results. As high school students, I'm sure we all fudged our data now and then to make our measurements match the reality we were taught to expect. As adults, some scientists have also felt the need to hide their results or alter their equations to make what they found match with what they expected – and sometimes, what they expected was dictated by their religion or philosophy.

One of the most famous examples of a scientist forcing physics to match his personal philosophy is Albert Einstein. Back in 1917, Einstein used his theory of General Relativity to try and describe the geometry our universe. When he was done chewing through his calculations, he found himself face to face with an equation that predicted that the universe should be expanding. Unfortunately, the scientific worldview in 1917 saw the universe as a rather boring, unmoving, unchanging place. Thinking something must be wrong in his thinking, Einstein added a single letter, the Greek letter Lambda, to his equations, and gave it a value that would make his equations hold the universe steady.

A few years later, Einstein decided that little Greek letter was the biggest mistake of his life. He was wrong, but for a while, no one knew that. But that very important little Greek letter will be the topic of a later monologue.

About the time that Einstein was chewing through his numbers, a man by the name of Vesto Slipher was observing galaxies at Lowell Observatory in Flagstaff, Arizona. Starting in 1912, Slipher began collecting information on how fast galaxies are moving toward and away from us. By 1924, he had looked at 41 galaxies, and remarkably found 36 of the galaxies are moving away from us. If the universe was unchanging and not evolving like Einstein, you'd expect galaxies to have random motions, like people milling around in market. If our galaxy were the produce section, you'd expect about half the galaxies to be moving toward us, half to be moving away from us, and their speeds shouldn't correspond to anything. While some may be racing off to pick up their kids, others may be milling around waiting to see if the cute produce guy comes out, while others are zooming in on a mission to find the best cantaloupe. The fact that Slipher observed most of the galaxies to be moving away from us, some with very high velocities, said that something unexpected was going. Either our galaxy carries a bad odor that is driving everyone away, or the universe is doing something interesting.

Slipher's observations and Einstein's equations weren't the first hints that all might not be boring and mostly stationary in our universe. In 1826, Heinrich Wilhelm Olber gave words to an idea that had been bugging the thoughtful for a good long time. Specifically, the sky is dark, and this has consequences. Every time one of us goes outside and notices that the sky is black at night, we are making a profoundly important observation. You see, if the universe is infinite in size and in age, then every where you look, your gaze should rest on a star. Some of those stars, like the Sun, are near and bright, others would be distance, and their light would be very faint by the time it reaches us. Still, the light from all the stars in an infinite universe would add up, and the light from those infinite number of stars would cause the skies to blaze from the light of a countless Suns. The thing is, when you and I go out at night, the sky is mostly dark even here in light polluted Boston. Sure, if I pull out bigger and bigger telescopes, I can find more more faint galaxies and faint stars filling in the spaces between the brighter objects. But even between these faint fuzzies I can always find blackness.

The blackness of the night sky tells us that the universe is not infinite in age and size. If the universe had a moment of beginning, even if it was infinite in size, than the light from the most distant stars wouldn't have had time to reach us. This is one of the fascinating consequences of light traveling at a set speed. The Sun, for instance, is about 8 light minutes away. If we could somehow turn the universe off and then back on, keeping everything where it is right now, we wouldn't see the Sun until our new, turned back on, universe was 8 minutes old. In our real universe, which is 13.7 billion years old, we can't see anything more than 13.7 billion light years away. The light from more distant objects simply hasn't had time to reach us.

Now, back when Olber was noting that the sky is black, they didn't know the universe is 13.7 billion years old. For all they knew, the stars were located in a shell that surrounded the solar system. This wasn't the standard theory by 1826, but they still had no way of knowing if the universe was infinite in age, and the sky was dark simply because the universe wasn't infinite in size, and there just wasn't that much glowing stuff out there. All they knew, because Olber pointed it out to them, was that the universe couldn't be infinite in both size and age.

So fast forwarding 90 years, and returning to the world of Albert Einstein and Vesto Slipher, there is a bunch of information floating around – scientists knew that the universe was finite in either age or size or both. They knew that most of the galaxies that are easy to see are moving away from us. And Einstein's equations, pre-Greek Letter insertion, seemed to say that the universe is expanding.

In 1929, Edwin Hubble stepped onto the scene to put all the pieces together. A few years earlier, Henrietta Levitte discovered that some rather inconstant stars called Cepheids change in brightness in a set way that is directly related to their average luminosity. These stars beat like hearts, and the ones with slower more plodding pulses are brighter than their faster beating peers. It just happens to work out that all the stars with a set pulsation period produce the same amount of light. If you know how luminous something should be, you can easily figure out how far away it is. We all do this when crossing the street at night. If we see really faint headlights, we know we can hang out safely in the middle of the road for a few seconds, however, if the headlights are really really bright, we know we are about to die. What we do naturally to figure out distance from brightness, astronomers have reduced to an equation, and using that equation, and Henrietta Levitta's Cepheid Period-Luminosity Relation, Hubble was able to figure out the distance to Vesto Slipher's moving galaxies.

Astronomer's have this habit of plotting everything they can, and being a great astronomer, Hubble plotted the distances to the galaxies versus their speed and discovered that things farther away appear to be fleeing our area of the universe faster than nearby objects.

This weird relation between distance and velocity actually tells us the universe is expanding. This is hard to explain without pictures or chalkboards, or at least being able to talk with my hands, but I'm going to give it a try. Start out by imaging that you are a very intelligent microbe living on a raisin that has been mixed into some raisin bread dough. As you sit on the microbe in the dough in some kitchen somewhere in cyber land, you notice the other raisins in the dough are moving away from you. As the dough expands, the dough pushes your raisin and the other raisins farther and farther apart. The raisins closest to you have less dough between them and you so they don't get pushed too far away, but the raisins on the other side of the dough ball from your raisin have a lot of dough between you and them, and all that dough does a lot of expanding, so that far away raisin rapidly gets pushed much farther away.

In our universe, it's the space between galaxies that's doing the expanding, and Hubble's plot of distance versus speed was showing him that expansion.

Now knowing the universe is expanding wasn't really enough to tell us there was a Big Bang. This is because expansion can come from a couple different things. In our raisin bread analogy, the dough is expanding and pushing the raisins apart. Now, if an impatient and deranged baker came along with a syringe of bread dough and started squirting dough between the raisins, you, from your microbial perch on one of the raisins, would see the other raisin's moving away from you in the exact same way that they moved away from you when the dough was allowed to expand naturally. In the one case, new dough is came into existence between the raisins, with the help of our insane baker, and in the other case, nature is causing the dough itself to expand.

Up through the 1950s, astronomers didn't know if our universe had it's own insane chef causing new space to spring up between the galaxies or if space was expanding out from an original singularity. Sorting out exactly what was happening required some more observational work and a lot more calculating.

The idea behind the Big Bang is that at one point everything in the universe – you, me, stars, galaxies, and even the real microbes on real raisins the universe over – was confined to a single, infinitely small point of energy. When that energy decided to become the universe, the Big Bang occurred and everything started expanding.

Any of you who have ever used a can of compressed air to clean out your computer have felt the can cool off as the air expands. This is one of those thermodynamic facts of life. When anything expands, it cools.

In the case of the universe, as it expanded and cooled atoms were able to spring into life out of the energy. Mass is nothing more then energy that's cooled off. For a while, the atoms and the light bounced around, constantly interacting and knocking each other all over like the atoms and light inside of that fluorescent light tube in your office or school. About 300,000 years after the universe formed, the atoms and light decided to stop fooling around, and the light went its own way. Well, that independent light is still out there, making its own path through all of space, and we can see it, and astronomers have named it cosmic background radiation.

And the first people to see that radiation was a pair engineering astronomers trying to do something totally unrelated. Like many great discoveries, their's was accidental, but wouldn't have happened at all of they hadn't worked to understand the weirdness they were observing.

These two employees of Bell Laboratories, Arno Penzias and Robert Wilson, were testing an ultra-sensitive microwave dish by measuring the background microwave signal from our own Milky Way galaxy. Now, our galaxy is a disk. When we look up through the top of the disk, we see fewer stars, and when we look out along the disk we see a lot of stars that form the band that stretches all the way around our sky. While testing their ultra-sensitive microwave dish on the Milky Way, Penzias and Wilson expected that they'd detect microwaves from the parts of the sky where there is a lot of stars, and not from the empty parts of the sky, and this is, mostly, what they saw. Unfortunately, they also detected this faint noise everywhere they looked.

Now imagine you are a podcaster trying to record podcast with new, ultra crisp sounding mic. If you play back your latest recording and hear this hiss in the background you're going to be pretty pissed. Imagine that you think it may be your heater in the background, so you go off to the back corner of your basement where theres no heat, no nothing, and you make a new recording and that hiss is still there. You're going to probably get more frustrated, and start trying new cables, and rant at some poor slob at the manufacturer's help desk.

Now, Penzias and Wilson went through many levels of frustration with their noise. Wilson and Penzias went so far as to try blaming pigeons for the noise. Unfortunately, after removing the pigeons from roosting in their ultra-sensitive microwave dish and scrubbing out the gifts the pigeons had kindly left them in their ultra-sensitive microwave dish, they still found this lovely little microwave signal every where they looked. At this point they decided the universe must be up to something and they called up some folks at Princeton.

About the time that Penzias and Wilson were fending off pigeons, Robert Dicke was working on figuring out just what color the cosmic background radiation we talked about earlier should be.

When we think about the color of light, most of us usually think about red and blue and indigo and colors that can be found in a box of crayons. The truth is, your eye can't see most of the colors that light can come in. The signal going from your wi-fi box to your computer is actually nothing more than a beam of light visible to your computer with a color called radio – FM and AM stations all transmit at different colors, the scientists, in their cleverness, call them frequencies instead of colors, because they like to create sophisticated vocabulary words they can associate with equations. Your television's remote control also uses light – in this case infrared light. And your microwave cooks food with light that happens to have a color that is very effective for heating chicken.

So, when Robert Dicke at Princeton set out to calculate the color of the light left over from the Big Bang, he had a pretty large palette to select from. At the end of his calculations, he found the universe should be filled with a low level microwave colored background of light. With this key bit of calculation, he and some collaborators got ready to build them selves a microwave dish. Unfortunately, they didn't get it built before their phone rang.

Wilson and Penzias, in 1963, found the light that Dicke had calculated. They were simply trying to look at our galaxy, but when they found some weirdo background noise in their data, they decided to figure out the source of the noise, and they found the Big Bang. In 1978, Penzias and Wilson got the Nobel Prize. Dicke did not, once again proving that life isn't fair.

To figure out that our universe originated from a single expanding point, scientists had to make a lot of observations, and theoretical break thoughs. Our knowledge of cosmology started with the simple observation that the sky is dark, and the realization that darkness implies the universe can't be infinite in both size and age.

From there, Vesto Slipher had to notice that galaxies seem to be fleeing away from us, and Hubble had to figure out how to measure the distances to those galaxies and realize that the universe is expanding. Once we knew the universe was expanding, we had to figure out if new matter was materializing between galaxies, or if the universe as a whole is expanding from an original singularity. That took more math and Penzias and Wilson's hard work to determine that the noise in their data was actually a signal from the beginning of the universe.

Today we continue to refine our understanding of how our universe began, finding new ways to study how our universe's expansion is evolving and trying to figure out just how our universe will continue to evolve in the future. Science can't tell us what caused that singularity to expand into our universe, and in my own comic timeline I write "Here Me Dragons" at the first unexplainable point of origin. There are some realms that I like to leave to the philosophers and wisemen. But perhaps one day, in the late of night, Aaron and Travis and I will take on those first moments, and discuss the personal philosophies that encapsulate our own worldviews. For now though, I'm going to try and wrap up this monolithic monolog and let you all get back to your own contemplations of life the universe and microbes on raisins in that bread your going to eat later tonight.

If you like what you hear, let us know, and if you find really long discussions on things like the Big Bang boring, well let us know that too. Check our site often, spam our message boards, and give it all a listen. Email us anytime at info@slackerastronomy.org.

On behalf of Aaron and Travis, this is Pamela Gay. Thanks for listening and remember, we want your spam.

Clear Skies and Clear Bandwidth. This has been Slacker Astronomy, a volunteer collaboration for you, for fun, for the voices in our heads.