THE UNIVERSE IS RINGING CAN YOU HEAR IT?

Mensan's novel method for plotting points in space-time reveals new view of cosmic history | by Harry Ringermacher, Ph.D.

In Don Lincoln's June article in the *Bulletin*, "Capturing the Big Bang," he jokingly referred to Douglas Adam's *The Hitchhiker's Guide to the Galaxy* and the computer Deep Thought's answer to "the meaning of life, the universe, and everything" – 42. The ultimate irony here is that Douglas Adams hit the universe right on its rim. It is ringing like a struck crystal glass, and the answer really is 42! Even better, I now know the ultimate question.

PHILOSOPHY ABATES WHEN EXPERIMENT PREVAILS

Isaac Newton once wrote, "If I have seen further, it is by standing on the shoulders of giants." Indeed, many giants have contributed to our understanding of the universe's origins. Understanding current theories, like my own, requires some review of these giants' work. Einstein, the successor to Newton, led the way with his 1915 publication of the general theory of relativity. He provided the foundation for cosmology, the study of the universe and its beginnings.

At the time, the universe was thought to be stationary, unmoving and eternal. General relativity, to the contrary, fundamentally seemed to show that the universe is unstable, either expanding or contracting. Einstein fudged his theory to accommodate the consensus and added a constant to the equations – the cosmological constant – to make the equations show a static universe.

At the same time, astronomers were observing spiral nebulae thought to be in our Milky Way Galaxy. Henrietta Swan Leavitt at the Harvard Observatory had discovered that a certain kind of star, called a Cepheid variable because its brightness varies over time, could be used to calibrate astronomical distances. Vesto Slipher at the Lowell Observatory had discovered that these nebulae are receding from us by observing a reddening (redshift) in their light spectrum.

Then in 1929, Edwin Hubble exploited these discoveries and added his own work, finding that these spiral nebulae have their own Cepheid variables and are nearly all receding from us at a speed that is proportional to their distances (Hubble's Law), which could now be calculated. And those distances are vast – well beyond our neighborhood of stars.

In one fell swoop, Hubble renounced our Milky Way as the center of the universe and pronounced the universe was expanding. Einstein was embarrassed because his cosmological constant was not necessary. His theory without it could have predicted that the universe was in motion. The debate had started. Some, notably George LeMaitre, a priest and physicist, proposed an expanding universe starting from an "explosion" type of event. Others, such as Fred Hoyle, supported an expanding "steady state" universe that has no beginning or end. Hoyle referred to LeMaitre's theory as some kind of "big bang." The name stuck and the picture of the universe expanding from a hot and dense origin is called the Big Bang theory.

The debate continued into the 1960s. But science has its way; philosophy abates when experiment prevails. In a 1948 *Nature* article, physicists Ralph Alpher and Robert Herman worked out the science behind the Big Bang and predicted that there would be a "relic" haze of microwave radiation uniformly distributed all around us in space. It is what was left behind as the energy in the Big Bang cooled down from the expansion to approximately 3 degrees above absolute zero. In 1964, Arno Penzias and Robert Wilson at Bell Lab discovered the primal radiation from the early universe known as the cosmic microwave background (CMB), the key signature of the Big Bang idea. In 1978, they received the Nobel Prize in physics for that discovery. Studies of the CMB followed in earnest.

A REVOLUTION IN PRECISION

Ground-based telescopes had the first go at exploring the universe's origins; however, Earth's atmosphere absorbs microwave radiation, so airborne methods, like balloons, acquired data on the CMB for some time. Progress was slow until the space program took hold and satellites specifically designed to look at the CMB were launched.

The first was the Cosmic Background Explorer (COBE) launched in 1989. COBE was the first to image the entire microwave sky. These microwaves originated from a time 380,000 years following the Big Bang, a period called recombination.

At that time the universe had cooled to about 3,000 degrees, cool enough to allow an electron to combine with a proton forming atomic hydrogen. Before that time, electrons and protons were free to fly around, bumping into one another in what is known as a plasma state. Photons of light were trapped between these particles and were absorbed and reemitted. When the hydrogen condensed, everywhere these photons were instantly and simultaneously freed. There was a blinding flash of light in the universe and those photons, whose wavelengths were typically 1 micrometer (one millionth of a meter), traveled through time in all directions, ending up where we see them today as the CMB.

As we observe the CMB today, its wavelength is about 1 millimeter. How can that be? This is the crux of the Big Bang scenario. The universe has been expanding – literally. The space itself is stretching. And anything "attached" to it, such as a wave of light, will also be stretched. Since the time of recombination, the universe has expanded 1,000-fold, stretching the original 1 micrometer wave to a 1 millimeter wave.

COBE was looking back in time at the infant universe and confirmed the predicted microwave signal with excellent accuracy. John Mather of the NASA Goddard Space Flight Center and George Smoot of the University of California Berkeley won the 2006 Nobel Prize in physics for their COBE work.

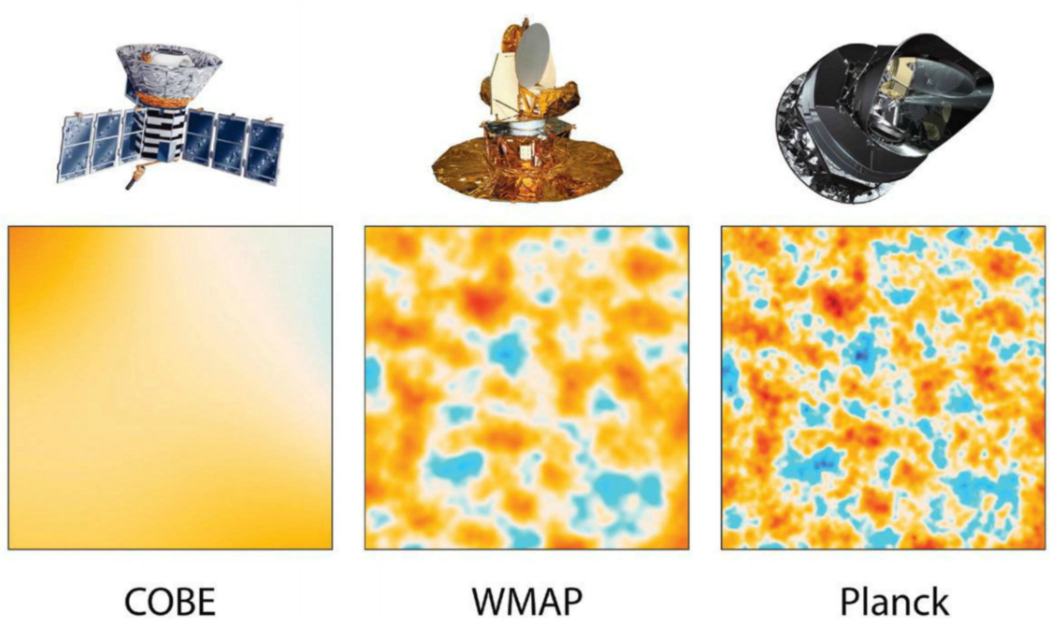
More accurate satellites followed, the Wilkinson Microwave Anisotropy Probe in 2001 and Planck in 2009. Each one was several times more accurate than its predecessor. Cosmology had experienced a revolution in precision. From analysis of the CMB, cosmologists had learned: The universe is 13.8 billion years old and space is Euclidean – flat as opposed to curved – so that simple plane geometry could be applied to it; and the universe will continue to expand forever.

These were philosophical questions prior to COBE. Moreover, studies of the CMB as well as galaxies had shown that there appeared to be insufficient visible matter, like stars, to hold galaxies and the universe together. This was first discovered in the 1930s by Fritz Zwicky, an astronomer at the California Institute of Technology. Studying galaxy clusters, he postulated the need for "dark matter," invisible matter to assist in binding the galaxy cluster. This was reaffirmed in the 1970s by Vera Rubin at the Carnegie Institute when she discovered the same problem in each galaxy itself. Rubin presented her work at the 2006 Mensa Colloquium "Revolution in Cosmology."

So, a new type of matter, dark matter, had to be postulated to explain the physics. Satellite probes showed that the universe comprised approximately 5 percent normal matter, 27 percent dark matter and 68 percent dark energy. Dark energy, a kind of repulsive gravity, was discovered in 1998 and was deemed responsible for causing an accelerated expansion of the universe that began about 6 to 7 billion years ago. Adam Riess of Johns Hopkins University, Saul Perlmutter of U.C. Berkeley and Brian Schmidt of Australian National University won the 2011 Nobel Prize in physics for that discovery. It turned out that Einstein's "mistake," the cosmological constant, was resurrected to account for the dark energy. Even his mistakes turn out to be right!

The 1998 discovery of the accelerating universe marked the first time that astronomers and physicists used a method other than examination of the CMB to analyze our universe. Great telescopes, such as the Hubble Space Telescope, peered at Type 1a supernovae, white dwarf stars that explode roughly once every 1,000 years in any given galaxy. Astronomers can generally count on being able to spot one such supernova per year in a group of 1,000 galaxies, and there are millions of visible galaxies. From our vantage point, the brilliance of the explosion is the same as the entire galaxy, which is composed of hundreds of billions of stars, in which the supernovae resides.

They explode with the same brightness every time, so they are called standard candles. When one explodes in a nearby galaxy, which has happened a few times, its brightness can be precisely measured. It's like knowing you are looking at a 100-watt light bulb 1 foot away. If you move the bulb to 10 feet, it will appear one-hundredth as bright, like a 1-watt bulb. Its brightness decreases as



The cosmic microwave background (CMB) is the radiation left from the recombination period 380,000 years after the Big Bang. The Cosmic Background Explorer (COBE) was the first satellite to measure the temperature of the radiation and provided confirmation of the Big Bang model of the universe's formation. Later satellites, the Wilkinson Microwave Anisotropy Probe (WMAP) and then Planck, improved accuracy and collectively pointed to the notion of a forever-expanding, Euclidean (flat) universe that is 13.8 billion years old.

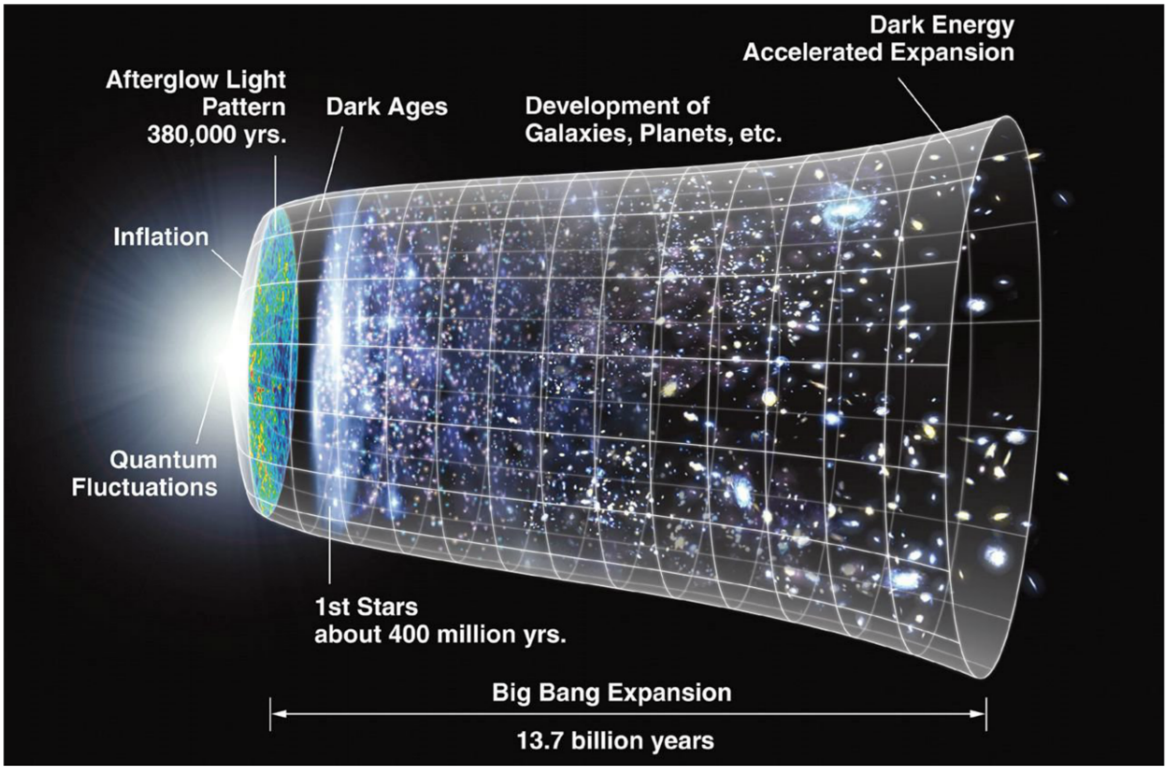


Figure 1: A pictorial representation of the expanding universe from its beginning to its present day

the inverse square of the distance – 10 times farther away means 1/100 as bright.

Reversing this procedure, if we measure the apparent brightness of a Type 1a supernova in a remote galaxy, knowing its true brightness in a nearby galaxy at a known distance, we can estimate the distance to that remote galaxy. In this way astronomers use these supernovae as beacons to measure distances to remote galaxies all over the universe. Due to the expansion of the universe, these galaxies are all receding from us. The farther away they are, the faster they are moving, according to Hubble's Law. By measuring the distance and speed of these receding galaxies in all directions (from the redshift of their light spectrum), we are mapping out the expansion rate of the universe all the way back in time. Figure 1 is a pictorial representation of the expanding universe from its beginning to the present day.

A NEW ASTRONOMICAL PLOT

Because all this "stuff" expanding is made of matter, it would seem that gravity would pull it back together, thus slowing down the expansion rate. In 1998, astronomers mapped this expansion expecting to see that but instead measured the universe slowing down at first but then speeding up and accelerating starting about 7 billion years ago – all this by looking at Type 1a supernovae going back in time. They found a single point in time, albeit somewhat fuzzy, about 7 billion years ago, when the universe went from decelerating to accelerating. That point is called the transition time.

They plotted the data on what is known as a traditional Hubble diagram, a graph of distance of the supernova versus its redshift. As was mentioned earlier, redshift measures the velocity of a star moving away from Earth. The greater the redshift, or reddening of the star's spectrum, the faster it is receding from us. So the plot shows distance versus speed of the supernovae back through time.

Although this type of plot is convenient, it is not very intuitive or easy to see the so-called transition time without going through mathematical gymnastics. Being lazy, I sought a more intuitive plot that could obviously display that magic point. There actually is such a plot, and it is discussed in virtually every cosmology textbook. It displays the distance of a galaxy or star against its lookback time. Lookback time is just what it sounds like. It's the time, looking back from the present, to when the supernova blew up and released its light impulse.

The trouble was that astronomers do not use this plot because, as described and analyzed by well-known experts in the field, you need a model of the universe in order to calculate the lookback time from the redshifts. You actually needed to know in advance the amount of dark matter and dark energy to convert redshift to lookback time. So, the plot seemed somewhat logically circular.

Nobody ever bothered to see if it was possible to create such a plot without needing a model of the universe because experts implied it was not possible. I am thoroughly familiar with Einstein's general relativity theory and the type of space-time geometry dealt with in the Big Bang theory. Upon examining the problem described, I realized that astronomers had exceeded what they could have done in a simpler way.

Supernovae are observed in all directions in the sky, and they are at all distances, and therefore times, from us. In fact, I showed that they are truly randomly distributed in time. There are so many data points, around 500, that the separation in time between each one is very small. All one needs to do is add up all the time increments of all the supernovae out to the given supernova you want to plot to get its lookback time.

This was new – a time ladder. By following Einstein's rules and this recipe, you did not need a model where one inserts the measured amount of dark matter and dark energy. You simply had to have faith in the universe (and Einstein) that the makeup of the matter would be taken into account naturally. The true test of this plot would be to see how well the standard Hubble diagram data would look on it once converted. The fit was excellent, at the 98 percent level of "goodness." And the results were published in the October 2014 *Astronomical Journal*.

THE UNIVERSE IS RINGING

I now had my wish – to locate the transition time in a simple way with this new plot. The point in time would manifest itself as a change in the slope of the data curve from decreasing to increasing slope. This should have been visible, literally. However there was what appeared to be noise in the data. No one had ever plotted this data directly against time. A standard noise-filtering analysis revealed, to my surprise, a series of decaying oscillations where the transition time should have been. At the frequency of the oscillations I measured, there would be approximately seven cycles (more accurately, 6.9 cycles) in 13.8 billion years, the age of the universe. Cycles of what? Cycles of distance to the supernovae in time. The galaxies were actually wiggling!

Turns out, I was looking at wiggles of the universe itself. For convenience, I coined a new unit of frequency to describe these oscillations – "Hubble-hertz" (HHz). A hertz (Hz) is a unit of frequency in physics – one cycle per second. But we are dealing with a few cycles over billions of years. One Hubble-hertz would be one cycle over 13.8 billion years. So our measured frequency is about 7 HHz.

Because I could not trust a simple analysis, I used three other independent methods to check for the oscillations. All the methods agreed, revealing a fundamental 7 HHz signal, and, in fact, the more sophisticated methods showed the presence of second and third harmonics at twice and three times the fundamental – 14 and 21 HHz. A plucked string on a violin vibrates and decays at a fundamental frequency along with its harmonics, creating its beautiful timbre. A lead crystal goblet rings and decays when tapped or rubbed in the same way. The universe is ringing in response to the Big Bang. To hear it, if you could, you would need awfully big ears.

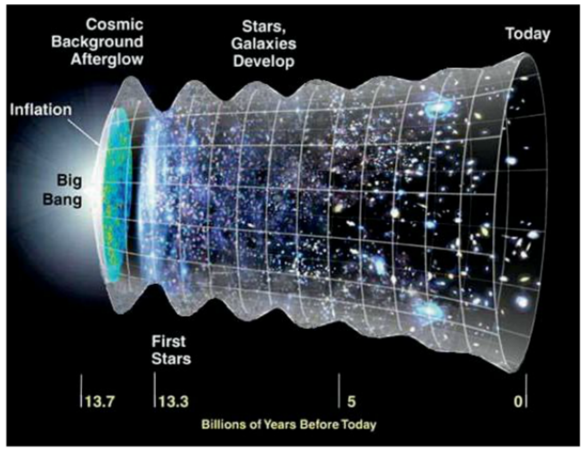


Figure 2: The universe from its beginning to the present day including observed oscillations

Physicists are wont to find explanations for things. My colleague, Larry Mead, a theoretical physicist at the University of Southern Mississippi, and I convened and thought about what this means. We proposed a simple theory for an oscillating universe called a "scalar field model." In this picture, the oscillation is a wave that changes back and forth between dark matter and dark energy, thus relating these two mysteries. We published this analysis in a second paper to the *Astronomical Journal* in April 2015. Figure 2 is the universe as described in Figure 1 with the observed oscillations added.

THE ULTIMATE QUESTION

Although professional physicists rigidly stick to the scientific method, I could not resist the ironies of the present findings. The universe has oscillated from dark matter to dark energy seven times since creation. But physicists, in their calculations, do not insert the cyclic frequency 7; rather they use angular frequency, 7 times 2Pi or approximately 7 times 6, which is 42!

The universe has revealed the famous answer. So what is the question? When I was 10 going to Hebrew school, I would listen as the rabbis said, quite seriously, that God created the universe in six days and rested on the seventh. So, in seven days it was all over and here we are today. I remember always thinking that God's day must be very long since I collected fossils and understood, even then, that the universe was very old. Now I know precisely the length of "God's day" – two billion years.