1905 - 2005
INSIDE EINSTEIN'S UNIVERSE

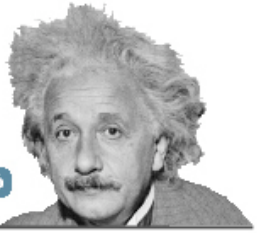
Journey through the Expanding Universe

The explorations contained in the "Journey through the Expanding Universe" demonstration manual encompass a wide range of topics concerning distance and motion in the universe. This document suggests a pathway through these explorations that allows audiences to build a model of today's universe, through the context of Einstein's revolutionary work, beginning in 1905. Using slightly more appealing terminology, here is the script for a 25-minute journey through the expanding universe, culminating in Einstein's most exciting prediction: the Big Bang!

We encourage presenters to read the "Journey through the Expanding Universe" demonstration manual, which contains several explorations not included in the presentation below, and a number of suggestions about how to make each of the activities presented below an even richer experience for your visitors. Of course, you are encouraged to add your own jokes and expertise to enhance or modify this presentation in any way. The Universe Education Forum welcomes feedback from you and your audience members at any time. Feel free to contact us at einstein2005@cfa.harvard.edu. Now, on with the show!

Most of the slides included in the accompanying Power Point are not essential to the core of the presentation and are merely intended as backdrops. You may wish to omit them and eliminate the use of the computer projector. The slides labeled "A Couple of Gals" and "Post Cards from Space" are the two slides that require audience participation. If you are not using the computer, we recommend printing these two slides out as color transparencies for use during the demonstration. Alternatively, you can simply stop using the Power Point after "Post Cards from Space" and turn off the computer for the rest of the presentation. This will make the second half of your presentation run more smoothly because you will only need to worry about turning on and off the lights in the room for the activities that require a dark room.

There are several ideas not included in this presentation, but detailed in the demonstration manual:
- Exploration 2 – Brightness and Distance
- Exploration 9 – Center of the Universe
- Dark Energy – the accelerated expansion
- Einstein's Nobel Prize – the photoelectric effect



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Please see the demonstration manual for more information about these and other presentation ideas, including Einstein connections.

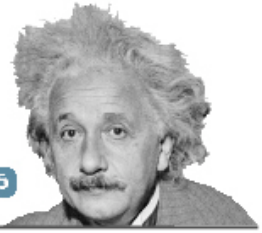
Overview of the Presentation

1. Welcome and Introduction
2. The Universe of 1905 – one galaxy, strange spiral nebulae
3. The Universe of 2005 – billions of galaxies, all the way out
4. Exploration 1 – Distance Ducks and a Galaxy Far, Far, Away
5. Post Cards from Space – messages in the form of light
6. Exploration 3 – Energy and Wavelength of Light
7. Exploration 4 – White Light and Diffraction Glasses
8. Exploration 5 – Glowing Gases and Their Hidden Messages
9. Exploration 6 – Messages from Distant Galaxies
10. Exploration 7 – The Stretching of Space
11. Exploration 8 – Einstein's Expanding Universe
12. Exploration 10 – Big Bang in a Can
13. Questions afterwards

Suggested Script for Presenter

Before the presentation begins, you should assemble your materials and make sure they are easily accessible for the demonstration. Don't forget to tie your rope to a stationary object (Exploration 3), roll your rainbow (Exploration 4), and distribute your galaxies and hidden messages (Exploration 6).

General Supplies: accessible electrical outlet, overhead projector, computer and video projector
Introduction: galaxy placard around your neck
Exploration 1: two galaxy placards (including the one around your neck)
Exploration 3: length of rope, tied to a stationary object (such as a chair, table, etc.)
Exploration 4: white light bulb in socket/table lamp, diffraction glasses in a pile/box, rainbow paper
Exploration 5: gas tubes (protected, but accessible), diffraction glasses
Exploration 6: pre-set galaxies and spectrum "secret message" envelopes, overhead projector
Exploration 7: Elastic band with sinusoidal wave drawn on it
Exploration 8: Galaxy placards
Exploration 10: gloves, hose, nozzle, fire extinguisher



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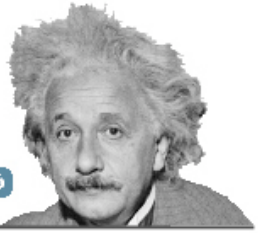
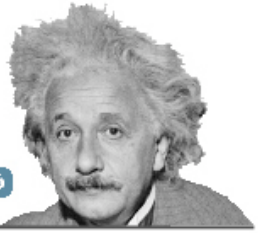
Guide to the Script:

What to say – suggested script (Column 1)
What to do – suggested actions (Column 2)
What to see – suggested images, "audience response/observation" (latter in quotes) (Column 2)
Italicized text – optional (i.e. prompts, omit for time, etc.)

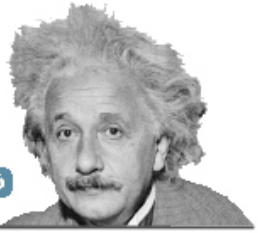
What to say	What to do	What to see
Welcome all to "Journey through the Expanding Universe" here at the [Your Museum]. My name is [Your Name] and I will be your guide as we embark on an exciting mind-bending (mind-stretching, even!) adventure through space and time and all the way "Inside Einstein's Universe" where we just might find ourselves in the middle of the Big Bang. This presentation is part of our 2005 Einstein Centennial celebration. 2005 marks the 100th anniversary of an exciting year for Albert Einstein. In 1905 our friend Albert began writing a series of revolutionary papers that changed our entire view of space and time and got us really thinking about our place in the universe. One of the most amazing ideas to come out of this work was that empty space, boring old empty space, was dynamic and maybe even had a beginning. Of course, I should warn that even though Einstein predicted this amazing new property of space, he was very uncomfortable with this idea. Let's figure out why.		Slide 1 – Title Slide
I invite you to hop into your time machines and travel back to the year 1905 with me. Ready? Here we go!	*Click to Slide 2*	
The universe of 1905 is a pretty simple place. We live on		*Slide 2 – Home*



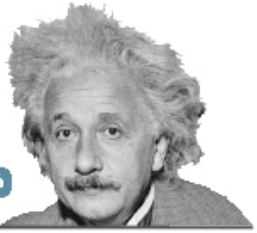
a planet, Earth, which circles a star, the Sun, which is the near the center of a big disc of stars, called the Milky Way. If you've ever been able to travel to a very dark place, where there's no light pollution, you may have seen this giant band of stars stretching across the sky.		*Sweet Universe, 1905*
The Milky Way is all there is to the 1905 Universe. There was nothing outside the Milky Way galaxy. In Einstein's day, "Galaxy" equals "Universe" and our solar system is right in the middle of it all. Isn't it nice to know that Einstein thought he was the center of the universe?		
The big question of Einstein's day concerned these weird fuzzy spirals in the night sky. Called spiral nebulae, no one knew exactly what they were. Some people thought they were new solar systems being born, while others thought they might actually be other discs of stars outside our own Milky Way. This was a source of huge controversy in 1905 – are spiral nebulae inside or outside our galaxy? Are they newborn solar systems inside our galaxy or are they entire star systems beyond the Milky Way? Is there any way to figure out what they are if we don't know how far away they are? Don't worry; I won't leave you hanging.	Hold up galaxy placard Drop galaxy placard so it once again hangs around your neck.	
We now know, one hundred years later, that these fuzzy spirals are in fact separate galaxies just like our own. We live in a single galaxy, made of billions of stars. Our Sun is not at the center; it is about two thirds of the way out. How big is our Milky Way? Well, let's just say that if	*Click to Slide 3*	*Slide 3 – Home Sweet Universe, 2005*



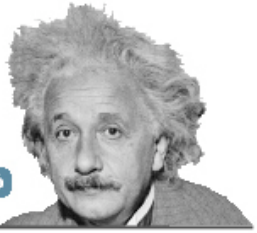
our entire solar system were the size of a quarter, the entire galaxy would be the size of North America. Our Milky Way is surrounded by billions of other galaxies, each of which contains billions of stars. In fact, if we look out into the night sky using the most powerful telescopes, we see galaxies out as far as we can see. We don't know how far out they go, but there are a lot of them. Maybe even infinite. What Einstein and others wanted to figure out was how big the universe really was. How far away are the galaxies?		
For this activity, I will need a volunteer.	Choose volunteer	
What's your name? Everyone, I would like you to meet Galaxy Name	Ask name, and give volunteer a galaxy placard	
Galaxy Name is located a certain distance away from you, the observers. I am Galaxy Me. Before I go find my place in the universe, I'd like you all to confirm that these two galaxies, Galaxy Name and Galaxy Me, are in fact the same size.	Position the volunteer at the front of the stage and stand beside him/her.	
Are these two galaxies the same size? Let's be sure. We're going to use a very sophisticated measuring tool, known as the "Distance Duck." Everyone take out your Distance Duck!	Get response from audience	"Yes"
What do you mean you don't know what your Distance Duck is?! It looks like this! Come on now, take out your	Demonstrate holding your hand	



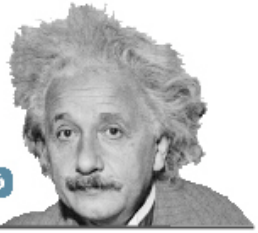
Distance Ducks, and measure us galaxies by closing one eye and putting each galaxy in your duck's mouth. Are we the same size? (The galaxies, not the people!)	in the shape of a duck's mouth.	
All right. Keep your Distance Ducks on Galaxy Name while I put myself in my place.	Move to back of stage.	
Do you have a clear idea of how big Galaxy Name is? All right. Keep your Distance Ducks frozen in exactly the same position and compare the size of Galaxy Name to the size of Galaxy Me. What do you observe?	Audience response Audience response	"Yes" "Galaxy Name is bigger"/"Galaxy Me is smaller"
That's right. Let's have a round of applause for Galaxy Name! (Feel free to use your Distance Duck to quack.)	Collect placard, lead applause, etc.	
What did we just observe? Objects that are farther away appear smaller. In astronomy, if we know two objects are the same size then the one that looks bigger must be closer.		
Take this image for example. If we assume that both the galaxies in this picture are the same kind of spiral galaxy (we'll talk about how we can assume that in a minute) and would be roughly the same size if they were sitting next to each other in space, which one is closer?	Click to Slide 4	Slide 4 – A Couple of Gals "The one on the left"/"The big one"
Great. We've established a way for astronomers to figure out how far away things are. One of the other things astronomers are interested in is what things are made of. This is a very perplexing question. On Earth, if we want to know what something is made of, what do we do? If we want to know what our backyard is made of, or what a		



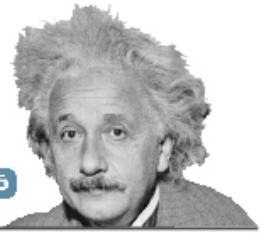
beach is made of, we go there, dig around, maybe scoop up a pile of sand or dirt or rocks. What about places we can't easily get to? How do we find out what they're like? Raise your hand if you've ever received a post card from some place you've never been.		
What's the furthest place you've ever gotten a post card from? Have you ever been there? What about you? What's the furthest place you've ever gotten a post card from? Have you ever been there?	Choose someone in the audience. Choose someone else. Etc.	
What about outer space? Has anyone ever gotten a post card from outer space?		
Well, in fact you have! If you have ever looked at a picture from a telescope, you have gotten a post card from space. What does this message tell us about the object it came from? *(Size, shape, brightness, something very obvious)*	Click to Slide 5	Slide 5 – Post Cards from Space "Color!"
That's right. Color! In this picture, we can see some lovely blue clouds, and here we have some lovely pinkish red clouds. I'd like you to remember this color pink as we talk about the light messages coming from objects deep in space.		
One of Albert Einstein's most important discoveries was about the different colors and energies of light. His work, for which he won the Nobel Prize, by the way, helped us create a model of how light shines.	Take out rope and tie it to a stationary object (if not already attached).	



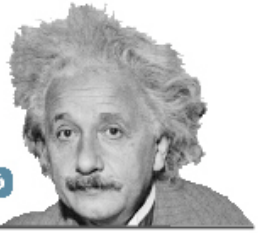
We're going to use this rope here to create our very own model of light. Of course, this is a model, so you have to remember that light is not actually a rope.		
Let's say I am a bright shining object out there in the universe. I am shining with a certain amount of energy. As I shine, I create a light wave. You, the observers, see that light wave as it shines. Can you see the wave?	Begin shaking the rope, creating sinusoidal waves across the floor.	
If I shine with more energy, what happens to the light? The waves become closer together.	Shake rope faster, creating more frequent waves.	
If I shine with less energy, what happens to the light? The waves become further apart.	Slow down, creating less frequent waves.	
High-energy waves…low-energy waves…high-energy waves…low-energy waves…	Alternate fast and slow shaking.	
In order to figure out what type of waves we're looking at, we need a very finely tuned detector. As it so happens, at this very moment there are about [(number of audience members) x 2] of those detectors in this room. Does anyone know where those detectors might be?	*Gesture toward your eyes, if audience doesn't figure it out.*	"Our eyes!"
Our eyes and brains are very good at detecting light. They can look at a beam of light and figure out if it is a high-energy wave or low energy wave.	Shake rope to represent different wavelengths	
The way they tell us that light is low energy or high energy is by assigning it a color – red for low energy, long wavelength light, and blue or violet/purple for high-energy, short wavelength light.	Click for Slide 6	Slide 6 – Good Morning, Sunshine



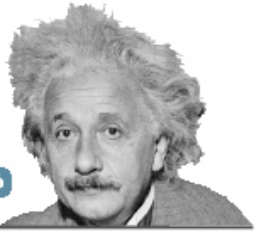
Of course, the story doesn't end there. There are some energies of light that don't have quite enough energy for our eyes to see. We call that infrared light. And some light is so energetic that it goes right through our eyes, not even noticing that we're there! Some examples of super-high-energy light are ultraviolet light and x-rays.	*Mouse click*	*Multi-wavelength information on Slide 6 (animated or inserted as a new slide)*
Let's everyone give a big hand for our eyes and brains. That's hard work figuring out what color the universe is!	Lead applause	
Now of course if I turn on this light, what color do you see? "White?" Where in the rainbow do we find white? Is white even a color? This light bulb is shining with light of lots of different energies in all different directions, and it's too busy for our eyes to figure out what's going on.	Plug in white light bulb.	"White"
In order to decode the message hidden in this white light, we're going to need another type of tool to help our eyes and brains out. Everyone take one and pass the rest on. You all look very fashionable!	Hand out diffraction glasses.	
These glasses work like a prism to spread out the light that comes from this light bulb. If you look at this light bulb with your glasses, what do you see?	Turn off all other light sources in the room.	"All the colors!" "A rainbow!" etc.
You should be seeing a number of different rainbows, but I think we need to focus our attention on one of them. Let's look at the bright rainbow directly to the left of the		



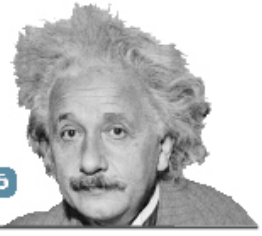
bulb. What color is on the right, closest to the light bulb? And what color is on the left?		"Blue/purple" "Red"
So what's going on here? Everyone take off your glasses for a moment. I have here a beam of white light. When it arrives at the glasses, the glasses spread the light out into all its component colors, red, orange, yellow, green, blue, and violet. When we look through the glasses, we see the light all spread out into a "spectrum" of colors.	*Hold up rolled-up white paper and move it toward the glasses. When it "hits" the glasses unroll the paper to reveal the spectrum for the audience.*	
Astronomers use a tool just like these glasses to look at light from space. Their tool is called a spectroscope. I want everyone to take off your spectroscopes for just a minute. Put them down, no peeking.	Turn on lights	
This light bulb is shining because there's a solid filament in the middle of the bulb whose atoms are giving off light. But of course, the universe isn't filled with giant light bulbs. Who knows what the universe IS filled with?	Call on people or repeat shouted-out answers.	"Stars!" "Galaxies" "Gas!" *(You can prompt "what are stars made of?")*
That's right. Our vast and galaxy-filled universe is filled with all sorts of glowing gas. For example, our Sun…Helios. I have here a tube of glowing helium gas.	Begin loading helium tube into power supply	
Without using your spectroscope (You there! No cheating!) I want you to tell me what this helium gas looks like to you. What color do you see?	Turn on power supply	"Yellow" "Pinkish"
Now I'm going to turn off the lights and I want you all to pick up your spectroscopes and take another look at this glowing helium gas. Remember to look at the pattern to	Turn off all other light sources	



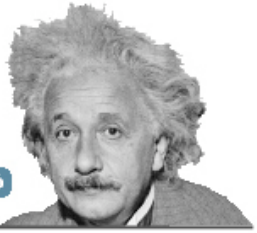
the left of the gas. What colors do you see? I see a red line, a thick yellow line, a big gap, a thinner green line, a little gap, and then two blue lines. Do you see that pattern? This pattern is unique to helium, sort of like a fingerprint. If you've ever seen a movie about detectives you know that the detective is always looking for fingerprints in order to identify people. If an astronomy detective sees this pattern coming from light in space, she thinks, "Aha! There must be helium out there!"	Put on glasses	"Red!" "Yellow!" "Green" "Blue" "Purple"
Now let's take a look at another type of gas: hydrogen. Hydrogen and helium are the two most common elements in the universe. Everyone put your spectroscopes down again! No peeking!	Turn off power supply, take out helium tube (caution: may be hot; use cloth to handle…may be cooler on ends.) and load hydrogen tube.	
Without using your spectroscopes, what do you see? Does the hydrogen gas look the same or different than helium? What color do you see? Does that pinkish color look familiar? Remember we saw that same pinkish color in our post card from the Trifid Nebula. If you see a pinkish cloud out in space, it's very likely that cloud is made of hydrogen gas.	Turn on power supply	"Different" "Pink" "A little blue"
So let's take a look at this hydrogen gas with our spectroscopes…what colors do you see?	Put on glasses	"Red line" "Blue line"



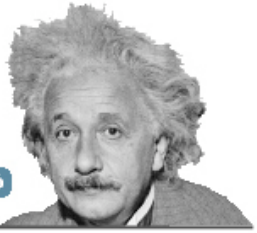
The spectrum, or fingerprint, of hydrogen is very different than helium's, isn't? If an astronomy detective looks at a beam of light with her spectroscope sees a red line and a big gap and a blue line she thinks, "Aha! Hydrogen!" I have a little rhyme I like to use to remember what the spectrum of hydrogen looks like. How many of you have ever read Dr. Seuss?	*Click for Slide 7*	*Slide 7 – Elementary my dear Einstein*
Well here in front of you, we have the very Seussian spectrum of hydrogen. I see "one line, two line, red line, blue line" Everyone say it with me now…"One Line, Two Line, Red Line, Blue Line."		"One Line, Two Line, Red Line, Blue Line"
What does the spectrum of hydrogen look like again?		"One Line, Two Line, Red Line, Blue Line"
I want you to keep that rhyme in mind as we move on to our next activity. Everyone please pass your glasses down the aisle so we can use them for our next group of visitors. Thank you very much.	Turn off power supply, put it away, collect glasses, and pull out overhead projector.	
By looking at the fingerprint of light from objects deep in space, astronomers can figure out what things are made of. As it turns out, the universe is made almost entirely of hydrogen and helium!		
Take this galaxy for example. These little pink blobs throughout are big clouds of hydrogen gas. And you can see here, if we spread the light from the galaxy out into a rainbow spectrum, we see the fingerprint of hydrogen.	*Click for Slide 8*	*Slide 8- In a Galaxy, Far, Far, Away*



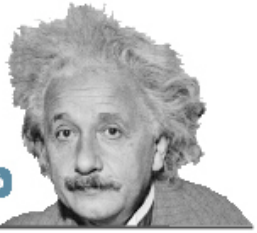
I'd like to take a look at the light coming from some galaxies in the universe, and I just happen to know that there are some galaxies out there in the audience right now. Is anyone sitting near a galaxy? I see one there…and there…and there… and there. Four galaxies! Excellent.	Encourage people to raise hands/hold up galaxy placards	
These galaxies look to be different distances away. Does anyone know how I can figure out their distances? Let's see, this one here looks the biggest, so it must be the closest. Let's call it Galaxy 1. Where's the next closest galaxy? We'll call that Galaxy 2. Now, Galaxy 3, and that one way far away over there would have to be Galaxy 4.	Hold up Distance Duck and measure four galaxies.	"Distance Ducks!"
I'd like to figure out what these galaxies are made of. Do you suppose any of these galaxies has a Top Secret light message to send me?	Wait for audience members to find "Top Secret" envelopes	
Oh good! Well, what I need now are four Light Messengers, one from each galaxy. Who wants to be the light messenger for Galaxy 1? Okay, you. Now Galaxy 2. Galaxy 3. Galaxy 4. Excellent.	Choose volunteers sitting near each galaxy	
I am going to collect your messages in order from closest to farthest and I need everyone else's help to examine them. Are you ready?		
Light Messenger from Galaxy 1, bring me your message!	Volunteer walks up	



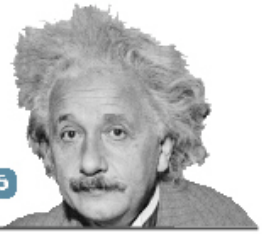
Thank you very much. A big hand for our first Light Messenger.	with envelope. Applause, etc.	
Let's see what this message has to say. Looks like there is lots of light coming from this galaxy. I see a whole rainbow of light, and something else too. Some color lines are much brighter than the rest of the rainbow.	Open envelope, take out and put transparency on the glass. Turn on projector.	
I see…one line…two line…red line…blue line. One line, two line, red line, blue line. Does anyone know what has this fingerprint?	Point to lines very obviously	"Hydrogen!"
There must be hydrogen in this galaxy! This pattern, or spectrum, represents all the light from the galaxy, spread out over the whole rainbow. The bright lines, or tall spikes, show us what energies of light are most intense. In this galaxy, we have very definite red line-blue line pattern. That, as you just told me, is the fingerprint of hydrogen.	*Click for Slide 8* Provide "tour" of the spectrum.	*Slide 7- In a Galaxy, Far, Far, Away*
Let's see what our next nearest neighbor has to tell us. Do we have a messenger from Galaxy Number 2? Aha! There you are. What message do you have for us?	Second volunteer brings message	
Thank you very much, Light Messenger Number 2. (Applause.) Well, this also looks familiar. One line…two line…red line…blue line…must be hydrogen!	Replace first transparency with transparency two	"One line, two line, red line, blue line"
Well, that seems reasonable. I wonder what will happen when I compare this to our first message.	Put first transparency back,	



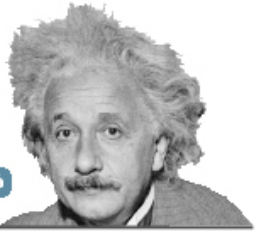
Now I must be careful to line up the continuous rainbow of energies underneath…this end here, my low energy, long wavelength light…and that end there, high-energy, short wavelength light…there! All lined up. And with all my energies of light lined up (you can see that the red starts here on both patterns) both my hydrogen lines should line up as well.	taking care to line up the continuous rainbows (NOT the hydrogen lines). Ignore any audience protests.	
Well, let's take a look at the next message from a galaxy even further away. Light Messenger Number Three, are you out there?	Third volunteer brings message	
Thank you very much. I'll just put this on top of my other messages, making sure to line up my continuous rainbow again…and my hydrogen lines should line up: one line, two line, red line, blue line.	Applause Place third transparency Ignore protests	
Well, let's get that final message from our very very far away galaxy. Light Messenger Four, what does your galaxy have to say?	Fourth volunteer brings message	
Thank you. Let's have one more round of applause for ALL our light messengers. Thank you all!	Applause	
Now, just to review…I collected light messages from four different galaxies, at four different distances. All four of those galaxies seem to display our token Dr. Seuss hydrogen pattern (one line, two line, red line, blue line), and they're all in the same place, right?	Line up fourth transparency Audience protest	
What do you mean they're not in the same place? I lined up all four rainbows!	Indicate lined-up rainbows.	



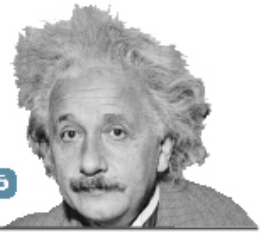
You're right! The hydrogen lines are at different places. What's going on?!	Look at spectra again.	
It looks like these lines are shifting, further and further toward the red side of the rainbow. This last galaxy doesn't even seem to have a red line any more; it has shifted BEYOND the red, all the way into infrared!		
Something must be happening to the light from these galaxies as it is traveling to us through space. Something must be causing this very strange shift toward the red. What do we know about red light? Is it high energy or low energy? Are red light waves long or short? Who remembers our rope model?		"Low energy" "Long wavelength"
[Leading question] I wonder what could possibly be causing the light waves to shift to longer and longer wavelengths. SOMETHING must be causing the hydrogen light to lose energy and have a LONGER wavelength. Does ANYONE out there have ANY idea what could make the wavelength of light longer?	Take out elastic band and begin stretching it so that the audience can see the drawn-on waves getting longer. Emphasize stretching.	"Stretching?"
As you can see here, I have another model, and for this I would like to thank someone named Albert Einstein. Albert Einstein's revolutionary theory of gravity suggested, for the very first time, that empty space was not just nothing, but it was *something!* He suggested that space was actually a dynamic *thing* that could stretch and expand. Now that's pretty strange! Does anyone's brain hurt? Mine sure does. Expanding space, how weird!		



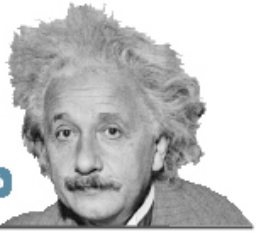
Let's consider the light coming from our galaxies for just a moment.	Hold up elastic band	
As it travels through space, traveling from its home galaxy over here…	Indicate a spot on the stage	
…to our telescopes over here, the space it travels through is expanding, stretching the light to longer wavelengths.	Indicate a different spot, and walk towards it, stretching the elastic band.	
A wave of light coming from a galaxy even further away (such as Galaxy 3 or 4) travels through even more space, and so it stretches even more.	Step to a spot further away than the first spot.	
If we look at galaxies out in the universe, their light appears kind of whitish, doesn't it? Well, if we look at very distant galaxies using the most powerful telescopes, something cool happens. The light coming from these very distance galaxies is stretched so much, their images actually look red!	*Click for Slide 9*	*Slide 9 – It's Not Easy Being Red*
In fact, some galaxies are SO distant that their light is stretched all the way beyond the red, into the infrared part of the spectrum. Galaxy 4 is an example of that. NASA's Spitzer Space Telescope is specially designed to look at things that shine in infrared light, so astronomers are using Spitzer to look at very very distant galaxies.	*Click for Slide 10*	*Slide 10 – NASA's Spitzer Infrared Space Telescope*
So if space is expanding and light traveling through space is stretching, what is actually happening to the galaxies out there in the universe?		



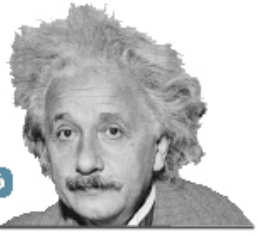
For this activity, I am going to need about 6 volunteers. Each one of you is going to be a piece of space that just happens to have a galaxy sitting in it. Take these galaxies and put them on, but remember that you are empty space, NOT galaxies. The galaxies are just floating out in space minding their own business.	Choose volunteers and give each one a galaxy placard	
If I line you up like this, we have what I like to call "The Observable Universe." Of course this is only a model, so it's not perfect. For example, here at the Museum our universe is sitting inside this room and all of you are looking at it from the outside. In the true universe, no one can have this view. We need to imagine that this room and everything else in world, including us, is contained inside this model. In order to do this, I'm going ask you all to use your imaginations. *As Einstein himself once said, "imagination is more important than knowledge!" Right?*	Line them up shoulder to shoulder	
Everyone out there in the audience, pick your favorite galaxy and imagine yourself inside it. Take a look at the galaxy next door. How much space is between you and your neighbor? Let's all use our Distance Ducks. How many galaxies could fit in the space between you and your neighbor? One? Two? Three? Four? Five? Now look at your neighbor three doors down. How much space is between you and your distant neighbor? About 10 galaxies? 12? 15?	Use your Distance Duck to measure out the space between galaxies Choose an estimate for your own chosen "home" galaxy	Audience members should raise hands/agree with you when you hit upon their estimated number.
All right. Now we need for space to stretch. Everyone hold your arms up like this, elbows bent at your side, your palms touching your neighboring space's palms on either side of you.	Demonstrate making V's with your arms.	



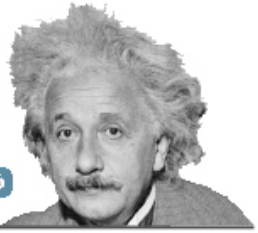
Now on the count of three, I want all my space people to stretch out, like you might do in the morning. *(It's okay to move).*	Demonstrate stretching your arms out to your side, making a T with your body.	
One, two, three, stretch! And freeze! Good job expanding, everyone. I'd ask you to leave your arms out, but I know that can get tiring. So everyone drop your arms and we're going to see what happened to the galaxies in the universe.		Volunteers move apart
First of all, I want everyone to find the galaxy that you live in and take out your Distance Ducks again. Now how many galaxies could fit in the space between you and your next-door neighbor? Twice as many as before? Three times as many? Now how about that galaxy at the end of the block? Three times as many? Five times as many? Nine times as many? Looks like the far away galaxies have spread apart even farther than my nearest neighbors.	Count up to the distance you yourself estimate. Start with the number you just said above and count up.	Audience members should raise hands/agree with you when you hit upon their estimated number.
Let's get some firsthand experience from the space inside the universe. What's your name? Hi *Name*. Can you tell me what happened to the galaxies in the universe as space stretched? What did you see? Which galaxies moved the fastest? Which galaxies moved the furthest? [Repeat with other volunteers in the line]	Ask several different volunteers about what they observed.	"They moved apart." "Galaxies further away moved faster." Etc.



[Optional]	*Repeat activity to illustrate other points described in manual.*	
Thank you everyone. I'll take those galaxies back, and you can return to you seats. Let's have a big round of applause for our expanding universe!	Lead applause	
Now I told you at the beginning of this demonstration that Einstein's predictions about an expanding universe made him very uncomfortable. Why is that? When Einstein first made this prediction – that space could expand – you must remember that everyone thought that the universe was eternal and unchanging. If the universe were expanding, Einstein thought, it would have, at some point, started out much smaller and much different than the universe we observe today. As it turns out, evidence collected in Einstein's own lifetime helped him realize that we do, in fact, live in an expanding universe.		
Let's review. We began this presentation talking about the amazing prediction that empty space could expand. Around this same time, astronomers had just begun to figure out that the Milky Way was just one of billions of systems of stars known as galaxies throughout the universe. Like detectives, we used the fingerprints of different types of light to figure out not only what those galaxies		



are made of, hydrogen, but also that the light from these galaxies is being stretched. The further away a galaxy is, the more its light is stretched. The light is stretched by space itself as it expands, and as space expands, it pushes the galaxies apart. We see galaxies moving apart from each other, which leads us to an interesting conclusion.		
If we see galaxies being pushed apart by expanding space, what happened in the past? What happens if we run the expansion backwards, rewind space, rewind time? We get a situation where all the material from these galaxies was much, much closer together, packed in, like sardines, into a very small space. And then, if this is true, at some point in the past, this whole thing must have started expanding.		
This early time, when everything was all packed together and suddenly started expanding, is given the name "the Big Bang." And so, we're going to end today's presentation with the beginning of time, the moment when the universe started expanding.		
We're going to use another model to show what the universe was like during the time of the Big Bang. I just happen to have a model of the Big Bang right here by my side, ready to go.	Pick up fire extinguisher and pull pin	



When I let this Big Bang out, it's going to get pretty loud, so you might want to cover your ears. You're going to see a couple of things, however. You're going to see the universe expand from a very small volume, this can, and you're going to see stars and galaxies form as the universe expands.		
Because this is a model, you have to imagine that everything we see in the universe, including you and your chairs and the museum and me and everything, is all inside this can. Are you ready?	Aim nozzle above audience as you hold extinguisher	
Count down with me. Don't forget to cover your ears! 5, 4, 3, 2, 1!	Squeeze handle releasing CO_2 into air above audience	
And that concludes today's presentation! Thank you very much, and if you have any questions, I would be happy to stick around and chat. Enjoy the rest of your day at the Museum.		

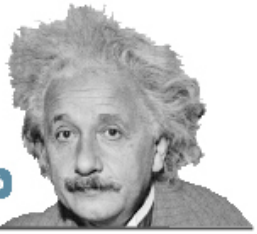
Ideas not mentioned:

Additional Slides

Supplemental Slide – There's No Place Like Home

The Universe of 1905 is a pretty simple place. We live in the Milky Way Galaxy – a large disc-shaped system of stars. People in 1905 were able to figure out that the galaxy was disc-shaped. They were also able to figure out how far away things were. We'll talk about this soon.

As you can see, our own personal star, the Sun, lives pretty close to the center of this galaxy. Our galaxy, according to astronomers of 1905, has always been around, and no one is really quite sure where it came from. The biggest mystery of Einstein's day, however, can be seen on this next slide.



Supplemental Slide – A Nebulous Question

You can see here on the left Cornelius Easton's sketch of the Milky Way star system: our solar system near the center, with all the stars around it. I want to draw your attention to the fuzzy spiral blob between letters A and B. As it turns out, there are a lot of fuzzy blobs in the night sky. Astronomers call these fuzzy blobs "nebulae." Astronomers in 1905 were particularly interested in the fuzzy blobs that looked like little mini-spirals in the sky. You can see a sketch of one of these so-called "spiral nebulae" on the right. The BIG question in Einstein's day was whether these spiral nebulae were located inside or outside of our Milky Way galaxy.

Some astronomers looked at the shape of these spirals and realized they were very similar to the shape of our own Milky Way galaxy. Perhaps, they suggested, these spirals were actually other galaxies outside the Milky Way. What do you think? Does the spiral on the right look like it should be inside or outside our galaxy?

This question caused a LOT of trouble in the beginning of the 20th century, so I'm going to spare you all the arguments and reveal the answer. Here is a picture of this very same spiral taken with the Hubble Space Telescope in January of 2005.

[MOUSE CLICK] This is, in fact, the Whirlpool Galaxy, located 37 million light years away from our Milky Way. Today we know that universe we live in is filled with millions, even billions, of galaxies.

Supplemental Slide – The Universe of 2005

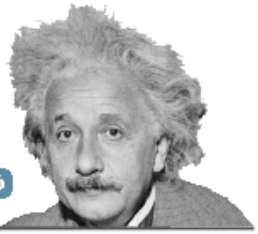
See slide notes

Supplemental Slide – How Far Are the Stars and Galaxies?

See slide notes

Supplemental Slide – How Far Are the Stars?

See slide notes



1905 - 2005
INSIDE EINSTEIN'S UNIVERSE

Supplemental Slide – A Nobel Idea

See slide notes

Supplemental Slide – Hubble, Hubble, Toil, and Trouble

See slide notes

Supplemental Slide – Messages from Space

See slide notes

Supplemental Slide – Pattern-ity Test

See slide notes

Supplemental Slide – Preserving the Static Quo

See slide notes

Supplemental Slide – Return of the Cosmological Constant

See slide notes