

NWX-NASA-JPL-AUDIO-CORE (US)

**Moderator: Michael Greene
September 25, 2014
8:00 pm CT**

Coordinator: Welcome and thank you for standing by. At this time all participants are in a listen-only mode until the question and answer session of today's conference. At that time you may press Star 1 on your touch tone phone to ask a question. I would like to inform all parties that today's conference is being recorded. If you have any objections you may disconnect at this time. I would now like to turn the conference over to Mr. David Prosper, thank you, you may begin.

David Prosper: Thank you and hi everyone this is me, (Dave Prosper), from the NASA Night Sky Network here at the Astronomical Society Pacific in a surprisingly rainy San Francisco California.

I'm really excited to present this teleconference with our guest speaker, Dr. Mandeep Gill, from the Stanford Linear Accelerator Center. Before we begin I just want to make sure that you can all have the presentation slides ready and ready to view. So if you don't have the slides up in front of you yet you can download them at bit.ly/nsmlensing - that's B-I-T dot L-Y slash N-S-M-L-E-N-S-I-N-G.

And if you have any problems along the way feel free to email us at
nightskyinfo@astrosociety.org. Now for a brief minute I'd like to hear from
the folks joining us tonight so Operator if you could please open up the lines
and if you could just give us your name and tell us where you're calling from
and what club you're with. We'll have an idea of who's out there listening.
Operator?

Coordinator: Thank you lines are now open.

(Chris Saltman): (Chris Saltman) with St. Louis Astronomical society.

((Crosstalk))

(Bill Wagner): (Bill Wagner) Berks County Amateur Astronomical Society Reading,
Pennsylvania.

Woman: (Unintelligible) high school astronomy teacher in St. Louis Missouri.

(Cary Adams): (Cary Adams) Miami Valley Astronomical Society in Dayton Ohio.

(Greg Donahue): (Greg Donahue) Celestial North, Seattle Washington.

Man: (Unintelligible) from the (unintelligible) Astronomical Association.

Woman: (Manit Sinwa), Gloucester Area Astronomy Club, Gloucester Massachusetts.

(Ronald Graney): (Ronald Graney), South Bay Astronomical Society in Torrance, California.

(Harry Treece): (Harry Treece), Astronomical Association of Southern Illinois, Carbondale
Illinois, crossroads of the next two solar eclipses.

(Michael Otule): (Michael Otule), a really interested astronomy kid.

David Prosper: Awesome; well, just thanks everyone for checking in and we'll just (unintelligible) great to hear from you all. And so to follow along with our talk just follow along with the PDF of slides and there will be a time for Q&A at the end of our talk. And now I have just a brief minute for the latest Night Sky Network News for our members.

For - this is actually going to be some pretty great news. We've recently wrote out some more updates to the site behind the scenes that should help both speed up the club events calendar the way it renders and sometimes doesn't and help with finding your location while still maintaining your privacy. So those things should be working much better for most folks now.

And we're also close to the end of our survey amateur astronomers. If you haven't taken our survey yet we ask you to do so very soon. You can find that survey at bit.ly/twentyfourteenastrosurvey. And our results will be published in a couple of months along with an update in the Sky and Telescope Magazine.

And also it's near the end of the third quarter so remember to log your events for chances to win our next quarterly prize as well as to receive some additional or replacement tool kits if your club has not already received them all. So now let's get started with tonight's talk. It is my great pleasure to introduce our speaker Dr. Mandeep Gill from the Stanford Linear Accelerator Center or SLAC. His topic tonight is cosmology from gravitational lensing or Professor Einstein teaches us about the cosmos through space time curvature.

Dr. Gill is going to take us through a tour through the universe of the very big and very small and show us the links between particle physics here on Earth and the warping of space time that enable us to see on the very large scales of our universe. And he answers some questions about the very small via the very large.

Dr. Gill is a member of the public affairs department and is an observational cosmologist at SLAC for concentrating on gravitational weak lensing. In 2008 he was a post-doc research fellow at the center for cosmology and particle physics at the Ohio state university concentrating on gravitational weak lensing and determination of cosmological parameters from this technique. He earned his doctorate at UC Berkley in 2004 in experimental high energy particle physics.

In the summer of 2005 he visited the large Hadron collider at CERN in Geneva Switzerland and observed or one may even say was odd by the construction of the CMS and atlas experiments. In a visiting position at Cal-Tech in 2006 he was involved in a cosmology project involving second order weak lensing. And ultimately better dark matter distribution determination of distant galaxy clusters.

And so Dr. Gill, with that, would you like to begin?

Mandeep Gill: Yes indeed David. Hope everyone can hear me well. Welcome everyone; it's a great pleasure to talk to you all tonight. And yes, David just let me know if you can't hear me or anything. I - it was great to hear where everyone is from. This is very interesting format for me. First time I've done this and I think it's pretty neat.

As you've heard I've been in different parts of the country and so it was neat to hear people from you know the South Bay down in Dayton Ohio where I was near there for a few years and all that. So I'm going to try to keep this talk kind of compact. A little bit more than I normally would so we might skip a few slides. And I actually have taken out some of the particle physics because I actually prefer questions more so keep the questions in your mind because I'm going to try to keep this to about 40 minutes of the talking part early on.

They are in the backup slides as we go through so I'm going to go ahead and start. The title you've seen is a little bit different now. It's how (hair) Dr. Einstein can come to the rescue and help solve the grandest mystery modern day physics.

Okay so let's go ahead to the second slide. Oh I guess - well they have numbers in the PDF at least and I've usually given this as PowerPoint, it won't have any transitions now but it should be okay. So for more info you can find a link that gives you a lot more resources at the top of (mandeve.org), that's my Web site. And you can mail me personally if you have any questions and you can like this page and ask for questions at the Facebook link there if you are so inclined. Great so with that we'll go to page three.

And so the talk plan is to talk a little bit about dark matter, dark energy, bring it to Earth for a minute because that's kind of big going way out there, introduce lensing and then how lensing can help us with dark matter and dark energy. And talk a little bit about the future in this field.

Okay Slide 4 is some of my inspirations I always like to bring in (Carlos Hagen) our sort of patron scientist you can say. I really like his work. In fact sometimes when I do this talk I show the pale blue dot video and won't have time here but I really recommend looking that up. (Unintelligible).

This is a place where I give this talk actually at that farm and it was dark by the time I finished so we just looked up and take in the third thing which is we have the night sky which a lot of you do. And you know astronomy unlike particle physics where I got my PHD which is harder to access in some ways, astronomy, the sky's always up there you know so there's this intrinsic thing. And I just tell people who feel like you know find the big dipper first, you know just get your hands around that and if you start knowing some of the stars, most of you know that's Orion there they'll be your friends, they're always there.

So that's where I start and I like to ground it in that. Alright so Slide 5 again particle physics and cosmology have re-converged and I can talk about that more later.

So Slide 6 is where SLAC is so some of you may live near SLAC and SLAC may be actually starting to re-begin tours soon but SLAC is a particle physics lab. And so if you go left there you're looking west, we accelerate electrons and (unintelligible) electrons and we start them at the top there right where it says looking west and bring them down. We used to have the six target program and then we had the collider so the building the rectangular building close to the bottom of the - of that picture on the left. That's a huge building in which there's a - we call it the collider hall. And we used to collide them at very high energies finding the third largest - third most massive particle that we know (unintelligible) goes on.

So at that time it was yes where it says (unintelligible) particle in the early 90's. Anyway so it's done a lot of particle physics and so how does that connect to astro at all? Well so if you go to Slide 7, astrophysics, you are scaling up you know these sort of telescopes used in the backyard so they're -

you see Fermi and (chommy) these are two telescopes that are used in space. But specifically Fermi the (unintelligible) telescope there gamarize some of the particles that come out when you collide particles together. They're very high energy photons and we had an expertise at SLAC in building crystals that would detect those gamma rays and so when you fly them in space or when you, you know we made those into an instrument that we could fly in space since we had expertise because they don't penetrate very far into the atmosphere. So you have to go into space for that energy photon and we can see them up there.

And you can see things like gamma ray (unintelligible) which are super powered, super nova that are beamed that us and discs, you can see black holes and gamma rays and different - we're looking for dark matter indirectly it has a gamma ray signature and the annihilation of dark matter. Anyway so we have - we had expertise and that's where sort of one of the connections between particle physics and astro came from.

Alright if we go to Slide 8, another place is - this is the history from one slide. So toward the left you know we're just showing you schematic in time going from left to right. And so as you also go back in time if you look on the bottom there the top row is time, the middle row is temperature, the bottom row is energy. So we're going up in energy and you know even if you don't know what GV - one GV a proton weighs about one GV in units so just to give you scale.

So our current universe is very low energy you can see ten to the minus 13 or so GV. But then when you went back to you know much less in a second, ten minus ten seconds you're at 100 GV and what you see is in sort of going left and right and back but early on you had - you see all these letters. Those were individual particles. Over time the quarks and all those (corrallast) into nuclei

into neutrons and protons which went into a nuclei, made atoms, the electron started going around the nuclei, they made atoms then you made galaxies then you made the thinker for example at a billion years - ten billion years you had the thinker finally by (Roda).

And so that's a connection that early universe physics you have to do a lot of particle physics in early you know just after the big bang singularity. You have to understand that particle physics so just how particles interact because there's no galaxies back then and nothing but particles. So many connections between the two.

So let's go to Slide 9 and some of you may have seen a pie chart but I like the cupcake picture. It's not a chart, it's the cupcake picture and this is a colleague of mine who liked to bake so she chose to use cupcake analogy. So this in one cupcake like chocolaty picture encapsulates all we what we know about the composition of the universe.

And we understand this - well we understand what the universe is, what the slices are made of pretty well now. Even if we don't - we haven't pinned down what the components are. But what this shows is the body is made of something called dark energy and I'll explain that in a minute. The frosting is dark matter; it's about 1/4 of the matter energy content so I'll use this term matter energy content.

And the sprinkles are what we're made of and it's actually mostly hydrogen and it's just 4% of the matter energy content and I say matter energy because (unintelligible) matter energy do have this equivalence, okay. So that's - we understand that division well. And this was not understood 20 years ago or really even 15. This is a pretty, especially that dark energy that was only

pinned down as being a major component 15 years ago, 1998 - so 16 years ago. We didn't know that before that.

So when I was going to school for undergrad that was not known. Great - so now we go onto figure ten. This is saying it in a different way. This is the sort of typical pie chart that we use and it shows the dark energy, dark matter and then the sort of normal matter broken into the different components and you can see that breakdown, okay.

And now we're going to go onto Slide 11. This is going to be the only equation slide. So for those of you who are you know okay with equations what we have - I want to explain why we believe in dark matter. Get a little bit of you know because we hear about it all the time you know some people think we just make it up. But really in 1689 Newton explained the motion of planets with equations.

So there's basically the first equation is (unintelligible) gravity, geo-constant M , and the capital M and small m are the two objects, D is the distance between the objects.

And the other equation below it is $F=MA$, law of inertia and so you just combine those two equations and you will get the lower equation. The $=F$ over $M = D$ squared over D is for circular motion, you get that form.

So the important thing to recognize in that last equation is the velocity goes as capital M there is the mass of the central object, the sun, so if I'm at a fixed radius so D is fixed, the more massive the object is the central object, the faster V has to be in that circular object. Or conversely if I take a fixed mass object and I go out in distance the - that object can go slower or will go slower to stay in the same orbit.

So Mercury rips around the sun in 88 days, we take 365 Earth days, Pluto the dwarf planet takes several years - I forget the number, 13 possibly. So it takes - oh no actually it's over 200, sorry I was thinking the other (unintelligible).

So for those who didn't like Pluto being demoted the new Orion spacecraft will be getting there next year so we'll have lots more interesting info by the way. So the point here is as you go out in distance you feel the gravity of the central object less so you don't have to go as fast to sort of stay in orbit, at an infinite distance you can just sit there and you wouldn't feel it.

Now if we go to the next slide - 12 -- we see the - what I show there are the velocity vectors of the different planets so going from in to out there's just the inner rocky planets, the four rocky ones. You can see the velocity of (unintelligible) as they go out from Mercury, Mercury to Mars.

Now Slide 13, so in galaxies we didn't expect an immediate fall off because galaxies don't have just one central object, they have a lot of gas and dust and stars that keep going out for a while. You know you see this all the time; you see this in the spiral galaxy if you see it face on like that. And so we - you might expect the velocity has to go higher for a while because you're including more and more mass within your radius.

But then it's got to start falling off when the matter gets diffuse certainly beyond the very diffuse outer edge it should fall. That's what you expect - this is what people expected but what they saw was Slide 14, the green arrows that when they measured tracers the tracers which are stars, you can see them in gas clouds as you get beyond the edge kept having a higher velocity, well a constant velocity.

And we'll - we see that schematically in the next page 15. So I've plotted there, I've plotted velocity versus distance so the dash curve is what we expected as I showed before and the red is the observed curve that people actually saw, okay. And so we infer there's some other kind of matter that we can't see invisible light directly, the evidence is all from gravity and the next plot, page 16 shows actual plots so again rotational velocity and the vertical axis distance from the center in this unit called kiloparsec so it's - a kiloparsec is - one kiloparsec is 3000 light years. So our galaxy is you know 50,000 light years across in net diameter something roughly like that.

So you get some sense you see this repeatedly in all these galaxies. This is really the clincher and it's where, it's one of these places to understand dark matter. Okay so a lot of people at this point say well what about - couldn't it just be planets you don't see or black holes you don't see because they - and people have actually searched in very many ways for those indirectly through lensing, through their gravitational influence on each other. And I'll just say simply for now here that there's very strong evidence that that is not the case. That they're not made of normal - that whatever the dark matter is it's not normal matter.

And then Slide 17 I show a few other places where it's indirectly quote seen so it's seen in these rotation curves, the velocity rotation curves is the galaxies that I just showed. In all these other and on the top in green in all these other sort of different astronomical observables we call them it's a cosmological component that lower pie chart because as I'll show you need it to make - to get the large scale structure, right, that is to get the distribution of where galaxies are, right.

And we're searching for it in colliders you know there's theoretical reasons it could be there in certain models but that's not guaranteed to us that that's true so we don't really know that. So just jumping straight to dark energy.

This figure is to kind of supposed to show that the universe was for a while slowing down so you see first it had this huge big bang so the time is vertical axis now and then the expanding universe there is to show the radius of the observable universe. It's you know has to be orange and then the blue. It's expanding but it's slowing down.

And then suddenly when it goes black it starts getting bigger faster. It's an accelerated expansion, things are not any - just moving away from us with a velocity and slowing down, they're moving farther. That was the observation that was made in 1998, okay. And that's won the Nobel Prize in twenty-twelve because it's extremely strong evidence from many different sources that I can talk about if people want to know it's (first sound) and super nova which are standard (candles).

But it's seen in many different arenas and the simplest explanation to that, we don't really you know what I see as energy is a stand in for our ignorance of you know why this is happening.

The next page - 19 -- slide 19 -- shows sort of one model. There's this thing called the (cassimere) fact which happens because there's virtual particles popping in and out of the vacuum. I'm using a lot of words here that - there's this you know foaminess and so if you want to know more you can go ahead to the extra cosmo resources. But essentially these are all theoretical ideas and there's no really great idea what - the simplest let's see the simplest idea is there's these equations, I should probably put them in, their called Einstein equations and they are what describe gravity to us fully in our universe.

We understand all gravity through the Einstein equations. And Einstein knew if he put in a constant he could get a steady state universe so that's what he did back in the 1900's before Hubble knew - had seen the expansion. So that's the simplest way we still do it.

So and that, (λ) is the term that the term - the constant term that Einstein used in his equations. So if you go to figure 20 that's the Greek letter (λ) at the top. And it's sort of what this is showing scale size is how fast things are expanding and again time on the horizontal axis. And you see an inflexion point at you know between ten and 14 billion years instead of slowing down it starts speeding up. And that's what's happening now. ABB is after big bang there.

So that's what we're seeing in the simplest explanation as a constant. Now why should it be a specific value, this constant energy density, there's no real understanding of that. You know some people say multi-verse, we're one of gazillion of universes and it was you know we're the right one for that.

I don't think that explains a lot and you know that's theoretical prejudice or anyway this is a very active area of research let's say. So I - the telescopes I work on are looking at these kinds of things.

So if you go to figure 21 another place we see dark energy and you also need dark matter to get this right is the structure of matter in the - it's the distribution of galaxies and the filament in between them that are made of gas and dark matter. We don't see the dark matter but we can infer it from different ways.

So the left on that slide we see universe and dark energy, on the right we see universe without dark energy and very different in that slide. And we're without dark matter would also be very different.

On Slide 22 when you actually compare data in the simulations there very close if you put in this dark matter and dark energy and sort of you know not showing ones that would be really different here but you can find those easily on the web or you know what it would look like. So this is the kind of thing that has really convinced people that we understand well that we have - that we got - we have the composition right even if we don't have quote the details of knowing what the dark matter particles are, what you know sets the scale in dark energy.

So 23 I'm going to step back, sometimes people take a sigh here, that's good if you want to do that. I just want to give this sense of scale because way out edge of the universe there, okay. So just for you know to get some sense of scale I like people to know you know the speed of light is very fast to us so the fastest slower orbit satellites go at 30,000 kilometers per second. The elapsed time it takes about 90 minutes to go around the Earth and light goes around about eight times in one second around the Earth, right? It's really fast.

The next Slide 24 shows some important distances in light time so the Earth circumference a little more than a tenth of a light second, the sun is about eight light minutes, (unintelligible) a lot of people know is about the system is about four light years, the milky way center is about from us about 30,000 light years so the diameter is understated, it's closer to 60,000 or 70,000 light years across.

The (unintelligible) galaxy is the farthest object you can see with your eyes, 2.6 million light years away, little smudge you know until you look at it with a

telescope. And the limit of the observable universe beyond which we can't see in light is 13.8 billion light years, (giga-light years) right? So these are - when I'm looking at galaxies they're very far away. They're usually hundreds of million to billions of light years away.

So people often ask me about planets and thing and I'm like well that's interesting but it's not what I work on my friend. So if we go to 25 I'm going to now step into lensing a little bit. So we're going to talk about what it is.

So Slide 26, what does the gravity do? Pulls us to the Earth, 27, holds the Earth in orbit around the sun and it bends light, 28. So what we have there is schematic, you may have seen these kind of rubber sheet schematic you know it's an imperfect analogy but in two dimensions if you warp a rubber sheet then you, you know balls sort of will roll that was normally going to go straight will sort of curve as it goes - dips into the well and out.

Okay, you often see these in these coin wells that you have at popular science museums and so massive objects bend light, they really bend light. I mean so all objects that have any mass bend light but on the Earth, light travels fast is very little. So you need a big object to bend light a lot.

So the first place this was seen, okay so Slide 29, Newton's Law of gravity you can calculate what would happen to a beam of light if it passes by a massive object and Slide 30 shows, because a lot of times people say this is only Einstein in affect. The interesting thing is the Einstein equations have a factor of two relative to Newton. So it's an interesting factor of two.

So you know if you just say light is bent by gravity in proportion to how mass is the equivalence equals MC^2 , light is an energy, what if it had the same mass. How would it be bent, you can get a bending and the only effect

of - the only sort of further effect from Einstein is this factor of two. So Sir Arthur Edington went out and said let's see what we see. So I'm going to show you a couple of schematics.

So Slide 31 you can see that if the light bends by the sun it will look like it came from a different direction, right, because we think light goes straight normally in our real life other than refraction that's true. And so in 1919 Edington went out and he went out during an eclipse when something would cover the sun, when the moon would cover the sun, so you could look very close to the edge of the limb of the sun and you can see the (unintelligible) in the open circles is where we knew certain stars would be but with lensing they actually were farther away. They actually all looked like they were farther from the central object. That was a really big deal when that happened, that's when Einstein was very celebrated.

So that was the first observation of lensing. And then there was the development on Slide 34 of the idea that gravity can act as a lens and in 36 Professor Einstein said the more certain things as they go by even more powerful gravitational sources like black holes you might get multiple images because light can go be bent in different directions and that's what he said. But he concluded of course there's no - other than observing the phenomenon so basically even this very bright friend of ours said this would not happen.

But then going to Slide 36 we're going to see that when gravity lenses light the images are distorted and magnified so what does it look like? So this is kind of cool. This (grevlin three) app is publically available for the iPhone only by (Kypack), (Kypack) is at SLAC, it's where I work. And so it was made by (Eli) and you can get that and check it out. It's kind of cool actually.

So 37, Slide 37 shows how you can get multiple images if light is bent around a massive galaxy or massive black hole or whatever in two different directions. And so that was observed in - on Slide 38 you can see two images and that was observed for the first time I think it was in the 70's. It was seen because we were able to get telescopes powerful enough to image that resolution.

And the way that we knew it was the same object by looking at the spectrum and so we could say it was the exact same initial quasar. So if you're looking at a galaxy, Slide 39, what happens is the - and there's another galaxy in the way, Slide 40, what will happen is the light will be bent all around and you will get an arc or an Einstein ring and we actually see those. That's a really spectacular image that's a real image that you're seeing there in 41.

So 42 is one of my colleagues, (Debbie), and so we're going to see what this if you use that (grevlins) app what would happen to her. So in 43 if you put it away from her head so she's behind, right, and that sun now the source is in front but it's already distorting poor (Debbie). And she doesn't look well there.

But if you go to Slide 44 we say oh my goodness she really needs to go to the doctor, the sun was right as the star or whatever the really strong lensing object was right you know in front you would get something like that where like we said before the whole galaxy becomes a ring around it. So it becomes very distorted.

So again 45 is comparing that to the ring with the Einstein eye so to speak. Then 46 is some pretty pictures of Einstein arcs. 47 - you can see in 47 these arcs and this is real image, you see a bunch of arcs and this is a cluster now. A cluster of galaxies so galaxies will actually swarm together in like a swarm of bees kind of and in that when you have a galaxy cluster its dark matter.

Mostly it's filled because when we saw there was six times more sharp matter that you can't see by eye but there's a lot of galaxies in it as well.

And so you're going to see all this sort of lensing and we see this regularly so in 48 I show what happens to a galaxy behind. It gets bent sort of (unintelligibly) we call it. It gets bent along that circle compared to the foreground cluster.

In 49 you can see this is simulation not a real image here. So you can see the center of the cluster in the background galaxies, in the galaxies behind it are very distorted. So the center of the cluster is in the lower left and in the upper right. You don't see it by eye as clearly there, right, but if you on the right hand side if you average the shape of all those galaxies they would actually average out to those lines in the upper right. You see those two lines that look kind of like chopsticks and that's what we do. We stack them together.

That's what weak lensing is. All of the images I was showing you before or the lower left what you see very clearly with your eye that's the domain of strong lensing. So you see it's a continuum but you tend to do analysis on these two things and quite different ways. So, okay yes so the average shape there on Slide 50 is that red line.

So in Slide 51 is a plot they made - what this shows is the vertical axis is the effect that sort of the amount of bending and then the horizontal axis is the distance from the center of the cluster that you know is acting as a lens as you look out. The amount of lensing is less and less as you go out and this is another unit we use arch minutes. Okay.

In Slide 52 is dark matter and lensing, Slide 53 reconstructing the lens. As I said gravity lenses light and so we can use the lens images of galaxy to

reconstruct the mass of the lens. And Slide 54 is Hubble image of cluster of galaxies and we want to see how much mass there is in this cluster.

So in 55 what you see is you see a reconstruction of the mass so from the lensing, I've skipped a lot of steps here, but from the amount of bending we know where the galaxies are already and we also from strong lensing constraints we constrained where how much mass those galaxies have. So those are the really sharp peaks right, all the needle like peaks, those are the galaxies.

The underlying smoother distribution their on top, that's the amount of dark matter which is smoothly distributed because we believe it's particles that are you know just smoothly distributed through the cluster of galaxies and that are particles by the way that are going through us all the time. This is what all astrologists believe are most - because either you have to modify gravity or they're particles that are going through us and don't interact very much just like (unintelligible).

We do see them with big detectors but we don't see them typically in normal deductors because they don't interact very much. So we reconstruct this mass of the galaxy cluster.

So in 56 this is a really cool mass map that was made as people looked at the amount of lensing in as you went back in time from us you know as you went back in time from us towards the beginning of the universe. Until you see this mass map of everything you know so it's dark matter and normal matter and 3D mass map's kind of cool.

Dark energy if we go to Slide 58 what I'm showing there is equal seven to zero so equal zero is now and then we use the term (redshift) as you go to high

Z, you have less so you're looking farther back in time things are less clustered. And then as you have time to build up structure things fall into you know gravitational wells and they build up and (de-lambda) you know it's like an anti-gravity force, it's pushing things apart and if - and so by measuring the amount of how much galaxies are able to gain structure, gain mass towards equal zero over time we are able to get a handle on how much (lambda) was pushing them a part earlier. And so that's a way that galaxy clusters can tell us about this (lambda) module constant.

There's many other ways. You know I work on galaxy clusters so I'm emphasizing that but there are many other ways. Okay so coming close to the end - so 59, gravitational (unintelligible). So DES, dark energy survey, is telescope - camera on a telescope that's working now in Chile right now.

Slide 60, LSSD is the future and this is going to be an amazing camera and telescope. This is going to be an 8 meter (avriture) you know and the biggest telescopes on Earth now are ten meters and it's going to be the biggest camera on Earth so it will take an entire - and image of the entire sky every three days of the entire sky that is visible to it. Deeper than has ever been done certainly from the ground so it's going to be really pretty impressive. And we expect to see great output from this network on that telescope actually on simulations for it.

On Slide 61 are some other upcoming lensing surveys so Summer in space, Summer on the ground and this cool image on 62 just because I'm got it sitting on that platform, that telescope, and really enjoyed it. Been very odd by the universe standing there so it's a really cool telescope.

So the summary, 63, lensing is an amazing probe, galaxy clusters give us some of the strongest evidence for dark matter. I talked about galaxies earlier

but galaxy clusters do as well. (Unintelligible) theories and dark energy and summary two, 64, DES and LLST will allows us to probe - are allowing and will allow us to probe deeper than before ever.

65, (unintelligible) would be interested if anyone participated in that. And that's you know citizen science we'll say for strong lens identification. That's closed right now but we expect to have - you can see the results there and we expect in the future to have more things like it. And so Slide 66 I just like these quotes and this is the point at you know in an in-person presentation I show that blue dot video sometime just because I really like the way that (Carlos Hagen) approached science. And that's ta quote by Einstein; the cosmic religion religious feeling is the strongest and noblest motive for scientific research in the New York Times magazine way back when.

And that is it, so there we go.

David Prosper: Awesome. Thank you so much Mandeep.

Mandeep Gill: Sure.

David Prosper: Now I'm sure there's going to be many questions so let's kick off our QA session. Let's open up our lines to the listeners, Operator, if you could tell folks how to call in with their questions.

Coordinator: Absolutely. If you would like to ask a question please press Star 1, make sure to unmute your phone and record your name clearly. If you decide to withdraw your question you may press star two. Again to ask a question press Star 1, it will take a moment for the questions to come through. Please stand by.

David Prosper: Okay. While we wait for the first question I have a brief one. Just on the space (warps) Web site, do you happen to know when they'll be reopening it, or?

Mandeep Gill: I don't know the exact time. I can ask (Phil); I think well, I would estimate within the next couple years.

David Prosper: Okay.

Mandeep Gill: Data coming in from DES and we're supposed to be able to use that data on it and I think the data they used before was either (Sloan) or (CFHDLS). So DES data is coming in right now so let's estimate next year. So you know if people want to check in yearly and you know what I could do is if you have a list of folks who listen or you know just something I can put out on Night Sky network once I know, (Dave), I can let you know and can put it out there.

David Prosper: Yes we can definitely put it in a follow-up article. That would be awesome.

Mandeep Gill: Cool.

David Prosper: Cool.

Coordinator: We do have a question from (Ramakash). Your line is open.

(Ramakash): Yes hi, basically I was wondering like you know just like gravitational lensing and that's done by a dark matter or you know matter as a fact but matter and dark matter I think you know that's gravitational lensing. But what about like you know dark energy? Can it do the same effect by gearing towards the mass or is it possible that it may deflect another?

Mandeep Gill: Yes people ask this and it's an interesting question. So what we believe about dark energy is that it's constant in distribution. So it's kind of like if you're shooting a ray through some sort of you know homogenous fluid because it won't bend one way or the other. You know if you're - so I guess the way to look at it is if you have layers of a layer of water where it gets dense or towards the bottom it's continuous density gradient and it's much denser towards the bottom. And you shoot a ray of light there or even through the atmosphere which could stem through toward the bottom.

Radio waves are a (fract) in the atmosphere and things will bend towards the more dense side. But if you shoot it through something that is ice tropic and homogeneous so the same in all directions then it just has no way to tell one way or the other. And all our experiments so far indicate this is the case that dark energy has no clustering, has no preference, so there is no way for a light ray to know what to do.

In theory you're right; any clustering of energy would do that. But so far in fact that's one of the pieces of evidence that we don't see any say lensing in empty space you know indicates that dark energy is not clustering. So I hope that answers the question.

(Ramakash): Basically like you know the clustering is what magnifies like dark energy and matter of fact it can cluster because of the clustering effect it can actually magnify and we'll be able to know through the lensing effect like Einstein or whatever.

But if it was like dark energy the - I mean the (unintelligible) that's coming to us we wouldn't be able to know that it was part of something that can deflect in a different way.

Mandeep Gill: Yes that is correct that in theory you don't know you know where the original object was and so all the galaxies, all the far away ones where you know there has been lensing. There we actually know that they by simulations they are deflected, we use the term (mark minutes) you know like quite a bit away from where they typically are.

But yes so we never know their original location, yes that's correct.

(Ramakash): Okay now can I ask a different question related to I mean in the same right now do I have to come back in the queue and ask a different point, different time?

Mandeep Gill: That I don't know but we should probably give a couple other people a chance.

David Prosper: We should probably give another, yes.

Man: Okay.

Mandeep Gill: Good, nice questions (Ramakash).

Coordinator: Our next question is from (Coleen) your line is open. Please check your mute function (Coleen).

(Coleen): On Slide 19 talking about the smallest scales, a vacuum is a rising mass of particles. Could you maybe explain that a little more?

Mandeep Gill: Well this is one of the theories so there is a - let me go back to Slide 19, there is this theory that says - so there's these things called, well, virtual particles and have you ever heard of the (Heisenberg) Uncertainty Principle?

(Coleen): Yes, yes.

Mandeep Gill: So what it says is that you're allowed to sort of create things in empty space as long as - you're allowed to create them for the amount of time that is inversely proportional to how massive - how much energy they have. It says ΔE , ΔT equal a constant. And so that where T is time and E is energy.

So you can create all these particles in space and maybe if you have - maybe those particles will have some kind of real effect. They can't really stay in space for a long period of time but maybe they have some effect on things near them for a little while. And so there's a thing called a (cassimere) effect when you put two plates together that because of this the virtual particles being there there's virtual particles everywhere but because the plates are close together they can't - there's, well we could say there's certain modes.

You know an empty space you can create all kinds of virtual particles between the plates because there's only a certain amount of space you're only allowed to create certain kinds. And what that ultimately does is it creates a little bit of pressure, it's a very settle pressure, and people have gone out and measured it and they've seen it. So they've seen and you can look this up on Wikipedia, the (cassimere) effect.

They've seen this and so people think well maybe if you have these particles in space maybe they also are creating a certain vacuum energy density that we're not and we don't know how to calculate that level right now but maybe in the future we will. So that's where that theory comes from basically. You know because I skipped through it quickly. We don't really know, we really don't but that's...

(Coleen): No that's good thank you.

Mandeep Gill: Thank you (Coleen).

Coordinator: Our next question is from (Tom Totten) your line is open.

(Tom Totten): Hi there, thanks for the lecture. On dark matter has there been any proof that if dark matter particles hit each other that they create an extra photon and therefore you see extra light around galaxies and that would be another way to measure dark matter?

Mandeep Gill: Yes so the what you just described is usually described is usually called the indirect dark matter detection as opposed to direct. Some people may be wondering we searched for them on the Earth. People make big wafers in (unintelligible) and (Germanium) or huge liquid (Zinon) detectors. Many different materials because they're hoping like with (Neutrinos) which were only actually discovered, directly detected 25 years after they were hypothesized from momentum (causation) regions that we'll see dark matter in the same way on the Earth.

And that's really until you, you know kind of see it, you know it's hard for people to believe it. And so what you just described is indirect and there's a lot of astrophysicists that want and look. So I mentioned that Fermi telescope near the beginning, that's one of the things it's looking for. Is maybe in the centers of galaxies maybe you know dark matter does cluster there as opposed to dark energy which does not cluster as far as we've seen.

And so those dark matter particles would annihilate and they would send us photon gamma rays that we would see. So maybe that happens there, maybe that happens in what are called dwarf galaxies around us like the (manganic)

clouds and so people are looking for that all the time. There's - that's as you can imagine a very difficult thing to disentangle from background because for example there's a black hole center of you know big galaxies which is doing a lot of emission x-ray and some in Gama ray as well.

And the center of the galaxy tends to be a pretty messy place to do observations. So people do look but there's been no clear you know incontrovertible evidence yet.

(Tom Totten): Thank you.

Mandeep Gill: Yes thank you (Tom).

Coordinator: Again to ask a question please press Star 1. Our next question comes from (Stuart Myers), your line is open.

(Stuart Myers): Oh hello, thanks for the presentation tonight.

Mandeep Gill: Sure.

(Stuart Myers): I was just wondering if you had any - if your opinion if it's possible - if you think there's a good chance that we'll detect dark matter particles with the accelerators that we currently possess?

Mandeep Gill: This is always an interesting thing when you as their scientist their opinion because you know I wouldn't bet lots on it. Let's say I would not bet my health. I you know I certainly hope - we all hope that we will find really cool things it's just we have no, you know, there's two things I would say. There are theories of - there's some theories that gravity has changed. I've alluded to that briefly. Things called modified gravity.

We really don't believe it's that for a few reasons I could talk about especially because this colliding cluster that showed the separation between matter and dark matter called the bullet cluster. So we most you know astrophysicist would strongly believe that it is particles.

But, but unfortunately there's a type of particle called a (gravatino) and others too that only, only interact gravitationally and you would never see them interact with matter in another way. You know (neutrinos) don't interact much but when they do you know there's 600 trillion (neutrinos) that go through us every second from the sun. If the sun's on the other side of the Earth they go straight through the Earth and they go straight through us.

But if you build a 50,000 ton tank of water as they did in Japan you see a few of these a day. And we have other detectors in the Earth, around the Earth. So you know we do hope that the dark matter would interact so we could see it. Certainly those people work on it directly you know on that direct detection but I would not guarantee that we will see it.

The next generation I'll say within the next ten years it's sort of an order of magnitude bigger detectors and if they don't see any signal at all I think a lot of people will have to throw in the towel and go to other models or you know say it's (gravatino) only and we will have to look in other directions for you know insight about it. That's what I would say about it.

(Stuart Myers): Right well I read just tonight a little just before I got onto this conference about some results from that AMS instrument that they have mounted on the space station.

Mandeep Gill: Right.

(Stuart Myers): And some of the people studying the results from that believe that the...

Mandeep Gill: Yes.

(Stuart Myers): Part of what they're talking about is huge in terms of mass.

Mandeep Gill: Yes so let's put a little pause on confirming those results because you know I saw those results come out. I had a friend email them to me and they are not you know confirmed at all.

You know unfortunately there's you know I do talk about science but I do like to sort of somehow distinguish between like you know more conclusive science or stuff that's really you know stuff we know, stuff that look conclusive and really speculated stuff. And so I would not call that (unintelligible), I would not call that confirmed by any means.

So you know keep your eyes open but you know like with all these kinds of things the next few months or year or two.

(Stuart Myers): I only brought that up because it would indicate that your most likely if that falls out you're most likely not going to see anybody create dark matter particles.

Mandeep Gill: Yes that's true and there are candidates like that and you're right about that. You know I only see - has not seen any evidence either yet you know that they've created any dark matter candidates. So you know we'll just keep our eyes open in all these arenas.

David Prosper: And we actually have to wrap up for tonight. But thank you for your questions. And thank you everyone. Yes, so that is we're - that is all the time we have for this evening. So thank you everyone for calling in and listening to this wonderful presentation. And a huge thanks to you Mandeep for giving us so much of your time and for this awesome presentation and your great answers.

Mandeep Gill: Thank you and yes thanks really for the questions. I appreciated those and (Ramakash), (Stuart) and everyone, those were really great questions so thanks so much everyone.

David Prosper: So that's all for tonight. You can find this telecom along with many others in the Night Sky Network under astronomy activities. Just look for telecom, that's the key word. Tonight's presentation with a full audio and written transcript will be posted with some more notes and updates by the end of this week - so bye tomorrow. And good night everyone and keep looking up.

Mandeep Gill: Keep looking up, alright take care.

David Prosper: You too, take care.

Mandeep Gill: Bye-bye.

Coordinator: That concludes today's conference, thank you for participating. You may disconnect at this time.

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