February 5, 2018.

Physics seminar

>>Dr. Garrison: I want to introduce our speaker for today. This is it going to be an interesting talk. This is doctor Peter brown. He's at the Texas A&M Mitchell institute. He's originally from Friendswood, Texas so he should be familiar with the area. And according to this his first job was selling SpaceDots and space center Houston. Back letters in physics from Brigham Young University and PhD from Pennsylvania state university. A few years after I did. And while he was there he was studying gamma rays and supernovae from the Swift satellite. He's currently a research scientist at Texas A&M where he leads a multi disciplinary AggieNova team of undergraduates.

>>Dr. Brown: Today -- I'm going to talk about some of the biggest scales in the universe and how we measure those distances in meters. You might see an image like this in the Hubble Space Telescope. The galaxy which has it's own billion stars in them. I'll give you an idea how we can measure distances nearby galaxy and to the farther universe. Methods of

use of standards we can use and measuring sticks for the universe. Particular issues we can constrain ((inaudible))

KATE (Writer): Microphone is far away, can't hear that great.

>>Dr. Brown: There's lots of different methods we used to measure distances. I'm not trying to cover all of these. There's different techniques and different types of objects and they can be used in different instances based on how bright they are. I'll focus on along the far right side. First a geometric distance, namely paramagnetic lacks, uses the earth as a normal observatory. So around the sun. The nearest stars show a slight shift in position compared to background stars.

We are familiar with this fact regarding car, nearby trees and distance, building, (inaudible).

KATE (Writer): Microphone too far away.

>>Dr. Brown: So that's the parallax angle that corresponds to a distance where one par second, it's 160th of a degree, and an arc

second is an arc minute. So then one arc second is 136th hundredth of a degree. So that's a tiny amount. And if the star shifts by that amount then it corresponds to 3.116 meters or 20 trillion miles. This is our first. The other method we can measure the luminosity and how bright it appears to us and farther distance using the inverse square log of light. The reflective light is diluted as it goes through space and covers an area. We can infer the distance. We can use this in a practical setting when you infer how far away car headlights are based on how bright they are. Not perfectly, not all car headlights are the same but you can tell when something is far away or about to crash into you waived on how bright the lights appear. So one of these types of objects is kin of variable star as a CepheiD. Henrietta Leavitt noticed a correlation between the period where which it gets brighter and dimmer and it's brightness. These are all pretty much the same distance in large (inaudible). Once we calculate the distance this becomes a period luminosity relationship where we can observe the period of a Cepheid star and infer its luminosity and take the brightness and get a distance. The explosion of white dwarf, type Ia supernovae. The idea wind that they explode when they reach a certain max limit determined by physics. So if all of these stars are exploding about the same mass, they create about the same amount of radioactive nickel that heats up the material. So then the luminosity is similar between different objects. The top shows the absolute luminosity over time. This is a period of over 20 days. So when the supernovae exposed it takes 20 days for it to get brighter and it will fade off. But we can parametrize the life over that 15 days, 20 days after its peak brightness and that's correlated with its peak luminosity. So once we take that into account we can calibrate these standard candle to a low dispersion and use them to infer distances. We use ParalLax to calibrate the luminosity relationship. Then we can find nearby galaxies and calibrate the distance to that galaxy within that to observe their apparent brightness and periods. So then we calibrate the distance to these galaxy, Type Ia

Supernovae so we can calculate the supernovae and we can calculate them distant. They can outshine the post galaxy. We can observe those very far away by understanding how luminous they are, then we are calibrating the distance to those distant galaxies. This is the more scientific plot version of that putting it together by noble prize winner Adam Riess, geometric methods such as parallax. Calibrate supernovae and the Ia Supernovae used to measure the distant galaxies participating in this expansion flow of the universe. So when the universe, we talk about this expansion universe, all of the galaxies appear to move away from us. It's not the center of the expansion or the center of the universe, but if you picture the galaxy drawn up and draw lines in between these individual galaxies, it will appear to each of them as if everything moves farther away from it. So it's just the change in the whole scale factor of the universe with everything getting farther away. So Edwin Hubble discovered this effect that all the galaxies moved farther away and there's a linear relationship between their distance to us and the speed with which they appear to be moving away from us. This is a characteristic of the scale of expansion. That something is twice as far away and everything is doubling. Then the speed will change when it's much closer away. We refer to this as as the Hubble Law. This allows us to infer a distance. Spectroscopic observations of a Doppler shift between a line from a known element that we have been observing to be red shifted because it moves away. We can use that to infer its speed with which if it moves away. So we have a distance and we will call it a red shift. That's the scale factor with which it moves away from us. So the current expansion rate of the universe is what we refer to as the Hubble constant, strange unit of kilometers per second per megaparsec. So we could cancel the distance out and have this in inverse time. But keeping this unit preserves these observed data points that you get. So then the Hubble constant is the (inaudible) of this line in kilometers of this second per megaparsec, while the Hubble constant is the local or current expansion rate of the universe, and it's called the Hubble constant. The measurement of that is not giving us a constant or consistent result. Edwin Hubble was actually off by an order of magnitude in what he measured the slope to be compared to our current adopted measurement. That had to do with issues of how he was, what he was assuming for standard moves in the universe. He was assuming that all galaxies had the same size. But now as you have seen pictures from Hubble. There's all different galaxies, and that's clearly not the case. So the Hubble constant dropped rapidly. It doesn't quite converge, actually opposing camps were arguing for Hubble 50 or 100 kilometers per second for quite a while. 50 kilometers per megaparsec. We can measure the Hubble constant to 10 percent. So did that and 2,000 the Hubble project result was released which was in the middle of 72 kilometers per second. But this is continued to be an active area of research in trying to pin this down better and better. So there's this other result by Allen Reed, 3 percent solution, trying to improve some of the different distances, how we calculate the supernovae. And I showed this the 2.4 determination of local Hubble constant. There's a new paper out two weeks ago where it's down to 2.3 percent now. Trying to getting every little last bit out that you can. We call this an error of precision cosmology. We no longer uncertain to a factor of two. Not even 10 percent where we are now arguing over a couple percent. So the question is, how precisely can we measure the Hubble constant and other cosmic parameters. To show you some of the issues I have a little demonstration for which I need two volunteers in what will work as a front row for us. I have this mystery stick that we will measure. And I have two (inaudible), one is divided into 16th of an inch and the other is eighth of an inch. I'll let you pick first. The uncertainty, how close do you think. This is initially (inaudible). Eleven of the other techniques that is normal in these big cosmology measurements is the idea of blinding. So recently the dark energy survey we have been trying to measure the Hubble constant and other cosmological parameters and there's a danger if get what you think in the right answer you (inaudible). So what we do now is you try to figure out what all your issues are and how precise you think your answer is before you reveal or unblind what your answer actually is. (inaudible) Galaxy, luminous our two answers we have the (inaudible), 11 and 51 64ths plus and minus 164th. That's pretty precise, the 64th of an inch. But the ruler has fine rulings on it. Our other answer is 12 and 1/16th of an inch plus or minus the 16. Out of those two rulers, the (inaudible) ruler, 16th of an inch and wooden ruler 18th of an inch which do you expect to be more precise? Everyone agreed on the metal ruler. Let's see. So you could be off (inaudible).

\>> (inaudible).

\>>Dr. Brown: (inaudible).

\>> (inaudible).

\>>Dr. Brown: Two answers that are relatively precise but aren't agreeing with each other. How much of that, can you tell me how long is a foot in inches? We are not going take authority, someone might have told you there's 12 inches in a foot but I want you to actually measure, okay.

>> (inaudible).

>>Dr. Brown: (inaudible).

>> Not exactly, it's a little bigger.

>>Dr. Brown: How long is that foot?

>> (inaudible).

>>Dr. Brown: Off by half an inch. So you thought (inaudible).

>> (inaudible).

>>Dr. Brown: The strength one quarter is per foot. This is called a (inaudible) ruler. This is designed to measure how long something will be after you shrink one quarter inch per foot. So in essence it's a (inaudible) in our. More accurately it's systematically off. If you (inaudible) those measurements with this ruler we wouldn't necessarily get the right answer. Maybe because it's systematically off. It might be more precise, but it's not accurate. Those two things could be a little bit different. When you think of how repeatable your measurements are is how we refer to precision. But we need some extra validation of your accuracy to know how good

your measurement actually is. A lot of you, most are not astronomers and the take home message is whatever field you are in you need to be worried about how good is my ruler. What systematic uncertainties are lurking in what I'm working on. So our question with how pre precisely we can measure the constants. So the precision of our measurements, the cosmic constant, is now sort of you might think forcing us towards contradictory information. If we take the Hubble constant as measured by some (inaudible) of the early universe and extrapolated that with is what the (inaudible) satellite is, they get a Hubble constant of (inaudible) meanwhile our supernovae measurement are at 72, 73. Which of our (inaudible) are larger we don't worry about it. But as the confidence that people get in that number increases and the (inaudible) bars get smaller it's revealing something is going on that physicist get excited maybe there's new physics when they extrapolate this number based on the physics we know and observe, we get a different answer than what we observe locally. It could be something exciting going on there or it could be that we just don't understand some of our uncertainties and there's a different error hiding in there somewhere. So how accurately can we measure the -- how precise, how accurately can we measure the Hubble constant and our candle luminosity. So we need to understand the systematic errors. This is just a pretty picture I made of the owe (inaudible) we see this things (inaudible) that's one of our biggest systematic errors and uncertainties. Think about what (inaudible) is in your field and causing headaches there. Donald Rumsfeld had a quote... (reading slide). Is that clear?

(LAUGHTER).

The idea is there are some uncertainties we know about and we are trying to worry and fix and improve. But the worst problem could be the ones we don't even know about. For type Ia Supernovae it's important we reduce the systematic uncertainties because our samples are growing so large that the statistical uncertainties are at the same level as our systematic uncertainties. We now have thousand of supernovae we can put on a plot like this to measure the Hubble constant and expansion of the universe and there's thousands of more coming. The new project on the horizon is we will find hundreds of thousands of supernovae. But if we can't reduce our uncertainties then we can't gain tracks and gain by those great numbers if we can't understand better what's going on (traction) some of these known unknowns that are identified in the community are the dark energy task force identified. Metallicity, reddening, evolution and there's a recent paper that came out from a new supernovae survey that had a lot of different components in it that went into their final uncertainty. And most of the astral physical -- each survey has to deal individually. Everything dealing with the explosion and uncertainties are best probes are ultraviolet observations.

Now through 2004 the number of ultraviolet observations of supernovae was pretty small. We had about 20 there and most were not that good. But the launch of the Swift craft which coincided with me going to graduate school, a new revolution in the way we can study supernovae. 2012 and 13, it's only continued to grow since then.

So Swift launched in 2004. It's mission were to study gamma rays where you don't know where they come from and they disappear quickly. So it was designed with a wild field gamma ray telescope that could detect them on the sky and the position of accuracy of a few arc (inaudible) which is good in terms of space terms. That means we can point a telescope and Swift has its own telescope. They can automatically re point and built in how close is it facing the sun, earth and moon. So it can determine (inaudible). It can report itself within about two minutes. So then it's staring at the position of the gamma ray burst and look for this heating glowing material from a collapsed star that turned into (inaudible). So pretty exciting things. But I sort of ignore that. The supernovae which is a more benign form of exploding star. One of the key things over here these are (inaudible) which astronomers use. Behavioral. This is green lights and blue light and then this is what they call ultraviolet before we got out into space. This is sort of optical light is what we can observe with Swift. The filter curves. And this was a spectrum of the type Ia Supernovae. When we spread out light into a rainbow and measure the flux of each individual color. We have a lot of optical lights and the flux dramatically drops. There's a lot of absorption from nickel and iron elements that absorbing of lot of light. So it makes it harder to observe. It also means there's a lot of interesting clues there.

So when I refer to photometry. You have a filter that only let's through light and has those certain wavelengths and you are measuring the flux. So then with these, it comes from an image. You take an image with a filter and look for a supernovae that's just a dot and you measure the brightness of that dot. The brightness in the optical compared to the brightness in the ultraviolet is one of your diagnostics for temperature or how much object absorption there is there.

So with these six filters when we make one measurement we can measure the flux and using those filters. This is the brightness and this is time. Maybe we make observations every other day. We can watch and the supernovae gets brighter and dimmer.

One of the key thing we are interested in is the peak brightness in each filter. That's a nice reference point we can compare different supernovae.

Now we have observed lots of supernovae with lots of light curves. This is roughly color-coded based on different kind of supernovae explosions. Type Ia we are talking about are the red one. We are always busy observing some supernovae or another.

So what types of things are we interested in learning. I mentioned dust. We want to know how much the light is being dimmed in order to calculate our luminosity distance based on the brightness.

And we need to understand intrinsic color varies in order to get the amount of dust right. Dust has a property that makes the light fainter, but also makes the light reader. So it scatters light at shorter (inaudible). Our sky is blue we are seeing scattered light from the sun. That's why the sun looks red when we look down at the horizon and looking through a lot of atmosphere. That's because when you have dust and other things it let's more red light through than blue light. We are still trying to understand the exact wavelength dependent on that dust and why it behaves that way.

So this is just a supernovae coming here and then the light that passes through is generally reader. Probably blue arrows representing light in other direction I should have (red). You don't need to worry about extinction about the units. These curves go up, so that makes it very sensitive. There are different effects that are smaller if the dust is smaller they absorb light differently. In a way that light is polar optical light through. You can get circumstance couple stellar scattering so. That reduces the amount of light that you lose per given amount of dust. For example, if the nova where the white dwarf may have had a small explosion, it blew out some stuff and that creates a shell around the supernovae before it explodes it would then cause some of the scatter. The effect you get compared to regular Milky Way dust is a solid line. If you have smaller dust that's represented by the (inaudible) line. And then the dotted dash line is this scatter effect. So both of them result in having less absorption in the optical. Less extinction. But they do weird things in the ultraviolet.

It's been found that this low value is what is actually seems to be going on. But we didn't know why.

Now I mentioned that all of those extinction laws (inaudible). That means it's hard to observe the supernovae if there's a lot of dust. So if it were heavily extinguished it would have to be extremely nearby. So undergrads in London discovered in 2014 the closest supernovae. It's not that bright (inaudible). It had a lot of dust in the way which made it maintainer. You can see the galaxy has a lot of dust.

We were able to get an ultraviolet spectrum of it where in red is 2014 you see the light disappearing in short wavelengths and this is the comparison supernovae that was nearby but not (inaudible).

We can compare those two and we see that you do get this low value in the optical compared to what expect in the Milky Way. But it got middle ultraviolet, (inaudible) between those scenarios.

But there's another effect that if the scattering of light is causing you to have less extinction in the optical, that should smear out your light curve offer broaden it. You have a time delay of protons being bounced into the line of site. So built a model to test this. This is the brightness versus time. These are the data points in the symbols. these lines are different models of where you put the dust. No case you get the dust scattering to match the observation. On the right panel we use a different formulation for the size of the dust stream then it seems to match perfectly.

So it seems like the dust extinction is consistent with inter stellar dust, not the supernovae it's self with no signs of circum stellar scattering. Before the supernovae exploded they studied the properties of the dust and the they concluded it look like Milky Way dust which then makes you ask the question are they right, are you right. Of course you want to be right.

And a graduate student that worked with me was able to address this in an interesting way. It's not something we expected from this observation. But we were using the Hubble space to look at the supernovae at a late time and observe echos of that light and it bounces off much more distant clouds in that galaxy. So the supernovae you will see (inaudible) moving outward. That just light bouncing off of these clouds and coming back to us. You can subtract one image from the early time image. You have these clumps here and then later times it's broader component out here. These observations were taken using different filters so you can study the color of the behavior of that scattered light which can tell us something about the size of the dust rings and sump. Interestingly what you found was over the whole area around the supernovae there's dust that has an extinction value close to that of the Milky Way. There's no Milky Way like dust there but as simple as we can put it a slab of dust is causing these brighter arcs that has a smaller value than the supernovae. So this tells us you could have a supernovae hiding behind this slab of dust creating the extinction law that we found. Setting all of the stars distributed through the galaxy you wouldn't see those if they are hiding behind the dust slab so you see them passing through more normal dust. So both studies were right and there's different kind of dust within the same galaxy. We don't know why the dust slab is doing that and why all supernovae that have a lot of dust seem to be hiding behind like that.

One of the complications that we are struggling with is if you infer the amount of dust by how much the light is red denned. You have to know how red the supernovae was. In the optical that's constrained. But in the ultraviolet we have a large scatter. So on the Y axis this is effectively the flux ratio between the survival in optical and the flicks ratio of color between the blue light and green light. So this is what we usually use to infer how much dust is there. And the behavior of the dust, different kinds, is represented by these lines. So all type Ia Supernovae have the same colors in the ultraviolet in the absence of dust they all would be clumped up here and if they had dust they would be smeared along these lines but instead we see this scatter down here. For clumpy maybe the supernovae are different here. Something is going on which is sort of concerning if you are assuming all type Ia Supernovae are the same type of explosion. They should all be the standard candles. We see with the ultraviolet there's something different which maybe related to these known unknowns or might be an unknown unknown we are seeing for the first time and need to figure out.

So one of the questions was whether those supernovae are bright in the ultraviolet or faint in the optical. So we had four supernovae in the previous panel in terms of ultraviolet brightness, two are bright and the other two are normal. In terms of optical brightness. Two are at the top and two are at the bottom so they are not even consistent within themselves in terms of luminosity so we don't know yet. But the theorist if they frame their models of how you can make these white extinction different -- these are spectra, here's the optical and ultraviolet. You can change the metallicity, how much iron, how much nickel, you don't effect the optical. But then you get different behavior in the ultraviolet. If you change the outer density gradient, how fast the material density drops off in your outer regions and explosion, it doesn't effect the optical at all but then the ultraviolet is strongly effected. So we are trying to tease out which effects is dominant. One of the other effects if it's an asymmetric explosion and you are viewing it from different angles it doesn't effect the optical but it does the ultraviolet. So these are important distinctions because if we were using standard candles across the history of the universe it's important to know whether these objects are change changing with time as metallicity would cause them. They were fewer metals in the early universe compared to now. So that's an evolutionary change and very significant. In on the other hand it's an explosion that we are viewing from other angles that's the same here or there. So we are trying to use the used to pin down the physical effect of this variation in order to know thousand fix the cosmology. As we step out we are sort of assuming the all supernovae are same throughout the whole region here. So we can better understand that.

One of the projects I'm working on is using the Hubble Space Telescope to measure distances using a different method that uses older redder type galaxies. The fussy blob compared to the blue spiral. Those type of supernovae might be different. So we are making it intended to be flatter because it's tied to the (inaudible) but measures supernovae in other galaxies. So beyond in optometry leading Hubble Space Telescope because it's more sensitive and able to get spectra, again we are looking at things that are similar in the optical but different in the ultraviolet in trying to understand why. The other thing we can do is with either ultraviolet spectra or the photometry from that. We can understand nearby novae in order to understand supernovae that might be observed by large ground based tell scopes or by infrared space telescopes. This shows the different type of supernovae that has a lot more ultraviolet flux. The type of supernovae over here, this continues (inaudible). We can read shift it to the expansion universe and correct for the distance which makes it fainter and prevents how its brightness will change through a given filter. And my undergraduate team this is one of the plots they made. This is the brightness versus the distance. Basically look back time in billions of light years. So the magnitude it reaches here the brightness level is easily reached by some of these next generations at the scopes. That's the 8 billion light years, half the way across the universe we can still see these supernovae.

Or the reason that keeps us from observing them farther is not that they are too faint, random hydrogen in the universe between us and them will absorb the ultraviolet light. So instead we can take these into the infrared and web space telescope, so this is the system gets fainter as you go farther out. Now these numbers may not mean much to you but the most significant object we have ever seen is close to a red shift of ten. Red shift of 20, we don't know if stars starting forming that far away. Whatever time they started forming if they explode like the supernovae the space telescope should be able to see that.

We are trying to under these systematic -- oh this is a relevant big telescope to cover the whole four days of faint magnitudes of one of its name humanitarian drivers coming towards the earth and detecting them far enough away that you might be able to do something about it. What you can do, astronomers is like there's something out there coming towards us, so this is a revolution that is coming that the large nap tick telescope thousands of supernovae they find every night. Millions of supernovae over it's ten year mission and hundreds of thousands of these type Ia Supernovae we want to use. And it's not something that astronomers are hoping and wishing for; it's being built. These are pictures from last month. The observatory structure is being built. It should be taking data in 2022, 2023. And so it's really up to us now to lay the ground work for it. In particular, because they will find thousands of supernovae we need to understand our known and not yet known systematic uncertainties in using supernovae as standard candles. I hoped I've shown that observations are key to understanding one of those issues. Thank you.

(APPLAUSE).

>>Dr. Garrison: Questions?

>> I was wondering was there a relationship between (inaudible).

>>Dr. Brown: So the question is whether there's a relationship between the size of the dust screen and the metallacity since both effects seem to effect the ultraviolet so much. Is that your question.

>> Right.

>>Dr. Brown: In those plots, no. In the theoretical models they are able to change them independently and independently they see similar effects.

>> Okay.

>>Dr. Brown: Whether there's a relationship in the galaxies between what is going on how the dust is being formed and what sort of metals are in the dust, that could be the case. But that could even make it more complicated. These effects I showed are independent.

>> Okay.

>> Do you know why it takes 20
days for a type Ia Supernovae
to be (inaudible).

>>Dr. Brown: Why it takes 20 days for a supernovae to reach its peak brightness. So the brightness that what you observe is driven by two effects. One is the size of the supernovae and the other is the amount of energy being released by the supernovae. So the energy being driven by the radioactive nickel, that's created in the explosion all at once. And then it's fading with the half life of about seven days or something. But meanwhile the supernovae explosion starts off pretty small, white dwarf is about the size of the earth, and then it's rapidly expanded. So when you see a brightening that's because mostly it's getting bigger. But meanwhile the energy being released by the supernovae is decreasing so that means the luminosity we observe rises so those two effects balance each other out and then we see its fading. Good question.

>> Would there be a difference
effect if you are in the

ultraviolet or farther
(inaudible).

>>Dr. Brown: The question is whether it would peak, whether it would peak differently at different red lengths. There's a small effect to that for the type Ia Supernovae. The ultraviolet peaks a few days before the optical. But in general it's a similar behavior with the rise and fall. For a different type of supernovae explosion when a red giant -- sorry it's already really big and so the effect we see with that is not a growing effect, it's a temperature cooling effect. And for those type of supernovae they start off bright in the ultraviolet and fade rapidly while the optical is flat for about 100 days. For those type of supernovae the temperature is a dominant effect you have a strong difference at different wavelengths the type Ia the temperature is constant so you see an effect mostly ever the radius and energy loss.

>> Seems like (inaudible)
Hubble distance say there's a
reddening effect it might show
up earlier in the atmosphere.

>>Dr. Brown: We have to compensate a little bit for it for effects like that and just the fact that a supernovae that's farther away in the universe is also light curve is stressed out. So there's different effects, we see shorter wavelengths and (inaudible) in --

>> How come there's a type Ia Supernovae and what causes them to be consistent in (inaudible).

>>Dr. Brown: How common are type Ia Supernovae and what cause them to be consistent in brightness. A rule of thumb for a galaxy of our size you should have a type Ia Supernovae about every 200 years. Which means we are a couple a hundred years overdue for one. But it's a random process. So what you need for a type Ia Supernovae to explode is a star about the mass of our sun to evolve into a white dwarf stage and that will take five to 10 billion years. Now what makes them explode at the consistent mass level is basically if you have a carbon (inaudible) white dwarf when stars burn. If you add material to it your star is upheld by the pressure of the carbon

and at oxygen. If you add more mass to it at a certain mass point everything will compress enough that your carbon and oxygen want to start (inaudible) and you get a thermal nuclear blow away. The 1.4 times the mass of our sun which is the limit, so if you -- as you approach that limit that's when the store wants to explode and that's why you have (inaudible) in explosion of energies. And that mass has to come by a different star. So it has to have a companion so our sun won't do this. You have to have a companion star spilling material to it up to that limit.

>> So there's a chance we may see a supernovae within our own galaxy within our lifetime.

>>Dr. Brown: Certainly.

>> What would that look like. That's amazing to think about.

>>Dr. Brown: Well, when copy letter saw one it looked like a star. When Tyco saw one, it looked like a star. So the name originally came from Stella nova which means new star. So they saw these two stars appear which is exciting because they thought all the stars

were eternal and always be there. So having a new star appear was quite a significant occasion. But it doesn't necessarily have to be that bright. It depends on how close it is. If it's on the other side of the galaxy there will be too much dust we won't see it. So there may have been supernovae going on and hidden by dust or something. But depending how close it is will determine how bright it is. But anywhere from not being seen to being a faint star to being as bright as venues and the full moon depending on how you are distance works out (venues, venus).

>> Do you have any stars mapped out to becoming...

>>Dr. Brown: So they have, people do study white dwarfs. The main way they get their projects approved by Hubble Space Telescope is by saying this is a progenitor we think it will explode and we want to understand this object because it might be related. So there's a handful these objects that they think it might explode as type Ia Supernovae and as far as other supernovae types the biggest star is beetle juice which is a candidate for a red

giant super explosion that could happen any day or thousands of years from now. Could have happened and we are just waiting for the light to reach us.

>>Dr. Garrison: Any other questions? I have a question. Could gravitational wind like a (inaudible).

>>Dr. Brown: Okay. Can colliding knew electron stars and gravitational (inaudible) be used as standard candle. What they call them are standard (inaudible). So they can actually, well from, pretty well from the gravitational wave signal itself what distances at. So when we can observe an object and get it's red shift, like for this object that happened last summer, it is one data point that you can put on that plot and say it is moving away, you know, order of magnitude 10,000 kilometers per second and 100parsecs away. So they got something like 60 plus or minus 20 or something. So it's not a very precise answer, but it's a completely independent answer and if you start getting more of these or you start, that are calibrating them, they can certainly be used in

a completely independent method.

>>Dr. Garrison: Any other questions?

Let's thank our speaker.

(APPLAUSE).

>>Dr. Garrison: Before you go I want to tell you about next week's talk. West Kelly will be talking about interesting work going on here with reusable (inaudible) space cast which will take off and land horizontally.

Also want to talk to the students who were in the (inaudible) taking the physics 1630.

Thank you.

(End of seminar)