

February 19, 2018

Physics Lecture Series

>> Recording started.

>>DR. GARRISON: Can I have everyone's attention? I want to introduce our speaker. He was the Associate Director at the Lunar and Planetary Institute and if you are not familiar with them, they are our neighbors like right over on kind of the corner of where the campus is and Meadowbrook, Bay Area.

Once we move to our new science building next year or this -- not next year, this summer. We will be closer neighbors. So in the future, with some of these talks, you can have short walk through the woods and go to LPI and visit those guys. So Dr. Treiman has been at LPI for quite a while; 25 or 26 years.

He studies planetary materials, particularly moon rocks and Martian meteorites and from these rocks, he gets the early history of the terrestrial planets, including large asteroids, emphasizing in their volatility like water and solvent, et cetera. He's here to today to talk about the planet Venus.

>>DR. TREIMAN: Thank you. That sounds pretty accomplished. I have to rewrite that. Anyway, Venus. What I'm going to talk about for you today is some work that we've done on its chemistry and materials of the Venus surface. And this obviously is not real Venus.

This is what the cover of the book in the 1950's looked like and you know, it is not like that anymore. So what I'm going to do in this talk -- I don't really know your background too much. I'm not assuming you know very much about planets and stuff. I will begin talking about what we know about Venus sort of broadly and focus on the data set that I will talk about, which is radar and

then at the end of the talk, what we were able to drag out of it which gets me into physics and I'm happy to talk to a physics class, physics group because none of the other people I have told this to, with my background, have any sense of what I'm talking about. Not that I have a lot.

I came into -- it took me a lot to understand ferroelectric substances. I don't understand it well, but that's what I'm going to go with. I am pretty proud of this work and it shows what planetary science is. We have some objects out there and we have to apply all different kinds of techniques to it. So in this one, you will see astronomy and radar and radio astronomy in effect, geology and material science, physics all together which I hope solves the problem there.

How do I advance this piece? All right. Okay. So Venus is the second planet in the solar system and it was -- because it had these huge thick clouds and I don't know if you can see this laser pointer here or not. -- you can see that it is covered with clouds and that the assumption was that it was water and it was a hot, wet planet and that picture, first off, in fact, it is not that at all.

The first radar measurements of Venus they were able to measure is the surface temperature and it turns out to be very hot, 470 Centigrade and radar emissivity. It has no water on the surface with that temperature. There is essentially no water in the atmosphere. It is nearly all carbon dioxide and sulfur dioxide in the atmosphere. So there is no dinosaurs and Martians there, unfortunately. A lot of good stories in the 50's based on that but too bad. Wrong direction. Let's try that way.

The planet itself is about 70 degrees of the distance from the sun that the earth is. .7 AU. Its year is about 225 days and it is almost in orbit with the -- 13 Venus orbits and almost 8 earth orbits and people make a big deal. Slightly smaller than the earth but not particularly. Any kind of planet

scale process that you might imagine for the earth, probably could have -- it has no moon though and slow rotation.

Its rotation is slower than its orbit. It goes backwards which is very peculiar. There is no other planet really like that. It has no intrinsic magnetic field, which you can sort of understand. The earth's field is probably a rotating conductor, core of the earth into the sun's magnetic field and sets up its own secondary field. Venus, if it is not rotating, there is no way to setup a field there.

Venus' atmosphere is mostly carbon dioxide and nitrogen and sulfur dioxide. Surface is 370° C. Ninety-two bars pressure and so the gas there is carbon dioxide at 92 bars. It's a super critical fluid that's hot enough that the critical point of the liquid and gas were beyond that and there's a lot of discussion about this, what this means in terms of the chemistry of the surface that's not part of this talk.

Venus atmosphere structure. I don't know if you are into the atmosphere structure and stuff, but basically stable down below, 50 kilometers down below. It doesn't convect and like I said, 50KM and that's what you see when you look at these. The clouds are mostly sulfuric acid droplets.

Some really cool patterns in it, particularly visibility is ultra violet and right there is a Akatsuki orbiting Venus. (inaudible) busted and -- it is not a large orbit but still an orbit around Venus. You can see those weird patterns there with the lighter and darker in reflected ultraviolet. The part you can see with the patterns is the night side. Actually the bright stuff is the sunlight reflected off of the planet.

Okay. There have been some (inaudible) back in the 1970's and I think the 80's. They were fairly primitive spacecraft by modern standards, but they took pictures of the surface you can see

here and shows that it is rock and sort of plated looking rock. There is no equivalent to that on earth and the chemical composition of the rock on the right side is very much like the sulfuric rock on earth.

The uncertainties are large and so it is not really clear exactly what they are. There is all kinds of -- they have different interpretations in how they form. With this kind of uncertainty too there is no way of selling with Venus.

So what I will talk about is radar images of the surface and these come from the Jones spacecraft which was launched from the space shuttle long, long time ago. It is no longer operating and died to Venus quite a while ago. It has S-band radar and several different modes and those are important to talk about. It has an active synthetic aperture radar and this pointer is not showing up, at least not for me.

But the synthetic aperture radar is a way of taking the spacecraft and using the motion of the spacecraft to make an extended aperture antenna. It is as if you had -- spacecraft is here and you take an image and here and you take another image and together it is an aperture this fix. So you get a lot more spatial resolution out of that. But the --

>> (inaudible).

>>DR. TREIMAN: Thank you. To do the synthetic aperture radar, there is a dish on the spacecraft --

>>DR. GARRISON: You might want to come closer to the microphone.

>>DR. TREIMAN: So this spacecraft is a radar antenna that points down to the angle of a surface and it will pulse down to the surface and collect all of the returns from the surface and the

returns can be in the -- in time, the further away the longer it is -- the longer it takes for the radars to come back, but also, in this direction, this would be Doppler shift because it is same at something that is slightly ahead of the spacecraft.

The return is going to be slightly slower, slightly longer wave length. So by combining the time delay and the Doppler shape, they can put that together and get a nice image of the surface. So that's an active mode.

In the passive mode, in between these pulses the antenna collects whatever was emitted by the surface itself and it is hot enough there, there is significant amount of radio emission from Venus' surface. Then they have active and pinged down to the surface and measure the time from -- that's how high the spacecraft was from the surface and you combine that with the best analyses of the orbit of the spacecraft and actual elevation with center of mass of the planet and you get the elevation of the spot. It's a really good system. It worked beautifully and so that's all we -- that's all I'm going to show you from that.

Okay. So this is an elevation map. Red is the highest and blue is the lowest. Mostly, in general terms, Venus is pretty flat. Like the earth, has a division between continents and ocean basins. It has one high standing which is Ishtar Terra. It is hard to tell with radar reflection, but it is pretty low. Elevations are only in range of a couple of kilometers. Because there is no sea level there, there is no obvious place to call zero.

There is two ways of doing this. One is by listing the distance from the center of the -- the planetary radius so you will see these numbers in 6,000's and such. The other way is to do the average elevation for the whole planet so sometimes you see some of +6 or -2 or something like

that. That's where those numbers arise.

Okay. So that was elevation. This is reflectance. The synthetic aperture radar sends out its pulses and so the portion of that imagery is reflected back to the spacecraft. This is a global band of reflectance and you see there is really quite a huge range in reflectance. Some areas that are very, very bright and others that are quite dark. So this is what -- we started looking at because it wasn't real clear and it never has been, why there are huge variations of radar reflectance on the surface. It has to be something about the surface materials.

The reflectance depends on the permittivity, and the nature of materials at the surface and the radar interacting with it. So let's see. So I just wanted -- brief tour of some of the types of terrain.

The surface of Venus is a real mess. It has volcanoes and it is hard to tell without the elevation. These are tall volcanoes and that one also. That looks more like one at the center and sort of flows going away from it. There are faults of broken arrows here -- systems with faults and these circular things, semicircular things which have no real analogue on earth and they are called coronae and there is a lot of thought about how they are formed and this is difficult to imagine.

As I said, lots of volcanoes. This is the upper center of the previous one and here's a 3D view sort of to let you know what it might look like. You will see a lot of these like this image coming out. They love to put Venus in orange and I don't know why. It is always in orange. Radar doesn't add color really, but I guess they want it in orange. Anyway, you will probably see these if you get into planetary sciences.

The thing to realize about these diagrams is to look at the caption and see what kind of

vertical exaggeration there is. This is like 10 times vertical exaggeration and these things that look like mountains have slopes of about 2° , so they are like Hawaiian Islands and very plain. They don't look like anything.

There are these corona features. This one is perhaps the most -- the elevation across this one and there are typically deep trenches on either side of here and here and sort of raised in the middle. A lot of argument about how they form. It is not real clear.

Lowland plains and they look dark because of low radar reflectance. They seem to be mostly the lava flows. It is hard to see. It is just flat, dark plains. There are some very strange clam channels and you can see one here and it sort of winds around and divides up down here at this end and this is a close up of the area here. This is very much like what you might see with a channel meandering and cut off meanders with islands in the middle of the stream. The surface temperature with 470°C water is not going to be the fluid. The lava is generally too thick to do this kind of stuff. A lot of ideas and no proof either way.

I guess the idea that I most favor is these are some kind of ionic metals, so perhaps a carbon. It has got even lower viscosity than water because water has the hydrogen bonds to hold the atoms together and these are just positive and negative ions so very fluid. Having said that, you have the matching shape of the channels, but it is not clear how you make that kind of lava there. There are lots of problems left there and unfortunately, all we have is this limited radar data.

There are highlands on Venus which are probably a couple kilometers than we see before. This is one called Alpha Regio. It is sort of like a mosaic and all little pieces here put together and there is a little corona down here. I want you to notice that there are areas here that I am not seeing

quite so well, but maybe. Brighter spots in here and those are higher elevation and what we see is that in some places, the higher the elevation, the higher the radar reflectance and that's what I'm going to get to. That's the point of this talk.

Okay. This is the continent area called the Ishtar Terra, which is 65° north latitude. It has a very tall mountainous region here, Maxwell Montes and a number of ridges and mountains that go around it. People compare that to Tibet where there is a flat plateau and then a mountain -- it is comparable to the Himalayas. This is kind of the processes that are so common on earth.

But having said that, (inaudible) plate tectonic story, so it is still not clear. We will come back to this. One last thing is craters and we don't have very much on earth. If you look at the moon, all kinds of impact craters and asteroids. There are a few on Venus and this is the global map and it is certainly not like the moon or Mars. There is a long discussion about what this might mean, but it seems to me that, at some point within the last billion years, Venus' surface was completely cleared off and all of the craters were erased and what we see are the ones that have happened in the past billion years rather than like the moon which is more like 3.5 billion or 4. Okay.

All right. So now I'm going to get to the -- that's the background and now sort of the research part of this. As I said, there are high radar backscatter reflectance in some areas on Venus and this is Maxwell Montes that I pointed out. You see brighter spots in there. The cause is unknown and it is very controversial. Right off, there is a difference here which is -- I did this work with an undergraduate intern and she looked at this and said, it is perfectly obvious what is happening at Maxwell is not the same as Tepev Montes because the edge is sharp and down here it

is diffused. Yeah, that's obvious to people that look at these in the early 90's and no one had ever put that together.

I went back and looked in the literature and sure enough, there were people looking down here and people looking up there and they were not talking with each other and so you had these arguments that had to be this and that. In fact, they are both right looking at different things. It took an intern that had no preconceptions that said, they are obviously right. I was sort of embarrassed, but it was cool anyway.

So let's look at one of the mountains. This is a pair of the volcanoes. What I got here is the backscatter image, the radar backscatter. It goes from the plains up to the peaks. It gets brighter and brighter and backscatter and at the top it turns black. The backscatter drops down and it drops way down, and it is not clear why. This is a material property because the (inaudible) shows the same pattern. It is in line with it and you can see the dark part here corresponds to the bright stuff here and the emissivity is less than the radar.

It is just collecting whatever is in the cone of the radar whereas with the SAR you are getting the Doppler and the time you are able to slice up the terrain. You can see this dark corresponds to this stripe and this sort of arch here corresponds to this arch here. It has something to do with the material properties of the surface.

Sometimes radar backscatter can be effective by roughness or the assets in the rock that are leaking subsequent radar back at the detector and you can get very high backscatter, but it is not a property of the material but how they are arranged.

So that's what we were doing. So what we did is we looked at an area in Aphrodite down

here and a couple smaller spots with that, trying to look at the elevations that were associated with this change from the very bright to the very dark. What we were able to do is use some stereo radar.

It turned out that -- not only what I described earlier but they took some part of an image in stereo, two different angles so this angle and this angle. So you can take the two different look angles and just like have your eyes in a stereo view of that and that it gets about an order of magnitude, better spatial resolution on elevation than the other does. So we pinned down what the elevation change was and whether we can learn anything from that.

So this is one of the areas we looked at. There is a low spot here and as you go south towards the highlands, the backscatter is up and up and then all of a sudden, it gets very dark again. Same here.

So the intern collected all of these areas and collected the radar backscatter from that and turned it into a graph of radar backscatter verses elevation and that's the red dots here. She has the radar backscatter coefficient there. Compare that with earlier work which is the emissivity, which is much different resolution and it shows the same pattern, but it is backwards. Remember the emissivity was black and they are essentially inverse of the emissivity minus one.

It is plus reflectance of backscatter equals what? One goes up and the other down. So what we were doing is refine what was done before. Go from this broad spread of black dots that is scattered around and find a very, very sharp peak in reflectance and after that it drops down to very, very low values, at about 4.8, 4.6 kilometers elevation above the average and that can be converted into a temperature. Because Venus is not convexing so they -- if you give me an elevation I can tell you the temperature supposedly. It is hard to test that but that's how it is done.

Very, very sharp change in material properties there, biometric, constraint or relative permittivity or whatever you want to call it. What kind of material does this? This is where you get into material science and some physics? It wasn't me and it was a fellow named Mike shepherd at the time, that said this looks like how a ferroelectric substance behaves and a ferroelectric substance -- I will do this down here.

This is the graph from the previous image sort of turned sideways to make -- to get temperature scale going up to the right. This is the -- graph of dielectric constant of a ferroelectric substance. You can see that the comparison is similar as you go down in temperature and goes up to a peak and then a rough drop down to low values. That's exactly what we see here on Venus. So this is his insight and we were able to confirm. Okay.

So let's what is a ferroelectric substance? That's a substance that maintains an electrical charge, an electrical dipole, and the example I have here, this is the -- here you have the oxygens -- okay the lead are the big ones and two different kinds of oxygens in green and red, which if you are colorblind they look about the same. People are not really good about doing the colors of lines. I'll fix this the next time I do this. I just pulled this off of the web.

But at low temperature, the titanium atom is offset to the center of this -- that produces a little (inaudible). A lot of peroxides are like this. If you get into the material science, you will see this all over the place. Solar cell materials and now there are peroxide memory, computer memory things. Many of them have this case where the atom is offset from the center.

You can imagine, of course, those temperatures bounce around a little bit and the temperature gets higher and higher and it bounces around a little bit more and more. At some point,

it gets warm enough that the average position of that titanium atom is in the center. If you apply a strong electric charge to this titanium, it might slip over to both the oxygens and this ferroelectric part. It can split and apply a field to it.

So I had a different ferroelectric, barium. It is the same structure. This cube of -- here is barium on the previous slide and oxygen and titanium and slightly above and oxygen is in the center.

What happens if you take a substance like that and apply an electric charge to it and increase the charges through the vector -- take an -- you probably have done this kind of thing. What happens here -- say you start off here and the titanium is here, and you increase the electric field across it and eventually, the titanium atoms flip over and go from here to here.

If you reverse the charge they stay in the same place until you can get them to turn over and go back down. So you get -- this is the basis for using ferroelectric as memory. Because it stays in this state or that state permanently until you apply a large enough electric charge to flip it. Okay.

The other thing you have to remember from this is that the slope of this is sort of the dielectric constant minus 1. When you are dealing with radar, we don't have large electric fields when it is omitted and travels down to the surface. That's a small electrical disturbance at the surface. So the electrical permittivity is slow at 0. That's basically how much field -- produces.

So as we increase -- as we increase temperature here, going from 390 -- I guess the color is going up. We see that the edges, these transition points move in and it takes less electric field to flip it over, because the atoms are vibrating more and more, and less energy needed to flip them over to the other state. What happens when you get to the middle here?

That's when the atoms are basically not -- they are not really caring which side they are on but look at the slope. Slope basically infinite at that point, at this transition temperature here where the ferroelectric property goes away. Relative permittivity, the slope at 0 because effectively into it. Not really because there is leakage into the system but becomes very high at that point and that's what you see here.

After that of course, at higher temperatures, it also collapses down and begins to behave like a normal dielectric substance, which I'm not interested in. Not true.

So the question is, for Venus, what could this substance be? Well barium-type and lead-type probably not the right answer. We don't find them anywhere on earth because of the natural chemistry, because the chemistry of titanium is different from that of lead and barium, so you rarely find both of these materials together in the geologic and normal earth system. Others are just as bad or worse and so, what I did -- my big contribution to this was to go through the geologic literature and find any substance that could reasonably be found in nature that was ferroelectric and there are not very many of them.

In fact, I was able to find one out of all of the minerals that are relatively common on the earth and that is the mineral called apatite and the chlorine version of it. It is common and has phosphorous and hydroxyl apatite and we have chlorinated water or toothpaste. It changes the hydroxyl and apatite and it is hard, so that's why it makes your teeth stronger.

Well and good, but -- so I'm looking down on one of the directions of it and it has these channels and the channels are where the chlorine, fluorine and hydroxyl can fit. So this side actually shows an excerpt with these channels. This is located at 90° and strip away all of the

calciums, phosphoruses and oxygens, and this is what it looks like.

Fluorine in apatite is a small ion. So it is perfectly symmetrical and doesn't have a permanent -- it is happy and not relevant. Hydroxyl apatite, OH, and it could be one way or the other, but that's so it could be ferroelectric, and it is a very low temperature. Normal temperatures -- it moves around so much that on average, there is no electrical. Chlorine is too big to fit in that symmetrical position, so it has to be offset.

So what you end up with the chlorapatite -- and they are lined up to one side of the symmetric -- plane of symmetry or lined up on the other side of the plane of symmetry and the electrical charge can shove them from one side to the other, and so this is a ferroelectric material. I looked at the literature and basically no information about chlorapatite, its electrical properties.

I found one thing, an unpublished master's thesis from Georgia Tech, which fortunately, if you are on the web there is no other way it could have been found. He did that experiment that I showed you before, find the electric charge and measure the polarization and by -- it's -- it suggests that it is transition temperature from ferroelectric to para-electric, is at the right temperature which is about 700K where we see on Venus.

So I wrote a paper about this and I declared it solved, sort of. Is it reasonable? I like to think so. The basalts are like anything on earth they have a moderate amount of phosphorous, which is a couple percent of apatite in the final rock and that's enough to do the job, but some tall volcanos on Mars don't show this effect.

This is called Maat Mons and you do not see this kind of change in reflectance, radar backscatter like you do on Tepev Mons. So the suggestion is on earth the apatite mineral usually is

fluorapatite. But Venus has a lot of chlorine and so maybe it becomes fluorapatite. And I know there are experiments to see if this is a reasonable inference.

I will close with the other part of the questions. This thing that might -- my intern pointed it out as being an important dichotomy. In Maxwell Montes, up here in the north, this area to the lines of Venus, the radar backscatter changes but very abruptly. Here's an example where you can see it goes from low backscatter to high in a sharp line and that's not what we saw (inaudible). This is something else.

This is the argument. Also, there are a couple of possibilities and it could be an atmospheric deposit, something that is carried up and deposited out at some temperature or some -- deposited some kind of product where the temperature gets down to a certain temperature, all of a sudden you are left with a particular reaction that the atmosphere can have, and it does right there.

Not real clear yet. This is just the kind of data, which I probably -- okay. This is the same kind of data that I showed you before where they measure radar reflectivity or backscatter and some slots going up next to Maxwell Montes, and her dots are red, and the earlier data are black. They are showing the same sort of pattern that follow each other. This is some kind of material property on the surface.

The radar data -- the backscatter data are more scattered here and that's probably because it is sort of rough and roughness can really affect the radar backscatter because of the fact that it is aligned with the perpendicular incoming beam and they are opposite to the beam, so that's a factor that complicates using radar backscatter for rough terrain. That's basically the same thing.

So here is a comparison of these two areas. You see that the surface and backscatter gets

brighter and brighter up to this cut off elevation and all of a sudden it turns dark. In Maxwell Montes, it is dark and maybe brighter and then all of a sudden at some elevation, it turns bright and maybe at the highest elevation, it gets dark again, and I'm sure someone is looking at that.

This is a puzzle as to why there is this difference, but I think that's my last slide. Basically the same. So in conclusion is that I think we have some kind of explanation for what's going on with the radar properties in areas like (inaudible) echo to regions. So no good feeling of what's going on at Maxwell.

I believe that would be the end and I want to say this is one of the cool things about planetary sciences is that we are forced to draw this all across chemistry and physics and geology and even in some planets, biology, although not Venus. It is really interesting to be able to do that. It's a lot of fun.

Our institute is just across the way. It will be closer once the forest is all gone and the construction debris is closed out. You are welcome to come over and visit with us and we have a nice library of planetary sciences. I have 15 or 20 people, senior scientists and post docs working on planetary things. If you have any planetary interest or questions, come on over and visit with us. We would be happy to meet you. Thank you very much.

>>DR. GARRISON: Questions

>> The active volcano (inaudible).

>>DR. TREIMAN: Clearly, volcanic is 80% or 90%, but active is a really hard question because we only have data from very short time there. Just about two years -- 3 years -- 3 earth years' worth of -- 3 Venus years of radar data.

In that time, there was no direct, evidence of any eruption. There is a couple of people who claim that in the (inaudible) data there is no bright spots and this to be high temperature emissivity that represents active volcanoes. It is a really hard question because you know, we had like three years' worth and so in some places we had 2 or 3 different passes. You might not see anything in there.

The other bit of evidence that there is -- there is active volcanoes among Venus is in the atmosphere composition. We have had many that have orbited and have measured the composition of the atmosphere from reflective spectrum and there have been a couple of times -- actually about 80 today with gaps in it. There have been when the sulfur content has spiked and quadrupled, and it ramps down in its exponential fashion and one of the explanations is volcanic eruptions. There is no real good answer to it.

Some say it would be impossible for a volcanic eruption to do that because it is stable up to 70 kilometers. So if you can puncture through 7 kilometers of stable atmosphere before getting above that -- I don't know exactly if this is right or not but if they are active, it would be massive eruptions, but we would really love to have another radar orbiter and maybe it lasts longer and be able to compare what's happening now with what happened back in the 90's. It is a great question and boy, I wish I knew the answer.

>> Why are the volcanos not larger on Venus, compared to like what you see on Mars or other --

>>DR. TREIMAN: That's part of it. The pressure -- let me start. Volcanoes are pretty large on Venus. They are not as big as the ones on Mars, but they are pretty large. They are larger

than many on earth and you can explain that on earth because the plates move over the surface of the magma and lava spreads out over time.

I think overall -- I didn't show the largest ones here because we didn't focus on that. Okay, so pressure. It has an effect mostly in terms of the volatiles in magma. A lot are volatiles and as the lava forms, it moves up a little bit because it is less dense, but when it gets far enough, the volatiles dissolve from the lava and makes it less dense and then it shoots up to the surface.

If the surface pressure is 90 bars rather than 1 bar, there's a lot less to push that up. On earth most volcanos have a paraelectric with the ashes and clouds of rock come up. On Venus, there are only a couple of places where people are like this has to be -- it is really unclear if there is any kind of paraelectric eruptions on Venus at all. That's another part of how high pressure plays into it.

>> If you back up to the previous slide, what are these graphs off?

>>DR. TREIMAN: I'm sorry. Silly me. What you are looking at here are cross sections through and across the Maxwell Montes and across the Tepev Mons and this is elevation stretched out as I go across the surface. What I'm trying to show is that at low elevation, it is dark and the higher and higher elevations it gets brighter and then cuts off to be very dark.

>> Why the color with the light and the dark?

>>DR. TREIMAN: These indicate the radar reflectance. I can see -- this is the second time I have tried this, and it hasn't worked well. I'm going to fix it.

>> I was wondering if you (inaudible). Is that something --

>>DR. TREIMAN: That would be a good thing to have.

>> Sure.

>>DR. TREIMAN: One of -- all of the (inaudible) had -- the last couple had colored cameras, so you get red, green, blue on the surface so that sort of spectrum. About as good as we got at the moment. Those show that the surface is reddish. It is hard to know because by the time the light gets through the atmosphere, it is sort of yellow-reddish, so there is an issue of how red the surface is compared to the atmosphere, but your question hits to another part of Venus study and it has this huge thick feel to the atmosphere and at high pressure. Absorption bands from gases tend to spread out which is like why -- sort of peachy color and -- the bands are spread out, but the point is there are a couple of windows in the near infrared and some might call them wavelengths, but there is a couple of them in there, where Venus atmosphere is close to transparent.

(Inaudible) had a camera that looked in a couple of those and you can see something of the surface there again and the camera didn't last very long, so very limited data, but that's a real target is to go back with an orbiter that can look through those windows down to the surface and at that point, we can do some (inaudible).

If the surface is hot enough we will not do a -- we will do emission spectrum so that's one of the next frontiers in Venus science. Good question.

>> So you transition from -- (inaudible).

>>DR. TREIMAN: That's sort of what I was trying to get at. The images I showed of the peroxide structure things, those go from the (inaudible) structure as the titanium becomes center and that's what you are talking about. For the apatite -- I don't remember what the symbols are.

>> (inaudible).

>>DR. TREIMAN: It is that kind of thing. They go from a -- they are both center

symmetric structures and -- I forget. PCOMM or something like that. With the chlorapatite at low temperature is not and it lacks the symmetry perpendicular to the C axis there. I forget -- it is exactly that kind of change we were talking about here.

>> (inaudible).

>>DR. TREIMAN: I think the -- of course -- in terms of Venus, you are right because I think that has happened almost. In terms of Venus, it is thought unlikely first because iron and whatever crystal (inaudible) has a conductor, so it will behave differently in radar and the insulator which is what we are looking at here.

As I mentioned, the surface of Venus looks orangish or reddish and that is inferred to be (inaudible) oxide, some ferric alloy at that temperature and it would oxidize and turn into the (inaudible). So I mean you certainly could see stuff like this, as you are describing with iron alloys on -- based on the meteorites and indication of Venus, that's not reasonable.

>> (inaudible).

>>DR. TREIMAN: In fact, that is true. They found that the base of the ocean, the pressures are not all that different here. In fact, down at the base of the ocean, don't have much in the way of (inaudible) in them because of the pressure being so high.

>> Do you know what color surface of Venus is? (inaudible).

>>DR. TREIMAN: There have been some very good attempts to do that and I caution, it is hard to note how your eye is going to interpret because of the visual processing of color is not the same as your spectrometer. But there is a website by (inaudible) Don Mitchell called "Mental Landscapes" and he spent a lot of effort and rushing data through these pictures and processing it

and trying to remove the atmosphere spectrum because the Russians also took images, so they have a pretty good idea.

So he tried to take that out and I think the image I had -- oops. One of his -- where are you? Just a few more. That's his best guess as to what the color actually looks like, based on the incident light and the reflectance (inaudible). If that color is right, you know, it is not exactly -- it would be much more red or orange and not real clear exactly, but there is another similar substance called (inaudible) which is more yellow like that. This is (inaudible).

>>Mental landscapes.

>>DR. TREIMAN: Yes. It is a wonderful website. He has just fallen in love with Venus and the Russian missions to Venus and all of the Russian space missions and it is a lot of fun. Thank you very much.

(Applause).

>>DR. GARRISON: Next week we will have another speaker from LPI. That is going to be Jonathan Kay and so, also after today's talk, talk to the -- everyone else have a good week and I will see you next week.

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