Student questions: Lori Glaze colloquium on "Venus: The Forgotten, Mysterious Planet"
9/27/17

Question 1: If it were possible to have a sample return mission for Venus, what are some things you would think were worth sampling?

I would definitely want to to bring back a sample of volcanic plains material so that we could do age dating and really understand just how young they are. If possible, it would be good to bring back some tessera material as well to see if they are older than the plains, and if so, how much older.

Question 2: Could the high temperature and high pressure at the surface significantly contribute to the global resurfacing?

It is possible that the very high density atmosphere is in some way related to volcanic resurfacing, in that lots of gases could be released to the atmosphere during the resurfacing process. I don't have a good feel for just how much gas, but perhaps it could be enough to tip the climate into runaway greenhouse conditions. This is pure speculation!

Question 1: What evidence, or lack of evidence, points towards there being just a single plate on Venus rather than the multiple plates here on Earth?

When we look at the Magellan radar images of the surface, we do not see anything that looks like the mid-ocean ridge-spreading centers we see on Earth (for example, the middle of the Atlantic ocean). We do see a couple places on the surface that look like some crust may be subducting under other crust, but not in the massive, organized manner of our plates (like around the edges of the Pacific ocean.

Question 2: Why are the lower 2/3 of the atmosphere so difficult to interpret while just above and below that layer we have a better understanding of what is going on?

Because we have NO missions that have been able to sample that part of the atmosphere! The orbital missions can see down just into the clouds, but because the clouds are so opaque, instruments in orbit cannot see that deep into the atmosphere. The one mission that tried to sample the deep atmopsheric chemistry (Pioneer Venus) clogged in the cloud layer, so there are no samples below that. We do have some information at the surface because the Venera landers took some measurments from the surface. But, nothing in between.

Question 1: Do you think life could have contributed to the continued wet and cool environment of Earth?

I do think that the presence of life on Earth has significantly altered the climate on Earth! The fact that we have plants and oceans that can process and hold carbon dioxide results in the completely unique carbon dioxide depleted atmosphere we have on Earth!

Question 2: How would you reverse the greenhouse effect on Venus or is it too runaway?

The term "runaway" is usually used when a climate has passed a point of no return.

Question 1: You mentioned that Venus doesn't currently have a magnetic field- did it ever? Is there any way to know without the magnetic signal recorded in surface rocks?

Right now, we do not know if Venus ever had a magnetic field. However, it seems very likely that Venus must have had a magnetic field at some point in its past. If Venus did have a magnetic field in the past, the lava rocks that solidified in that time would have recorded the magnetic field in their metalic minerals (we see this on Mars, which also does not have a magnetic field, but does have a "remnant" magnetic signature preserved in some rocks). However, much of Venus' surface is at temperatures so high that the magnetic signature may have been "erased". This is a major question for Venus!

Question 2: The radar images of Venus provide a very rough depiction of the surface. Is it possible to compare similar resolution radar images of Mars or Earth, where we have studied the surface, to better understand the surface of Venus?

Yes!! And we do that a lot ☺. The radar images have been used very successfully to compare the volcanoes and lava flows with similar features on Earth and Mars.

Question 1: How consistent is the hypothesis of a liquid water ocean on Venus within the last giga-annum consistent with the hypothesis of catastrophic crustal resurfacing?

This is a very interesting question. As far as I know, no one has yet looked into the relationship of "recent" liquid water and volcanic resurfacing.

Question 2: You mentioned that it's hard to get a volcanic ejecta plume to rise through the atmosphere due to the high densities involved; wouldn't the high level of wind shear that must occur at some level of Venus' atmosphere necessarily imply some sort of atmospheric convection which could cause particulates and/or aerosols to rise?

The problem comes right near the vent where the explosion occurs. At those altitudes, the winds are almost non-existent. Usually, when a volcano explodes, the material comes out at many hundreds of meters per second (several times faster than the wind speeds, even at the top of the clouds). As the ash and gas rises above the volcano, it entrains and heats up air from the surrounding atmosphere. If the plume can entrain enough air before it runs out of momentum, it will be buoyant and will continue to rise. If it runs out of momentum and is still more dense than the surrounding air, the column will collapse. The problem is that the surrounding air is already very hot, so it is hard to become buoyant.

Question 1: I've heard of possible balloon-payload missions to one of the layers of Venus' atmosphere; what data other than noble gas measurements does this promise?

A balloon mission would be able to provide very important information on (1) the chemical reactions that are going on in the cloud layer, (2) the wind dynamics, (3) composition and size distribution of cloud particles (sulfuric acid droplets), and (4) how the sun interacts with the chemicals in the clouds.

Question 2: Does the high atmospheric pressure affect/filter out smaller impacts on the surface, leading to the apparent lack of impact craters?

Yes, the dense atmosphere does filter out the smaller impacts. However, this does not explain the complete shortage of large impacts on the surface compared to someplace like Mars. Also, Mars, Earth, Mercury, and the Moon, all have huge impact basins caused by major impacts early in their history. Venus does not appear to have one of the large impact basins. Either it never experienced a major impact (unlikely), or all evidence of major impacts has been completely erased.

Question 1: Could absorbed sunlight in upper cloud layers and near-full attenuation of sunlight at the surface be responsible for the extreme difference in wind speeds for these two domains?

I don't think this is the whole answer, but we do need to understand much better how the sunlight interacts with the chemical species in the cloud layer! This would help, but there is much more that remains to be understood.

Question 2: Would the orbital, rotational, and lack of magnetic field/tectonics be explained by a captured rogue planet origin for Venus?

Hmmm, I don't recall ever hearing this hypothesis suggested to explain these features. There have been some hypotheses that Venus used to have a significant moon that subsequently escaped Venus' graviational influence, and that the presence and then loss of that moon may have affected some of these geophysical characteristics.

Question 1: During the talk, it was mentioned that Venus' surface consists approximately of 80% volcanic rocks. Are the 20% left composed entirely of tesserae terrains?

Not entirely. The 80% number refers to the volcanic plains, that appear to just be covered in lava flows. The remaining 20% is made up of large volcanic cones, smaller volcanic features, and the highland tessear terrains.

Question 2: Other than the resurfacing process mentioned during the talk, the paucity of craters on Venus may be somehow related to the very dense and acid atmosphere that probably is very corrosive to incoming meteorites?

Yes, see the response above. Certainly, the very dense atmosphere will burn up the smaller meteorites, so we do not expect to see any small craters on the surface (and we don't). However, this does not explain why there are so few large craters.

Question 1: Why are missions for asteroids chosen for NASA funding than other missions (like ones to Venus)?

Great question! Asteroid missions are interesting because these rocks have been floating around the solar system since the solar system was formed. Because the collision of these materials is what originally formed they planets, they carry materials that can tell us what went into the makeup of Earth and the other planets. They also provide clues to where our water came from, and potentially to how life originated on Earth. These are all very fundamental questions! There are many asteroids in our solar system that can each tell us something about this story. So, I'm not saying it's not important, but I do think we need to explore all parts of our solar system (not just asteroids and Mars ☺).

Question 2: How do we know that Venus never experienced plate tectonics in the past?

We don't know that Venus never had plate tectonics. It very well could have had plate tectonics at some point in the past, but if it did, evidence of that has been erased by the young volcanic deposits. If the tesserae are actually ancient contents, they may provide clues to whether or not Venus had plate tectonics at some point in the past.

Question 1: You mentioned periodic overheating in Venus, could this account for the total resurfacing of the planet and if it does, can it also account for the evaporation of water with the intense heat?

The assumption has been that the water was long gone prior to the major resurfacing event. The thinking has been that because the interior is so dry, the mantle is very viscous and cannot convect freely enough to drive plate tectonics. Heat builds up over time, and then periodically, there could be a major event that results in lots of volcanism over a short period of time. However, there are many unknowns here!!! If Venus really did have water more recently, then maybe the mantle is not dry, and we are left scratching our heads ☺.

Question 2: The scaled picture of earth against Venus' atmosphere, shows Venus' atmosphere about 70km from the surface which far exceeds our own atmosphere thickness. Is there a possibility that Venus started with our atmosphere but the lack of escape for the gases and heat continuously increases the "cloud cover" thickness to get to the 70km as in will it keep growing?

You are correct that Venus' atmosphere is MUCH thicker than ours. It is thought that both Venus and Earth probably started out with reasonably similar atmospheres (that didn't resemble either of the atmospheres we have today). It is a bit of mystery how Venus has accumulated such a dense atmosphere, especially with no magnetic field to protect it from solar wind (which has almost completely stripped Mars of its atmospheres).

Question 1: You mentioned that recently it was published that Venus might have retained water until 1 billion years ago, as opposed to the common belief of 4 billion years ago. Which hypothesis, 1 or 4 billion years ago, is now considered to be more compelling in what ways?

I think the basic assumption in the community is still that the water was lost 3-4 billion years ago. However, the point of the paper is that our current measurements are not sufficient to rule out either case!!!

Question 2: You told us that we cannot expect the lander on surface of Venus to last longer than 5 hours because of such high temperature there. Which top 5 tasks would you choose for the lander to be most prioritized over other possible tasks?

Great question!! That is what mission design is all about ☺, trying to prioritize your science questions and making sure you get the most important measurements first! So, by far the most important measurements that need to be made at the surface are to understand the minerals that are contained in the rocks and the overall elemental makeup of the rocks. To do this properly, you would want to sample several spots at your landing location to make sure you have adequately characterized it (and not just measured some unusual rock that happened to be there). With the additional time, I woud want to start drilling so we could make the same chemistry measurements as a function of depth. This would tell us something about how the rocks have weathered over time (measurements of the rock surface), and as we get deeper, would tell us more about where the rocks came from originally. Drilling in the hot environment is a challenge, so that could take some time. In addition to these measurements, it would be nice to make measurements of the atmosphere over that time period to see if there are any changes in temperature, wind, or atmosphere compostion over the short time period we are there. Finally, I would want to make sure we are sensitive to any possible seismic signals. It is unlikely we would experience a Venus-quake within 5 hours, but if we did, we'd want to know!

Question 1: How are probes/landers be engineered so that they can withstand the extreme conditions of pressure, temperature, sulfuric acid clouds, etc?

To withstand the sulfuric acid and other corrosive clouds, we usually use titanium which is resistant to corrosion. To withstand the temperature, we use materials like wax (contained in packets). The wax absorbs the heat and melts and that helps keep the air inside the probe to stay cool (like a glass of water with ice cubes; as long as the ice cubes are solid they keep the water at the same temperature; when the ice cubes are completely melted the water starts to warm up).

Question 2: Do you think that Venus at one time may have had active plate tectonics?

I think it is certainly possible that Venus had plate tectonics at some time in the past.

Question 1: How can we use Venus to simulate and improve measurements of exoplanet atmospheres with remote observations?

When we better understand the Venus atmosphere, we can build better models of how atmospheres work and what different climates look like. These can be used to not just describe what atmospheres look like today, but they can also be used to understand what Earth, Venus and Mars were like a long time ago. Then, when we can measure the composition of explanet atmospheres, we can use those models to understand if the exoplantes are anything like the planets we know, whether now or at some time in the past.

Question 2: Has there been any effort to create a pressure-temperature profile of Venus' atmosphere, specifically looking for temperature inversions and their associated gaseous absorbers (i.e. a stratosphere layer)?

Yes, there has been some work to measure the temperature and pressure profiles. We have a few profiles through the atmosphere (from Pioneer and Vega), and we have lots of measurements above the clouds from Venus Express.

Question 1: Can you talk about the instrument payload for VICI?

The VICI instruments are built around the same instruments that are currently on the Curiosity Rover. These instruments are reliable and the measurements from Venus would be easily comparable to those on Mars. The payload includes a neutral mass spectrometer and tunable laser spectrometer (the core of the Sample Analysis at Mars – SAM – suite on Curiosity). The payload also includes a Raman/LIBS spectrometer similar to the ChemCam on Curioisity and the SuperCam that will fly on Mars2020. In addition to these core instruments, VICI has an atmospheric structure investigation (temperature, pressure, winds), a camera for imaging the landing site during descent, and a gamma ray detector for measuring potassium, thorium, and uranium at the landing site.

Question 2: Have you considered looking into extremely high energy polarized LIDAR instruments to observe the upper (and possibly lower) atmosphere of Venus via an orbiter?

Yes!! I've thought a lot about such an experiment. An atmospheric lidar could make lots of kinds of measurements, including upper level winds. It is very difficult to see into the lower atmosphere, however, because of all the scattering.

Question 1: Can we use atmospheric spectra of exoplanet transits to determine whether or not an exoplanet has similar properties to Venus?

Yes, we can! And we are starting to do that. We can observe spectra that can at least tell us what the major chemical species are in an exoplanet's atmosphere.

Question 2: Does the fact that Venus lacks a moon possibly explain some of the mysteries of Venus's rotation, atmosphere, and/or surface activity?

Possbily, but it is not really clear what all the implications are of not having a moon. Some have also suggested that Venus did have a moon at one point, but that the moon escaped from Venus' gravity.

Question 1: How much do you think we could learn about the Tesserae formations just from a soil sample?

I think we could learn a HUGE amount about the tessear from a soil sample ☺. Even just understanding the amount of silica present in the rock will tell us whether the tessera rocks were originally more like basalt or more like continental rock. The exact minerals that are present can also tell us not only what kind of rocks are present (basalt or not), they can also tell us how those rocks have been weathered over time. The type of weathering will provide us with information about what the atmosphere was like when the rocks were exposed. If Venus ever had a different climate (cooler, wetter), that would show up in the weathered minerals that are present.

Question 2: Is there anything in particular that you'd be interested in knowing more about, but would require landing a rover on Venus for at least a couple months in order to test/observe?

There are always lots of things we could do if we had the ability to move around on the surface for a longer period of time ☺. If we had longer on the surface, we could include humans in the process of making decisions about where and what to sample. We could also move around to different types of rocks to make sure we're getting a representative sample of the surface. There are definitely plusses to living longer on the surface, but we can get almost everything we really need in a very short period of time.

Question 1: It seems like when we talk about geologic process on other planets that we end up being very Earth-centric in our observations. My question is what can we learn about volcanism on Mars that may help us learn more about volcanism on Venus?

That is a very good point! Interstingly, the more we've studied the volcanoes on Mars, the more we realize that volcanism on Mars and Earth are very similar! One thing that is different is that both Mars and Venus do not have plate tectonics. Because they both are "single-plate" planets, their volcanoes are what we call "heat pipes" where magma comes up straight from the mantle. In this sense, we can see on Mars how these types of flows have been emplaced.

Question 2: My other question is related to mission selection. Is their a global effort to cover the vast amount of targets in our solar system when national agencies select missions? (for example, since we did not make Venus a priority, does that affect the priorities of other agencies such as Russia to focus on Venus)

In some sense, yes, the individual agencies do pay attention to what targets the others are purusing. However, at the same time, if a particular agency decides they want to place a high priority on a particular target, they don't really care what the others are doing (or not). It is certainly not well organized.

Question 1: What are some precautions taken in the construction and design to extend mission life in the intense Venus atmosphere?

We do a huge amount of testing of every part of the mission (the probe/lander, and all the instruments). Those tests need to reproduce the full set of environments that the mission will encounter. We have to demonstrate that we have confidence everything will perform as we expect.

Question 2: If you could have a mission time of a month what kind of experment would you run?

If I had a month on the surface, I would set up my experiments such that I could survey the surface and then select several specific surface locations to sample. We could also run more complicated analyses that take longer to set up and run (such as some of the analyses that are run on Mars). Finally, I would like to bring a seismometer so that I could record any possible Venus quakes.