Student questions: Morgan Burks colloquium on “Mercury, 16 Psyche, Mars, and Titan: Exploring the Solar System with Gamma Rays”

4/11/18

Question 1: On Titian is the dust going to be an issue with the craft when it lands and flies from point “A” to point “B”?

Yes, all the instruments, including our gamma ray spectrometer, are being designed to withstand the environmental conditions, including temperature, dust etc.

Question 2: On Titian is there going to be a way to test for seismic activity on the surface with the craft?

Yes, they will have a seismometer onboard. Search for NASA Dragonfly and you can read about the various instruments on board.

Question 1: What combination of properties makes germanium the most ideal mineral for use with gamma ray spectroscopy as opposed to other minerals?

Germanium is a semiconductor, like silicon, which allows it to collect the charge (liberated by the gamma-rays) very efficiently. However, compared to silicon, it has a higher atomic number and is thus also better at stopping gamma rays.

Question 2: What are the trade offs considered when identifying a detector cooling system for missions to the outer solar system?

There are many tradeoffs including mass, power, longevity, ruggedness with respect to rocket launch, and the amount of vibration produced.

Question 1: Do you foresee other spectrometry methods being created and what do you think it would be?

Many groups are working on detector materials that, unlike germanium, do not have to be cryogenically cooled. However, none of them so far give comparable resolution. But eventually they might achieve something close.

Question 2: If you could learn everything there is to know about one aspect of space what would it be?

Is there life on other planets!

Question 1: You mentioned that the spectrometer housing has many layers of infrared shielding; what material do you use to create this shielding?

The shields are made from aluminum that is highly polished to an optical mirror finish. Then a thin layer of nickel is deposited, and repolished. Then a thin layer of gold is deposited. The gold surface then reflects 98% of infrared photons that land on it. The nickel is just there to help the gold adhere to the aluminum.

Question 2: I'm curious to know more about the Ge crystal you brought in; the main thing that struck me was the shape and general non-crystalline appearance. Is this a natural Ge crystal you ground and shaped into what we saw today, or is it a synthetically “grown” Ge crystal?

The germanium crystal is grown in a lab and comes out as along, slightly irregular, cylindrical “bool”. It is then carefully machined to the shape that you saw. The machinist must take care not to disturb the crystal structure when machining (i.e. put in cracks).

Question 1: Are there any significant challenges you face when dealing with the photon energy levels at 16-Psyche vs Mercury?

In both cases, Mercury and 16-Psyche, the number of photos we measure per minute is low (a few hundred). That is not a problem. Germanium detectors only have problems when, for example, trying to make measurements next to a reactor.

Question 2: Would you please elaborate on how pulsed neutron generators will aid in the gamma-ray measurements of Titan?

Titan has an extra challenge because its atmosphere is so thick that cosmic rays do not reach the surface. It is the cosmic rays that produce the neutrons, and the neutrons that produce the gamma rays that we measure. Thus, on Titan, we skip the cosmic rays and produce our own neutrons wit the pulsed neutron generator.

Question 1: What is the housing material made of for the gamma ray spectrometer, i.e. the golden metallic cannisters and housing?

The housing and IR shields are made with gold-plated aluminum. The gold plating is to help it reflect infrared heat (see question on IR shields above)

Question 2: Why is the potassium map of Mercury such low resolution when other elements such as sodium have a much higher resolution?

The resolution of the elemental maps will depend on many factors. One of which is how strong is the signal that you are measuring. I’m not an expert on this particular question but I’d think that the Potassium map just had lower statistics compared to other elemental maps.

Question 1: How much money does it cost to design, build, and launch a gamma ray spectrometer?

That is a complicated question because this instrument is based on many years of research and development. It also depends on what costs you include: testing, integration to the spacecraft, documentation, etc. But if I had to give a number I'd say about $2 million for our part of the project.

Question 2: How are the gamma ray spectrometers of today different from those like the one sent to Mercury on MESSENGER?

We have a better understanding of infrared shielding, radiation damage, and we can take advantage of improvements in commercial cryocoolers.

Question 1: When the Messenger satellite was orbiting Mercury, were you able to utilize passive heating for the annealing process?

No, we always used the active heater. It would be too hard to control the passive heating because it depends on how the spacecraft is facing (whether the Sun, Mercury, cold space etc.), and that is constantly changing as it orbits Mercury.

Question 2: You mentioned that the environmental temperature on Titan was about 200 degrees C, which was about perfect for the detector. How much can the temperature diverge from 200 before the detector will be too inaccurate for the data to be useful?

Yes, expect that it is about -200C! (not positive), perfect for our detector. To be more precise, the temperature on the surface of Titan is about 94 Kelvin, plus or minus a few degrees. We can operated anywhere from about 110K down to 70K without problems.

Question 1: How is gamma ray spectroscopy used to study bodies and regions of space outside of our solar system?

There are many astrophysical objects that emit gamma-rays: galactic nuclei, super nova remnants, black holes etc. Check out the INTEGRAL spacecraft, made by the European Space Agency, for an example of using germanium detectors to study these things.

Question 2: What will be the most difficult challenges to overcome in the design of the Titan Dragonfly mission?

I can only speak about my instrument. It had to last for a very long time, 9 years cruise to Titan, surviving radiation damage etc., and then work perfectly once it gets there!

Question 1: How much more reliable, or how much better is gamma ray spectrsocopy compared to that of x-ray spectrsocopy when analzying different objects in our solar system?

Both techniques are very useful. X-rays can only be used to look at the surface of a material so are subject to weathering effects. Gamma-rays can penetrate more deeply so can look at bulk properties. But x-rays are easier to detect, because they have lower energy.

Question 2: Since NASA/ESA have already put a lander on Titan, have any proposals gone about of the possibility of a lander on Enceladus so we can try to figure out what is going on in the SPT?

I'm not knowledgeable about Enceladus, though it would be amazing to put a lander there! The Huygens probe did land on Titan but its total time was only a few hours before it died (that was how long it was designed to last and completed its mission, plus extra, before dying). The information it revealed was so exciting that there is great desire to go back and explore Titan in greater detail.

Question 1: What is the backend programming language used in the data acquisition and analysis software in the Gamma-Ray Spectrometer?

The flight software is being done by Johns Hopkins Applied Physics Lab. I'm afraid I don't know what language they are using.

Question 2: With technology constantly advancing will the technology in the Spectrometer being built for the Psyche mission be more or less the same as those previously built.

There are many improvements. As stated in a previous question, we have a better understanding of infrared shielding, radiation damage, and have access to better cryocoolers. But the basic technology is the same.

Question 1: Using these high resolution gamma-ray spectrometers does the thickness and composition of the atmosphere have any effects on the data that is received from the surface?

At Mercury, Psyche and Phobos, there is no atmosphere so it will have no effect on our measurements. At Titan the atmosphere is so thick that we have to land. Then it will be negligible.

Question 2: is there ever times when there could be data received that reveals a type of composition that has not been seen here on Earth; has there been new discoveries of new rock compositions in our solar system, and are you expecting any anomalies in these upcoming missions?

That is certainly possible, though I'm not aware of any substantial new rock types. But I'm not a geologist so can not give an expert answer here.

Question 1: How much does this entire system cost roughly, with the detector and cooling and protection?

That is a complicated question because this instrument is based on many years of research and development. It also depends on what costs you include: testing, integration to the spacecraft, documentation, etc. But if I had to give a number I'd say about $2 million for our part of the project.

Question 2: How has, or will, GRS help in deep space observation?

There are many astrophysical objects that emit gamma-rays: galactic nuclei, super nova remnants, black holes etc. Our GRS is not involved in these measurements. But check out the INTEGRAL spacecraft, made by the European Space Agency, for an example of using germanium detectors to study these things.

Question 1: Are spacecraft that are capable of carrying gamma ray spectrometers also capable of carrying other kinds of spectrometers at the same time? Or are the parts too specialized to have a craft carry both?

Spacecraft routinely carry many types of spectrometer at the same time: gamma-ray, x-ray, visible, IR, UV etc. You want to cover as many types of measurements as possible.

Question 2: Are all gamma spectrometers lost in space or are some designed to make it back to earth?

So far none have made it back to Earth. It is too expensive and, since all the data is sent back by radio, there is no scientific reason to return them.

Question 1: What is the difference between measuring gamma rays and measuring other short wave radiation thats emitted from stars?

By other short wave radiation, I assume you mean x-rays? X-rays are easier to detect, because they have lower energy and are easier to stop in the detector. They give complementary information to gamma rays as they reveal slightly different physics processes.

Question 2: How is your cryo-cooled system better for measuring gamma rays than looking for Compton Scattering through electrons?

Gamma-rays Compton scatter in our detector (along with photoelectric and pair production) and that is part of the detection process. I also design and build Compton-scatter cameras for gamma-ray imaging. But at present they are too expensive, complicated for space-based applications.

Question 1: You showed how Mars Odyssey used germanium detectors to study water and another component on Mars. Can I ask what other compositions were studied on Mars using this same germanium system?

There have been many papers published on Mars Odyssey gamma ray data. Here is one to get your started.

B. C. Hahn et al., "Mars Odyssey Gamma Ray Spectrometer elemental abundances and apparent relative surface age: Implications for Martian crustal evolution"

Question 2: You spoke about kneeling on the 16 Psyche mission and bringing the temperature back to baseline to combat the radiation damage. While it appeared you are currently in the testing phase, if successful what other missions do you plan on applying this method?

We used "annealing" on the Mercury MESSENGER project. We currently are performing lab tests to improve the technique. We will be using it on all future missions including Psyche, the Martian Moons Exploration, and Titan Dragonfly (if we get selected!)

Question 1: What is the lowest temperature that the coolers reach?

We operate around 90K. They can get as low as 70K, depending on the design and ambient conditions.

Question 2: What are Kevlar suspensions?

Kevlar fibers are used to hold the detector in a form of spider web. This keeps in rugged with respect to rocket launch, and isolates it thermally from its environment.