Student questions: David Blewett colloquium on "MESSENGER's View of Hollows on Mercury, and Links to the Planet's High Volatile Content"

2/1/17

Thanks to all of the students who attended my talk and who submitted questions. This is a lot of questions! During the *MESSENGER* mission, I was in charge of the "Ask a Question" portion of the *MESSENGER* project website. Over the course of the mission, I fielded hundreds of questions from the general public. You can browse through the Q&A here: http://messenger.jhuapl.edu/Resources/Questions-and-Answers.html
The questions are organized into various categories, like the spacecraft & engineering, impact craters, geology, the journey to Mercury, and so forth.

So, while I am not able to answer all the questions that have been submitted by ASU students, you could take a look at the website if you are looking for further information.

--Dave Blewett

I was on the Internet surfing and I read that in 1859 there was a sun storm that hit our solar system, and I also read that it will happen every 150 years. My question is Messenger or Mariner10 are ready for the next sun storm since they are orbiting Mercury?
Neither *Mariner 10* nor *MESSENGER* are operating any more. However, it is true that solar storms ("coronal mass ejections") can cause problems for spacecraft. On a few occasions, *MESSENGER* images were affected by solar storms. See the example here: http://photojournal.jpl.nasa.gov/catalog/PIA15479

In the future like a million years ahead would Mercury crashes the sun at some point since it is very close to it? Also, are Mars and Mercury are the same planets but different temperature? I know that Mercury has no atmosphere unlike mars, but in the end are they very alike by looking at craters and color?
Mercury and Mars are quite different. Mercury is much more dense, with a relatively large iron core.

Specifically, how did the sun bring MESSENGER's orbit around Mercury down until it crashed into the planet's surface?
The orbit of a spacecraft around a planetary body is not necessarily stable against perturbations by the body's "lumpy" gravitational field, or by the gravitational influence of other bodies. In the case of *MESSENGER*'s orbit around Mercury, it is tugging by the Sun that causes the orbit to change. Because of gravitational perturbations by the Sun, the orbit of the spacecraft around Mercury is constantly drifting toward lower periapse (altitude of closest approach) above Mercury's surface. The spacecraft occasionally performed "orbital correction maneuvers" using its main engine to boost the periapse back up to avoid hitting the surface. But, once the propellant has all been used, there is no way to avoid the inevitable: the closest approach altitude decreased until it reached zero, and the spacecraft crashed on the surface..

Out of all the data MESSENGER provided, which information that was gathered, in your opinion, is the most important or makes the biggest impact on our own planet?
The *MESSENGER* team put together a list of the Top 10 Science and Engineering results from the mission: http://messenger.jhuapl.edu/index.html#top10

I am getting ready for graduate school in a space related field but have only take up through calc-multi-variable and the second year of physics. What are classes you wish all of your graduate students had already taken before hand such as more physics or more math or chemistry?
I think a class in statistics would be very useful, maybe something like a course on "statistics and data analysis in the physical sciences". In my work, I find that linear algebra is much more useful than calculus.

One question I had was: If the volatile theory were true, would there be evidence if their release in the thin atmosphere of Mercury?
It is possible that the volatile species are present in Mercury's exosphere, we just aren't able to see them with the instruments that *MESSENGER* carried.

With current technological progression rates, would it be feasible for a rover to land on Mercury within the next 50 years?
The dynamics of getting to Mercury are very difficult. Even sending a robotic lander to Mercury would be challenging (you can read a top-level study for a Mercury lander that APL conducted at http://sites.nationalacademies.org/SSB/SSB_059331 .)

What gives the blue/cyan color for the hollows?
We don't yet know.

Since there is such a large amount of sulfur minerals on the surface of Mercury, has this allowed the sulfur to band together and erode faster in some areas from solar winds, which has created some of the larger hollows?
It appears that the Low Reflectance Material (LRM) color unit contains more sulfur than other terranes on Mercury. Since the LRM appears to be the unit in which hollows form, loss of sulfide minerals is likely contributing to formation of hollows.

If we had a powerful spectrometer on one of the orbiters, could we point it at the bright blue reflective material and find out exactly what it is made out of? Are there any proposed missions to put a lander on the surface of Mercury?
Great question. In my talk, I only had time to cover the colors of surface materials as seen by the multispectral camera. But *MESSENGER* also carried a spectrometer that measured the reflectance of the surface from the ultraviole to near infrared. However, in this wavelength range, Mercury's surface is almost featureless - meaning that there are no diagnostic absorption bands that can be used to tell if certain minerals are present. The *Bepi-Colombo* spacecraft will carry a thermal-infrared spectrometer that should allow for identification of the minerals on Mercury's surface.

How much did it cost to fund the messenger mission?
At the time that *MESENGER* was selected, the cost cap on Discovery-class missions was about $300 million. This includes building the spacecraft and the instruments, the cost of the rocket for launch, mission operations for the approximately six years from launch to orbit insertion plus the one-year primary mission in Mercury orbit, and support of the science team for data analysis and archiving.

How would the spacecraft help determine the structure of Mercury's core? Is this based on the chemical compositions of surface rocks?
Precise tracking of the spacecraft's radio signal allows geophysicsists to determine how the planet's gravity affects the motion of the spacecraft. From this data, it is possible to figure out the structure (mass distribution) inside the planet.

When the satellite is finally out of fuel, why can't we create a satellite that would crash from outer space but still be capable of sending information or pictures from the ground of a planet?
When it hit the surface of Mercury, *MESSENGER* was traveling at about 8,700 miles per hour, so there was no chance of surviving the crash. In order for a spacecraft to "soft land" on a planet, it must carry a special landing rocket (parachutes, which can work on Earth, Venus, Mars, or Titan), are no help for landing on Mercury or the Moon because there is not atmosphere. The landing rocket and fuel for it add a lot to the weight of a spacecraft, so it would need a larger, more expensive rocket to launch it from Earth. A Mercury lander just is not possible within the budget of NASA's Discovery program.

How has your work at NovaSol influenced your current goals?
I worked at a private company for about 7 years after getting a PhD in planetary science. I was using the same techniques that I had used in grad school to study the Moon and Mercury, but applying them to military and medical problems. I think that experience in industry gave me valuable perspective, somewhat different from the academic world.

In your exerience, do Beijing scientists approach space exploration differently than the U.S.?
I think that scientists in China are a lot like scientists in other countries - they are fascinated by nature and want to make discoveries and share them with the global scientific community. And, like scientists elsewhere, they grumble about political interference, inefficient bureacracies, and lack of funding. China is following a logical set of steps in their lunar program (two robotic orbiters, a lander, and coming soon, a sample-return mission). In the U.S., it can be harder to have a long-term program because of the vagaries of the Congressional budget process.

What kind of woven cloth did you use for the sunshade?
Ceramic.

Why do you think that the hollows are found in the LRM?
The material that is subject to loss (sublimation, or destruction by space weathering) must be more abundant in the LRM than in other mercurian materials.

What factors could cause a preference for equator facing slopes during the formation of hollows?
Slopes that face the equator receive more sunlight, and hence get hotter than slopes that face the poles. Hence, if high temperatures are key to formation of hollows, we would expect hollows to be preferentially found on equator-facing slopes.

What effect can the coronal ejection have on these hollows? Could there be any correlation between solar activity and the rate at which these form?
Energetic particles from the Sun certainly affect Mercury's surface, and might play a role in destroying material to form hollows.

Do we know if there is lava flow on Mercury and does any of these "young" formations speak of the volcanic activity on Mercury?
There is a lot of evidence for lava flows on Mercury. There are large smooth plains deposits (similar to the maria on the Moon) and flow fronts are visible in some images. This link to the *MESSENGER* image gallery will take you to lots of pictures of explosive and extrusive volcanic features: http://messenger.jhuapl.edu/Explore/Science-Images-Database/By-Topic/topic-63.html
See also http://messenger.jhuapl.edu/Explore/Science-Images-Database/gallery-image-1579.html

In regards to the MESSENGER instruments, how does the color wheel motor not freezeout? Certain motor lubricants are known to fail in space conditions so how is this avoided? Also what is the advantage of using a color wheel? What can be gained here that couldn't be done in post processing computer analysis?
In any spacecraft component that has moving parts, failure of the lubricant is a concern. Spacecraft designers place a lot of emphasis on "heritage", that is, has a particular piece of equipment been flown successfully in space before? If so, it is likely to be selected for use in a future mission.

In order to learn about the composition of materials on a planetary surface, it is necessary to make measurements of the amount of light of different colors (wavelengths) that is reflected. One way to do this is with a filter wheel. The filters allow only light of a specific wavelength range to pass. For example, the *MESSENGER* camera had filters at 433, 480, 559, 629, 699, 749, 828, 899, 947, 996, and 1012 nanometers (that is, from the blue to the near infrared). It is necessary to make the measurements in the different wavelengths to start with - it cannot be reconstructed later.

How much thermal pressure is exerted on the mirrors next to the solar cells? How much fuel does this save? Also how much fuel is used trying to orient the sun-shield towards the sun at all times? If this needs to be adjusted often it would greatly reduce mission life. Mission engineers at APL used solar radiation pressure to help steer the spacecraft, saving some fuel. Look at this list of Top 10 Technology Innovations, and go to #4 "Fire Sailing": http://messenger.jhuapl.edu/index.html#top10

Where else in the solar system do we see hallows, and do they form the same way? Hollows are not found on any other known planetary surface. However, as I mentioned in the talk, similar features form in the carbon dioxide ice south polar ice cap on Mars.

What exactly is the shadow method used to determine the depth of craters? If you know the angle of the Sun above the horizon, then you can calculate the height of a thing that casts a shadow by measuring the length of the shadow. It is a simple trig problem: height = (shadow length) $\times$ tan (θ). In the case of hollows, the thing casting the shadow is the top (brink) of the hole, so the "height" is the depth of the hole. We measure the length of the shadow using image processing software. The position of the Sun at the moment that the image was recorded is also known, so we have the angle "θ".