Science AMA Series: we're Bruce Jakosky, Dave Brain, and Rob Lillis, science investigators on the MAVEN mission that is orbiting Mars and studying the planet's upper atmosphere. AMA!

AmGeophysicalU-AMA [1] and r/Science AMAs[1]

[1]Affiliation not available

April 17, 2023

Abstract

My name is Bruce Jakosky (http://lasp.colorado.edu/home/maven/about/teampartners/principal-investigator/) from the University of Colorado. I'm the Principal Investigator of the MAVEN mission, and have an interest in the complex volatile system on Mars, reaching from the deep interior to the region that interacts with the incoming solar wind. My name is Dave Brain (http://lasp.colorado.edu/~brain/David_Brain/Home.html), and I'm a member of the science team and an Assistant Professor in Planetary Sciences at the University of Colorado. My research focuses on interactions of the solar wind with planetary magnetospheres and the implications. And I'm Rob Lillis (http://sprg.ssl.berkeley.edu/~rlillis/), a Research Scientist at the University of California at Berkeley and a member of the MAVEN science team. I'm interested in the energy input into the Mars atmosphere that comes from solar storms and the corresponding response of the upper atmosphere. The MAVEN (http://lasp.colorado.edu/home/maven/) spacecraft has been in orbit around Mars for just over an Earth year. We're getting enough measurements that we've now been able to see the general behavior of the upper atmosphere and also its response to a significant solar storm. We've determined that atmospheric gas escapes from Mars to space in large enough quantities that this loss probably was a major mechanism for changing the climate on Mars and turning it from a warm, wet environment to the present-day cold, dry environment. We will be back at 2 pm EST (11 am PST, 7 pm UTC) to answer your questions, Ask us anything!

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Science AMA Series: we're Bruce Jakosky, Dave Brain, and Rob Lillis, science investigators on the MAVEN mission that is orbiting Mars and studying the planet's upper atmosphere. The team's first result

AMGEOPHYSICALU-AMA R/SCIENCE

ABSTRACT

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What are the long term hopes for the study and what do you predict the results will be?

huge_ox

The MAVEN mission is focused on understanding the role that loss of gas from the atmosphere to space has played in the history of the climate. This is important because Mars shows us lots of evidence for climate change, and we want to understand what processes were responsible. By looking at loss today, we can understand the processes, and this lets us extrapolate the processes back in time to determine the total loss through time. The MAVEN mission is all about climate change on Mars.

Do you believe Mars is atmospherically rare, or is there evidence that there are many more planets like Mars (or is it simply too hard to tell without a spacecraft like MAVEN)?

p1percub

Within our own solar system, both Mars and Venus have atmospheres similar in composition (mostly

first result, *The Winnower* 2:e145035.56415 , 2015 , DOI: 10.15200/winn.145035.56415

carbon dioxide). But in terms of atmospheric density, no other solar system body is terribly similar to Mars (earth's is ~100 times thicker, Venus is ~10,000 times thicker, the moon is 10 billion times thinner etc.).

Over what kind of timescale did Mars lose it's atmosphere? Have ye discovered anything new about the large scale atmospheric circulation patterns on Mars?

[IceBean]()

We think that Mars lost most of its atmosphere early in its history. At that time, the solar wind and the solar extreme ultraviolet radiation that drive were greater, and loss would have been much greater than it is today. It's very likely that the loss of atmosphere started when the Mars magnetic field shut off around 4 billion years ago, and that the bulk of the loss occurred over only a few hundred million years. We see loss continuing today, but at a pretty slow rate; looking today still lets us understand the processes that can drive escape to space.

Bacteria and algae had and continue to have a measurable effect on our atmosphere,

have you been looking for the same indicators of life to see if they explain atmosphere composition?

[Monster_Claire]()

Living organisms can have a substantial effect on the composition of an atmosphere. On Earth, almost all of the oxygen in the atmosphere came from plants, for example. However, MAVEN was not designed to examine the trace gases that could be present that could tell us whether there was life on Mars. The European Space Agency, along with Russia, will launch a "Trace Gas Orbiter" next year that will examine exactly this question.

I think someone misspelt the flair.

Also, what cool things can the orbiter do, or have?

[Tactical_Wolf]()

Solar flares are brief but intense emissions of energetic light from the Sun - usually at x-ray or extreme ultraviolet wavelengths.

Cool science from the orbiter: The orbiter has 9 science instruments that measure the energy coming from the Sun (solar wind, sunlight, magnetic field), the top layers of the atmosphere (neutral particles, charged particles, and charged properties), and escaping atmosphere (neutral particles and charged particles). These instruments work together to tell us the whole process of atmospheric escape from the Sun to Mars to escape, and this strategy will enable us learn more about the history of loss over time.

Cool things the orbiter does:

1: During certain times the orbiter performs "Deep Dips", where we lower the closest point of the orbit more deeply into the top layers of the atmosphere. This takes a lot of vigilance on the part of the spacecraft operators, and we can learn more about the regions from which particles escape. We don't do this all the time because it takes a lot of fuel - there's a trade off between mission lifetime and how deep in the atmosphere we can go.
2: The orbiter has an "Articulated Payload Platform" that has three different instruments on the

end of it. It is basically a metal "arm" hanging off the spacecraft, with hinges that allow us to turn the instruments to look in different directions without having to turn the entire spacecraft. 3: The orbiter carries a relay (a special radio) for talking to landers and rovers on the surface. We can use the relay over coming years to transmit data from the rovers back to Earth.

If you were in charge of the national budget, would you increase funding for NASA? If so, how would you want to pay for it (raise taxes, cut certain programs etc.)?

QueenofDrogo

I think it's important that the U.S. have a space program, and that we're exploring the world around us. But I don't know what the right size for the NASA budget is. Right now, it's a fraction of a per cent of the federal budget, some $19billion. Of that, about $5billion goes to the robotic space program (planetary science, astrophysics, heliophysics, Earth science). With that kind of money, I think we're doing some pretty spectacular things, and making some really exciting discoveries! However, I would like to see some changes in how we allocate the available money -- in how we have structured the space exploration program.

How do you tell what gasses are in the atmosphere? By color?

ManicFrizz

Great question! We look at light coming from the atmosphere to determine what's there. The way that different chemical species interact with light acts like a kind of fingerprint that we can detect. Hydrogen gas emits and absorbs light at very specific wavelengths that are different from the wavelengths that carbon dioxide emits and absorbs light. MAVEN uses measurements of ultraviolet light to determine what gases are in the upper atmosphere. But infrared and other wavelength regions can be used as well.

Additionally, MAVEN has an instrument that collects particles from the upper atmosphere and measures their mass directly, telling us which species are there.

Is is possible to use the models you're developing for understanding dramatic climatic changes in Mars to better understand how climates can change on other planets such as Earth? Or vice versa - do climate change models for Earth inform your analysis of what happened on Mars?

firedrops

I think we can use the MAVEN data to tell us how other atmospheres might behave - in the past, present, and future. At its heart the MAVEN mission will tell us how the top layers of an atmosphere interact with the space environment. By measuring and understanding the processes as they happen at Mars we are better able to predict how they might occur elsewhere - at Venus, comets, and planets orbiting other stars! This is one exciting aspect that drew me to this mission in the first place - the opportunity to understand how atmospheres *everywhere* work.

That said, there can be some fundamental differences between the atmosphere of Mars and other bodies that make the comparisons hard (but not impossible) to make. For example, Mars is unprotected by a global magnetic field, while Earth has one that may prevent the atmosphere from having been stripped away by the solar wind.

Do you think it would ever be possible to put the atmospheric gas back on Mars? If so (Maybe even if not) would it be possible to colonise Mars at any point and how do you feel this would effect people on the Earth?

RavenTa

If the gas has been lost to space, then it's not possible to put it back. But if it's been locked up in the crust, then it could be possible. Indications so far (and they're pretty strong) suggest that loss to space was a major process in the changing atmosphere. That would mean that we couldn't put it back into the atmosphere. In many ways, MAVEN is a "terraforming" mission, telling us whether the CO2 that we would put back into the atmosphere to warm the climate is available on the planet. Unfortunately (or fortunately, depending on your view), our results mean that terraforming Mars may not be possible.

Has the atmospheric loss been constant, or do you think it has accelerated/decelerated at some point?

What is the range of instrumentation available to the MAVEN Orbiter? And are they any tools that it doesn't have that you would love to have on another orbiter?

kerovon

We think the rate of atmospheric loss has changed over time, and that escape rates were much higher in the past. We think this because when we observe young stars in the galaxy that are similar to our own we see that they are much more active. The solar winds are stronger, the ultraviolet light they emit is greater, and solar storms are more frequent and more intense. All of these things should lead to more energy being deposited in the atmosphere, and more loss.

Evidence for this idea from MAVEN observations comes from observations of solar storms today, which have conditions similar to what we expect for the early solar system. During solar storms today we wee escape increase by factors of 10 or 100 or more!

The work your team does is incredible.
Is the Martian atmosphere suitable for our current solar farming structures? I'm curious to understand if the weather is too volatile for your current designs?

jasontroyhimself

Sure, solar panels are in fact used by two of the Mars Rovers sent in the last 15 years (both Spirit and Opportunity). Both dust storms and cumulative dust are a problem for solar panels. Dust storms reduce the solar flux substantially when they occur and wind-blown dust can slowly build up on solar panels and reduce the amount of power they can produce. Spirit and Opportunity were both very lucky in that dust devils (Mini-tornadoes) came along at sufficiently regular intervals to clear the dust away from the panels. Dust accumulation was the reason they thought the rovers would only last for 90 days, but this constant cleaning kept them going for years and years :-).

Other than CO2 being frozen and thawed at the poles, are there other interactions of atmosphere and the ground?

DigiMagic

Two additional ways that the atmosphere can interact with the ground are:

1: It can chemically interact with surface rocks and minerals. For example, Mars is red because oxygen in the atmosphere interacted with iron-bearing rocks in a reaction very similar to the process that forms rust on Earth. Similarly, carbonate rocks (limestone is a type of carbonate) form when carbon dioxide interacts with surface minerals in the presence of liquid water. We haven't found a lot of carbonate on Mars, but we have found some.

2: Atmosphere can be "sequestered" in the surface or subsurface - basically trapped or frozen in pore spaces in the ground.

This is really interesting to know. What's the future application of this knowledge? How might this play into a crewed Mars mission or (stretching here) a colony?

frostedturkeypanini

When you say 'future application', I assume you mean the practical consequences of the science we are doing for future human activities on Mars. While MAVEN is mostly focused on the science of understanding what happened to Mars in the past, we do carry an energetic particle detector that measures particles of energies that will cause damage to human tissue. MAVEN is characterizing how the fluxes of these particles change with the occurrence of solar storms and changes in the direction of the interplanetary magnetic field. Any future human mission to Mars will no doubt involve plenty of time spent in Mars orbit, which is where MAVEN is making these measurements.

When people on the internet (and /r/space specifically) speculate about transforming Mars, an argument about the atmosphere commonly ensues. People's intuitions about how much atmosphere Mars can hold onto and for how long tend to be all over the place.

If you could magic a breathable atmosphere onto Mars right now, how long would the various mass loss mechanisms take to strip the atmosphere into something not breathable?

viliamklein

The rate of loss of atmosphere to space is low today, because the solar wind and solar extreme ultraviolet radiation are not able to drive large loss rates. So an atmosphere would last a long time before being lost to space. However, there may not be enough gas to put into the atmosphere to warm the planet, as so much was lost to space early in history.

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viliamklein

Great question. The important thing here, IMO, is the issue of timescales. When terraforming of Mars is discussed, it typically is a process that should take 100-1000 years. Atmospheric loss by the processes that MAVEN measures happens on much longer timescales of hundreds of millions of years or more. For example, at the present-day loss rates we estimate that today's atmosphere could be removed in billions of years. Early in solar system history, when loss rates were higher, that same amount of atmosphere would have been removed more quickly.

Loss to space was the most popular process for forming Mars' atmosphere before the MAVEN mission. Has there been any unexpected learning to come out of the MAVEN mission? Do you think a probe similar to MAVEN would be valuable on future missions to gaseous planets, Venus, Gas giants, Titan? Venus, in particular, probably having similar loss to space processes?

siliconlife

Excellent question. There have been plenty of surprises to come out of the MAVEN Mission so far, concerning Aurora, dust detection etc. But I don't think we've seen any huge surprises so far in terms of the rates of atmospheric escape that MAVEN is measured. There's plenty more to do in terms of measuring the escape rates under different solar conditions and different seasons, and we are placing much better constraints on those escape rates than has been done previously, but no, no huge surprises in terms of escape rates.

I'd like to hear about the what a typical "day at work" is like working on a mission like this. I imagine there are lots of slow days.

A_Suvorov

It's actually incredibly exciting and hectic! There is a lot that has to be done every day, even for an orbiter mission where one day looks much like another to the spacecraft. We have to decide what observations to do (and we do this separately for each week), whether we need to do a maneuver to keep the orbit "trimmed" properly, and work any anomalies that have come up. In addition, we're analyzing the data to get science results, and writing it up for publication in the scientific literature. And, now, we're working on writing a proposal to NASA to continue the observations during an "extended mission". There is way more work that needs to be done than we can easily do! At the same time, a "typical work day" actually involves email, phone calls, meetings, just like any professional work environment. It's exciting, however, because I just have to remember that we're operating a spacecraft that is orbiting Mars!!

Do your analyses help to explain what caused the loss of gases, or the root or the demagnetization? Along lines of the the terraforming theories, do you think it would be possible to one day re-form a habitable atmosphere?

gingertrees

Okay, three good questions! Yes, the data that MAVEN is gathering is helping us to understand the processes by which the gases are being lost from the atmosphere, and how those rates of loss change with external conditions such as solar flares and interplanetary coronal mass ejections (big belches of billions of tons of fast-moving hot gas from the sun).

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I know that dust accumulation on solar panels is an issue, but I have always wondered why they don't have something similar to a windshield wiper. Is it a design feasibility issue, or would wipers just not remove enough dust?

quietsamurai98

Moving parts on spacecraft always add risk. Windshield wipers would also add mass, which is expensive enough to make people think hard about whether they are necessary. Dust-resistant materials, or continued reliance on "cleaning events" (i.e. gusts of wind that clean the panels when the rover is in elevated regions) may be a better solution for now. (This answer is coming from a scientist working with an orbiter, and not an engineer working with rovers and landers, so please take the answer accordingly.)

If you could personally decide the specs on a new probe to arrive at Mars tomorrow - and you had unlimited funding - what instruments would it carry? Why? And how would they compare to those on MAVEN?

HyenaCheeseHeads

The most interesting scientific questions about Mars center on whether there is life there today or ever has been in the past. MAVEN does not address those questions directly, but is looking at the nature and history of the "habitability" of Mars by microbes -- what makes a planet habitable, and how does the habitability change due to basic physical processes?

Answering the question about life might be possible from the upcoming Trace Gas Orbiter to be launched next year. If certain gases are present, they might be indicators of life.

But, more likely, the question about life will be answered by collecting samples from the Martian surface from regions that had water and might have supported life, and then bringing them back to Earth for detailed study. That allows us to get the most information on the samples. And, if there are positive indications, it allows detailed follow-up in other laboratories. So my highest priority would be for a sample-return mission. NASA is moving in that direction, and plans to collect and cache samples with its 2020 rover. But it isn't clear when a separate spacecraft would go, retrieve those samples, and bring them back to Earth.

Thanks for what you're doing! I get excited whenever a new probe is gathering data and helping us understand other planetary systems better.

Many people don't realize the ramifications this has for understanding our own system. Can you explain it to them?

3literz3

It's always awesome to see the public getting excited about planetary exploration and the work we do! Well, to state the obvious, whenever we send well-instrumented probes to other planets and gather data we haven't gathered before, we always learn huge amounts about both the state of that system (whether it be the surface of a planet or its atmosphere) and how it either currently varies or has varied over time. Also, the sign of a successful planetary mission is one that not only answers the questions that we currently have about a given planet or planetary system, but that discovers new phenomenon that were not even expected and therefore generates new questions for future explorers to answer.

is this mission an info-gathering one...or are there images involved? :)

3rdCoastal

MAVEN is the first spacecraft ever sent to Mars that doesn't have a camera! We're producing images, but from ultraviolet light rather than from visible light. This tells us about the composition of the upper atmosphere. But, really, MAVEN is about determining properties and processes that come from approaches other than imaging. We measure the magnetic field, the ion properties, the atmospheric structure, the solar-wind properties, and so on. The questions we're trying to answer don't require use of images. On a cost- and resource-constrained mission, we can only fly the instruments that contribute significantly to our objectives. Remember, also, that there are many spacecraft currently at Mars, both in orbit and on the ground, that provide images!

How much more do you hope to get out of MAVEN? What will be the limiting factor?

HyenaCheeseHeads

Fuel will be the limiting factor. At some point in the next few years we will have to raise our "periapsis" (the lowest point in the orbit) to reduce the atmospheric drag that contributes to orbit decay. After that the orbiter is designed to survive into the mid-2020's.

We of course would be very happy if MAVEN could continue to make observations and do new and interesting science for many years. The exciting thing about spacecraft missions is that the new observations invariably lead to new science questions that we would like to solve.

I'm not sure if this still falls within your specific areas of expertise, but could there be any ground-based (on Mars, of course) indicators that could stretch back enough in time to tell something about the evolution of Mars atmosphere? I'm thinking of something like old rocks with characteristic mineral compositions, that could have been measurably affected by the very old Martian atmosphere.

Also, what kinds of things would you look for with a future, improved, MAVEN-like mission?

forthnighter

The history of the atmosphere is a very rich topic, and gets input from many areas. We're measuring the behavior at the top of the atmosphere to learn about escape to space. Curiosity is looking at the behavior at the bottom of the atmosphere, on the surface, to look for ways in which atmospheric gas may have been incorporated into rocks; by looking at rocks of different ages, we might get direct information on the history of the atmosphere. The Mars Reconnaissance Orbiter is looking at the ground from orbit; it takes high-resolution images that tell us about geological processes, and it makes remote-sensing compositional measurements that can map globally where atmospheric gases have been incorporated into the surface rocks. Even Earth-based telescopic measurements are playing a role, mapping out compositional information in the atmosphere that tells us about the history of the gas.

In terms of a MAVEN follow-on mission, we're still trying to get the first results out of MAVEN! However, an area that has not been examined in detail is coupling between the lower atmosphere and the upper atmosphere. That may turn out to be an important driver of the long-term behavior of the upper atmosphere.

Regarding loss of the atmosphere, you mention the primary reason being the loss of a magnetic field. Is there any reason to think this wouldn't also happen to any similar mass planet, and if so does this imply that any habitable planet must be closer to Earth's mass than that of Mars?

Cynthereon

First of all, it is not a settled scientific question that a global magnetic field forms an effective barrier to atmospheric loss. It certainly is possible, but as I said in the answer to one of the questions above: The possibility that a global magnetic field might actually allow more atmosphere to escape seems counterintuitive. On one hand, a global magnetic field does form a shield to the escape of charged particles over most of the planet (the North and South magnetic poles are the areas where the field lines are open and atmospheric ions can flow out. However, a global magnetic field forms a much larger barrier to the solar wind and therefore can absorb a lot more energy from it and hence may be up to drive more atmospheric escape out of the north and south poles that would otherwise happen without the global magnetic field. It's an open scientific question and the subject of much debate still. However, I think your question is also getting at whether any similar mass planet could lose its magnetic field. That's a difficult question because there are several planetary factors that can affect the ability of the interior to produce global magnetic field. A global magnetic field is caused by a combination of turbulent convection and rotation in the liquid conducting outer core of the planet. The way to maintain this turbulent convection is typically to keep sufficiently high flow of heat out of the core. So to zeroth order, yes a smaller planet will lose heat faster and so will have less heat to lose as time goes on and will therefore have more difficulty keeping this turbulent convection going. However, there are two additional considerations: the initial size of the core (which is conductive) compared to the rest of the body and the ease with which heat can escape out through the crust. Concerning the size of the core: Mercury is smaller than Mars but it has a much larger core and hence, even though it has been around for ~4.5 billion years, it still maintains enough liquid in its outer core to sustain a global magnetic field. Mars does not have plate tectonics, and therefore does not lose heat out of its crust as easily as the earth does, therefore the (probably) outer core cannot lose heat as easily, providing another possible reason why Mars' core cannot sustain a magnetic field.

What is the up/down-link speed like for MAVEN? How much data is stored, sent and received for a normal week of operations? Is it any different during deep dips? Is everything downlinked in order or do you have to fight your colleagues to get priority?

HyenaCheeseHeads

We have communications sessions with the Earth twice a week, and enough on-board storage that we can hold data for up to two weeks. That way, if the spacecraft or the deep-space net has a problem, we don't lose the data. During the deep dips, we have communications sessions daily, as we need to track the spacecraft more carefully; as a result, our data return can be much higher. We have a set of priorities on how data gets downlinked, so that we don't have much fighting within the team -- in the end, the amount of data that we take is tied to how much we can send down, so that avoids any arguments!

What are our chances of getting high resolution photos of phobo's monolith anytime soon? Or will they always be airbrushed

Piffdolla1337

Every spacecraft that is in orbit has been trying to make observations of Phobos, and MAVEN is no exception. We're interested in whether it could be the source of dust that is infalling into the planet, and whether we could measure gases coming out of the moon that might tell us about its history. We don't have results to report yet.

As for airbrushing of images, you'll have to talk with the teams working on those spacecraft that can take pictures!