Heliophysics Education Community-20250805_180155-Meeting Recording

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So thank you for joining us for the the August edition of the Heli Physics Education Community meeting. My name is Michael Kirk. I lead the heliophysics education activation team at Goddard, otherwise known as heat. Yeah, we come together every month to.talk about current happenings in heliophysics education and in science education more broadly. Our speaker today is Jared Espley.

Espley, Jared R. (GSFC-6950) 29:43

I will definitely talk about planchet manuscripts.
We're going to stretch the word planetary a little bit to include a lot of objects throughout the solar system.
I think that's that'll be great. And we'll also talk a little bit about what we mean by magnetospheres.
I've targeted the general kind of aim of level of my talk for our education colleagues here online. I see some of my colleagues here at Goddard who are specialists in magnusric physics, Helio physics as well.
So I'll try to have some, you know, technical tidbits as well.
But I really also hope that this will lead to an open discussion and we can just have a free form question and answer about all the cool things in the solar system and how they all basically all have magnetospheres in one type or another.
So OK.
So like I just said, we're we're talking about what is a magnetosphere. We'll talk about what the types of magnetospheres are throughout the solar system.
They will take a tour through the Solar system and then, because this is my specialty and because it's a good contrast to the lot of the magnetic physics here, physics that you hear about terrestrial stuff will delve a little bit into the details of the Martian magnetosphere to.
Kind of give you a little flavor of how things can get different.
For other objects in the solar system.
OK.
So what is a magnetosphere?
So everybody here probably already has an idea.
Again, I know many of you are educators and have explained this to your own audiences before, and some of you are literal experts in this. But I do think there is a little room for us to be a little careful when we talk about what is a magn.
I think the kind of one of the classical definitions of a magnetosphere is the object around an object where the magnetic field dominates.

And I think this is where where?
The word probably originally came from in the 50s and 60s as they were starting to explore space and they started to understand that they had something to go above the atmosphere and they started to realize that they can describe this as the place where the magnetic field Dom.
So that leads us to another common way of using the word magnetosphere, which is very similar to that first one, which is this. It's the space environment around the planet. Basically somebody says this and they mean it's not in the atmosphere. It's not the ground.
No, it's not the cross, not the plan itself.
Nor is it the thin layer veneer that is our atmosphere.
But it's also not deep space.
It's still associated with the object that that that you're talking about. And so that which of course means that it's not the solar wind.
So there's just like everything in life, you dove into the details and there'll be transition zones.
Where do you transition from, say, the atmosphere into the magnetosphere?
Where do you in fact transition from the magnetosphere into the solar wind into deep space?
Please.
Well, that leads us to the kind of third technical definition that I've heard use.
And this is where a lot of the experts in the field, especially terrestrial magnetospheric systems, will use the word heliophysicist.
They'll use the word magnetosphere to refer specifically to the plasma environment between the magnetopause, which is a boundary in the magnetosphere, or the OR the area in general and the ionosphere.
And so for the technical experts in the room, you'll notice that when we all use the word in this way, which many people do, this technically excludes, say, like the bow shock, many of the classic things that we think about as part of a magnetosphere, technically the bow.
Shock is above the magnetopause, so just point out that there's a lot of different ways to kind of broadly use the word magnetosphere, and I think that's helpful in the context specifically here for planetary maintenance here, because we're about to talk about how.
The wide variety of things.
Which is in contrast to how you normally would focus exclusively on the trust of managers fear.
OK.
So what are the broad types of magnetosphere that are out there on the solar system?
Well, the first one is the intrinsic magnetosphere.
This is the the one that you're most familiar with.
This is what the earth has. This originates from the combination of a Dynamo and A and

the solar wind a a flowing of fluid plasma in this case.
So Dynamo of course, originates in the core of an object.
It means that there is both electrically conducting material in the core.
And there is motion that takes magnetic field.
And feeds it forward in in a Dynamo effect and eventually produces a global object size, planet size, magnetic field, and you're so your Dynamo then creates the global planetary magnetic field which interacts with the solar wind to create an intrinsic magnetosphere.
It's locked into the object.
Second major category of magnetospheres are induced magnetospheres.
These are magnetospheres where you also have the flowing solar wind, the flowing plasma moving past, but it interacts.
With the atmosphere directly of a planet, and in this case that means that the magnetic fields from the solar wind pile up on top of the ionosphere of the of the object and are inducing magnetic fields in the ionosphere and those create a interaction that creates many of.
The same characteristic features that you would find in an intrinsic magnetosphere, but the source of the obstacle, the source of the magnetic field.
Is not deep interior to the object, but instead the ionosphere, the atmosphere itself.
Which is being having induced currents created as a solar wind flows past it, and then the third major category of magnetic is not not a magnetosphere.
So these are things in the solar system that do not have either an internal Dynamo or they do not have a substantive atmosphere.
They might have an exosphere where you have a tiny well. You have very diffused particles floating around non collisionally, basically vacuum.
And so that's an exosphere.
Just ignore that if you don't have a proper atmosphere with collisional interactions with with gas dynamics, then you end up with the solar wind directly interacting with the surface of the object and it just flows directly in.
There's no way for the solar wind to flow in plasma to know that there is an obstacle there.
There's no shockwave traveling back upstream or anything.
The solar wind just plows directly into the object and embeds itself.
In what and what is there?
So in fact, we see this on the moon and we'll talk about that.
So those are the three major categories intrinsic, which is what you mostly think of when people say magnetosphere induced magnetosphere and not a magnetosphere.
These are the broad categories that that we have in the solar system.
OK.
So let's talk a little bit about some examples of intrinsic magnetospheres on the left I'm showing a schematic of the Jovian magnetosphere.
At Jupiter, this is the largest magnetosphere in the planet.

This is A and again a trinit magnetosphere. That means that.
Jupiter itself.
The planet has an internal Dynamo that is creating the the obstacle to the solar wind flowing around. It creates many of the classic features that you see at like a terrestrial magnetar.
There are differences, especially related to how it seems like the Dynamo at Jupiter itself is is different than the Dynamo that's occurring, and deep in the core of of Earth, which makes sense because of course Earth is a terrestrial planet.
Obviously, canonically, and it means that it has the cross, it has the mantle.
Has the core and has iron in the interior, whereas a Jupiter it's a much different interior structure. It involves the upper atmosphere, the the lower atmosphere, and then it gradually transitions into helium metallic hydrogen layers where it gets extremely exotic types of matter and conditions in the inter.
Of Jupiter, but nonetheless, clearly there's conducting material. There's clearly.
Motion. There's clearly field because clearly we're creating a Dynamo just as we are at Earth.
But it's a different type of Dynamo, it seems like, but it results in basically the same kind of broad features that you have at Earth.
Interesting thing about the Jovian magnetosphere is it wobbles back and forth as it as it spins around, in part because of the iopasma Taurus, which is produced by the moon IO or volcanic material is literally blown out into space like the volcanoes on the surface pile literally blow.
Stuff into space.
And then that populates into a Magneto disk around Jupiter.
And as Jupiter's rotation axis, which is tilted, spins around and wobbles, it creates all sorts of interesting interactions.
I think I was now pivot to talking about the the other example of an interesting manuscript that I put on here, which is mercury, which is kind of the other extreme example of an intrinsic manuscript in the solar system.
It's basically as small as you can get and still be an intrinsic magnetosphere.
There is a a Dynamo it seems, and inside of Mercury.
It Mercury's a pretty small planet is smaller than some of the moons of the solar system. In fact, we'll talk about that. But but when the Messenger spacecraft flew by.
It was clear that there was a global planetary scale magnetic field, and so it's presumed that it's coming from a Dynamo.
Inside, it's presumed that that Dynamo is created by tidal interactions with mercury and the sun as mercury is so close, it kind of pushes a pole.
So it's not necessarily the same source of heat that that.
Our internal molten material at Earth is created by or the material in Jupiter.
It's more that it's just constantly being tidally flexed and therefore it has a material there that that's liquid.
And the magnetosphere there at Mercury is, like I said, extremely small, extremely

close to the planet.
But it's clearly intrinsic to the planet.
It's not something to do with any atmosphere.
There is no atmosphere or mercury of of any sort besides a very thin exosphere, so it makes for a very interesting second type of of intrinsic Manius your other objects in the solar system as I've listed them down below, that do have intrinsic magnetospheres include Saturn, Neptune, Earth.
I won't talk about any of those.
Saturn, Neptune are interested in that, right?
You get every every time.
You're here in, in this meeting.
You're probably mostly talking about trustworthyophysics.
Mostly I will mention that Uranus is a ridiculously complicated system.
It rotates on its side relative to to the ecliptic plane to how the planets orbit around the sun.
So it it is rotating completely sideways, relatively speaking, and then the magnetic field itself at Uranus is tilted again.
Pretty drastically away from that rotation axis.
So unlike earth where.
Magnetic north and.
Polar north.
The the physical spin N are more or less lined up.
It's not like that at all at your Ness, and it's sideways. And so it it makes for a ridiculously complicated magnetosphere.
And someday we hope to send a a flagship mission there to explore that that ridiculously interesting and complicated landscape.
I also point out that Ganymede is the largest moon in the solar system.
It's the moon of Jupiter.
It's so big that it's bigger than mercury and it seems to have its own intrinsic Dynamo, which?
Which makes it to have its own intrinsic magnetosphere inside the Jovian magnetosphere.
So you've got an intrinsic magnetosphere inside of a magnetosphere.
It's a fantastic place.
We've got a teeny tiny bit of a tad of information about this location. A colleague online. In fact, Jasmina Martos has looked at some of the data that we got from Jupiter.
And it's sorry from Juno at Gany mean.
And it's a really interesting.
Very unexplored environment.
So I look forward to having more information from future missions there because frankly, Juno is only has a few passes that get close to Canopy. The sun itself in the solar system creates a magnetosphere or a heliosphere.

That's the whole thing that goes out and the interaction there instead of the solar wind is the interplanetary medium which flows over the solar magnetosphere, which we usually call the heliosphere.
OK, better keep going.
It do spend you just spheres so 2 examples that I've listed here are Venus.
That's one of the canonical examples I'm induced manusphere where again the atmosphere is a primary obstacle here, where currents are being induced in the upper atmosphere of the object. You'll notice the diagram looks vaguely familiar to general magnetic diagram. The one on the left with with Venus.
We'll get into Mars in much more detail in a SEC.
Comments you might think to yourself, I don't really.
No, Jared, do they really have any newsfears? And and the answer is yes, they definitely do.
And you might think to yourself, Jared, are they in fact planets and you're technically correct.
But again, we're going to stretch the definition of planetary amino spheres, because comets are such an interesting thing. Basically, as you can see, there's the two canonical tails, something you might have had the occasion to see of your own eye.
You could see the dust tail.
You might also, if you have the right circumstances, be able to see the eye on Teles.
Ignore the dust tail and we're going to talk about the iron tail, which is basically.
In magniosphere of the comet.
So once you look at the physics that's involved in the in the in the in the ion tail, it's exactly the same as an induced magnetosphere like it Venus or at Mars you've got a bow shock, you've got the atmosphere of the comet which is the coma, the.
The neutral gas that flows out from the from the comet as it heats up and then gets ionized and all of a sudden you've got yourself a giant ionosphere, which then is able to act as an obstacle and have currents induced in it and create an induced magn.
And so comets are, in fact, a pretty canonical induced magnetospheric interaction.
Like I said, we'll talk about Mars in detail.
Titan, it's super interesting.
This is the largest moon of Saturn.
It has a an induced magnetosphere.
It doesn't seem to intrinsically have a Dynamo inside of it, but the extra interesting thing about the the Titan magnetosphere induced magnetosphere is its flow into a subsonic plasma. Normally the solar wind is supersonic, just means that the the types of interactions are are related to Super Son.
Plasma activity.
The Saturnian system means that Titan is plowing through a subsonic plasma.
And so it makes it for an extra complicated system as well to try and disentangle what's going on there.
So we won't talk about that in detail, but I could give a whole talk about each one of

these magnetospheres. As you can imagine.
OK, non a magnetosphere.
OK, not a magnetosphere. Includes the moon as we talked about. Solar wind plunged directly into it, and plants hydrogen, potentially.
There's some people have talked about potentially harvesting things from the moon that have been implanted.
There a lot of the major asteroids, including Ceres and Vista, probably do not have magnetospheres either.
There's no intrinsic Dynamo.
There's no intrinsic locked in magnetism in the crust. There's no atmosphere.
The solar wind just plows into these objects, so that's probably true even for some of the smaller moons in the solar system, including Europa and IO. I know I told you that bio flings volcanic material up into space, but it doesn't actually create an atmosphere.
That stuff just.
Flows out and enters the Jovian.
So most asteroids likewise probably do not have any sort of magnetosphere interactions.
The solar wind.
OK. Last category which is not a category exactly.
It's stuff that we just don't know.
We don't know where to put them yet, so asteroid psyche is gonna be visited by the spacecraft psyche sometime in the next few years.
I think they're supposed to arrive in 20-30 if I remember correctly, they had to take a very long looping route to get there.
Asteroid psyche is the largest metallic class asteroid.
We don't know for sure.
That's made out of metal, but all the surface, all indications when you look at it with telescopes.
Radar, etc. It suggests that it is probably made out of largely made out of metal, as large as such asteroid and solar system. If that is in fact true then it'll possibly would have an intrinsic magnetic field, something that probably not a Dynamo is not big enough to.
Have molten motion inside, but it might have a locked in magnetic field.
Might be a giant refrigerator magnet with a permanent magnetic field.
In the middle of it, which might make for a magnetospheric interaction.
I'm super excited about that mission to see where the results are there and I'll just note in my others of things that we don't know yet.
What about any other M class? Asteroids, metallic class? Asteroids?
I mean, Psyche is the biggest one, but are there other such metallic asteroids? And what would their interactions look like?
Pluto, we don't know if it has a magnetosphere or not.
Nobody really strongly suspected it would.
And so when New Horizons made its mission to Pluto, they had to cut the

magnetometer that was originally going to be included with.
With it.
So they couldn't actually measure whether or not it had a magnetosphere directly or not, but they did have some participant instruments on board Pluto, and it seems to suggest that it probably does have more of a interaction of some sort induced or intrinsic than you might have origin.
Expected it doesn't seem to be moon like where Pluto's just being hit directly by the solar wind and and there's no further interaction.
So it's real shame, because who knows when we're going to get a chance to send a magnetometer to Pluto again?
That new horizon?
I have one, but of course it's extremely challenging to get these messages together and get them out there.
So likewise Yeris, which is the one of the other largest icy.
Dwarf planets. We have no idea if it would have a menu just for not Callisto, the second largest moon of Jupiter, possibly as an intrinsic magnetosphere, where it's got a teeny tiny bit of a Dynamo going on, just like anime.
But it's it's very unclear and kleisto's probably the least visited of the Jovian.
Planets or the Jovian satellite moons and Triton, the major moon of Neptune, is possibly could have a an induced magnet. Certainly seems to have a substantive amount of atmosphere outgassing from it.
That's very unexplored.
We just have the one flyby a Voyager.
Lots of future work for people who could work on future missions. All right, so I promised that I would delve into the details here of the Martian magnetosphere.
Again, that's actually in part because that's part of my background. But I also thought it'd be a nice contrast to get into a little bit of the nitty gritty compared to some of the heliophysics work that you guys typically would hear about with the sun or the earth.
So the Martian manusphere is an induced manusher's. I've already been talking about, but that means that it still has many of the same features that you would recognize from intrinsic manuscripts.
We have a shockwave, a bow shock where the solar wind first flows in.
So the schematic diagram with the blue speckles is showing you where solar wind particles would be, and then all the little.
Lines that we've drawn in our different boundaries and different areas and the orange is where the neutral atmosphere of Mars kind of extends to approximately.
To the densities that is there. So this is a schematic diagram. So obviously you know just kind of cartoon like but it also is meant to be representative in terms of the the density of the colors.
So you can see.
Then again, we've got a bow shock that's actually has a neutral atmosphere extending beyond it a little bit.

That creates for some interesting interactions in terms of things that you're able to image. We have colleagues who have imaging spectrometers that are able to see the neutral atmosphere of Mars.
Extending beyond the bow shock, you have a man utter sheath where you have really energetic, shocked soul wind that's been energized and basically piling up against the obstacle of the idesier of the planet.
We have what we call the Indus. When you destroy boundary, which would be the magnetopause or intrinsic magnetosphere.
Sometimes we call it magnetic pilot boundary because it magnetic field of the solar wind literally piles up there and it increases and then you move into the ionosphere.
And and and beyond and into the magnetosphere.
Plasma dynamics occur.
Lots and lots of reconnection and plasma waves throughout all this system, and you'll see in green the little crystal fields there. We'll talk about that. Why that's important at Mars. Many of the planets solar system have crustal magnetic fields.
Mars is crystal magnetic fields are particularly important.
I just embedded the diagram to scale that I was just showing you in using the red dashed lines.
That's the Martian magnetosphere. Inside a schematic, a scale schematic of the terrestrial magnetosphere.
And obviously the planets are slightly different size, but it doesn't really matter at this scale.
So the both planets there are approximately in the center. The Martian magnetosphere is the red lines with the bow shock as the outer boundary and the inner boundary of the induced magnusuric boundary as a second. And then you can see all the terrestrial features.
OK, you already figured out what my main point was.
Did Marshall Manusher is way smaller and this makes for some interesting contrast to the terrestrial Manius sphere.
And that's because, of course, the terrestrial Dynamo is created a very strong planetary magnetic field that holds the stand off the solar wind at much farther distances than the Martian magnetosphere does.
Trying to keep an eye on my time. OK, so I told you the crustal fields at Mars are particularly important.
This is a map of the crystal magnetic fields.
I won't go into the nitty gritty of all. What, what? Everything means, but basically any place you see colors, the more intense the colors are, the stronger the crystal fields are on the surface and anywhere you don't see any colors at all.
We flew a spacecraft over the entire region with a magnetometer over the whole planet over and over and over, and that means there just aren't crustal magnetic fields in those regions where it's Gray those Gray regions.
It was immediately obvious once this map started to come together.

And the mapping was being done, or almost all in areas where there's been extensive resurfacing of the Martian surface over time.
So there are areas where there's a lot of strong volcanic activity. You can see many of those volcanoes labeled their Valles Marineris breaking apart under the strain of the volcanic.
Mass of volcanic material that's that's uplifted. And the Tharsis to the to the left of Pharaohs, Marineris and then some of the giant craters as well.
Hellas on the left there and argyer on the right.
Utopia planesha in the upper left is thought to be a possibly a crater.
So basically anywhere that there was been resurfacing, the magnetic field has been wiped out and what So what?
We think that means is that Mars used to have an intrinsic magnetic field like earth and then at some point it ceased, presumably because the core froze out because Mars is smaller and you no longer have the liquid material to be flowing around to create an intrinsic D.
Once it froze out, then whatever.
The crystal might fields.
Whatever magnetic field they were experiencing at that point was locked in, and if nothing happened to those rocks for billions of years, we saw today. Whereas if something did happen like volcanism and wiped those rocks out, it lost that locked in magnetic field.
So it's a remnant magnetization that is basically tracing the history of that billions of years backwards.
And creates this really interesting opportunity for geology and geophysics for us and for a magnetospheric physics.
I'll just go back a couple slides and say.
It creates these little crystal bag fields create a substantial obstacle to the solar wind in their own right and local regions. And in fact, that's what this little animation shows schematically.
Basically, I'm going to hit play in a moment and it's going to show you this is what the solar wind sees when it encounters Mars.
It's the obstacle of the plasma and magnetic pressure, and so let me play this and you can see that it's mostly kind of spherical. And that's the induced Magnus here from the from the asteroid. But it's got these.
Gigantic bulges, which are the strength of the crystal magnetic field standing off the solar wind and the Martian day is approximately 24 hours, just like the Earth's, and so you can imagine over the course of the day as the solar wind travels interact with it there.
All sorts of plasma physics occurring reconnection events.
Wave particle interaction instabilities that are occurring throughout the Martian manuscript makes it a fantastic plasma laboratory.
OK, I'm gonna quickly hit a few science highlights from the Martian magnetosphere,

and then we'll transition to. I'll wrap up and hopefully we'll have some time for for discussion.
So one highlight I wanted to make sure you knew from the Martian magnetosphere is that we know from geological studies looking at dry riverbeds, mineralogical evidence, etcetera, the ancient Mars was wet. It's unambiguous.
We also know very unambiguously with her own eyes and her own instruments that modern Mars is dry.
So something drastic happened to cars, climate change and Mars. Not same type of climate change, of course happening here on Earth, which is caused by human activity.
This is catastrophic climate change over slow motion over billions of years.
But we went from an ancient wet Mars.
Warm, wet environment. Potentially habitable environment, warm and wet to a modern cold and dry environment over billions of years.
The MAIMEN spacecraft, which is at Mars, has been studying this and has confirmed the primary hypothesis.
Here that the solar wind interaction, this martial magnetosphere in large part because it is relatively small, has been able to be stripped away.
The atmosphere has been able to be stripped away by the solar wind, so over billions of years, bit by bit, molecule by molecule, the Martian atmosphere is blown away by the wind by the solar wind and literally lost at an implantary space forever.
And that's what caused climate change at Mars over billions of years.
Another highlight that I wanted to hit is there's a lot of interest in space weather.
At Mars, we did a study showing on the left where we use the radar marshes, radar to try and observe the ground.
So these little white traces that you can see in the left most diagram is the ground that's being hit by the radar, and then you can see the subsurface in some parts.
That's not actually what I was interested in because again, I'm I'm a plasma physicist.
I was using this as kind of the the noise version of it because occasionally you get a radar return like the one here on sea where you couldn't see the ground at all.
It's completely wiped out.
And that's because the March and ions tier is very dynamic and you would have communication blackouts using radar.
This is relevant here on Earth when people are trying to communicate across the planet using radio frequencies, they worry about radio blackouts on Earth.
At Mars, it meant that our radar could not hit the ground and do studies there.
So there's a space weather.
Dynamic space weather that occurs at Mars.
It's really interesting.
This is a artist rendition of what Aurora at Mars would look like.
Aurora at Mars would not be confined to the Poles.
The Aurora and Mars we found are distributed throughout the planet, and there's a variety of different types of Aurora. We probably give you many multiple talks on the

Aurora of Mars.
Last thing I wanted to say was comment Siding Spring, which was a comment that entered the Solar system back or not in the Solar system, but was discovered back in 2013, just in time for us as the MAVEN spacecraft was about to arrive at Mars just.
A year after the discovery of the comet.
It was originally thought it might literally hit the planet, but instead just barely skim the planet.
And we were there literally in the nick of time, literally just a few days after Maven arrived, just like we had a brand new spacecraft, a brand new car, and we had like, you know, like a we were going to drive a new car through a hail storm.
Like literally, the day we drove it off the lot, it was it was something like that.
And so people were really stressed out because they didn't want to lose their spacecraft.
Due to a comet scientist like myself were super excited.
Basically this is a schematic showing you what what, what the encounter looked like.
Basically, the Gray is the entire coma of the comet.
And then, like I said, the inner coma where the really strong atmosphere of the comet is kind of schematically here on blue. And then this commentary magnetosphere is approximately like like this purple diagram. And then Mars's motion relative to the comet look like this. Anyway, the Mart.
Magnetosphere is inside the dot. That's how small the Martian magnetosphere was.
So for a few hours.
Right after our spacecraft got there.
We had two magnetospheres interacting together and it made for a really interesting set of observations.
It basically looked like a solar storm, but instead of solar wind activity, it was commentary activity.
OK.
I think that's it.
So I'm going to bring us back to saying we talked a little bit about what is a magnetosphere. And I particularly wanted you to go home with the idea that there are different types of magnets here, intrinsically induced and the not a magnetosphere.
And then the the 4th.
Non category of stuff we don't know yet.
And there's lots of things in the solar system that are super interesting.
I'm very excited about the possibilities of being able to explore other magnetospheres as well, and that the Martian Magnus here is a particularly dynamic, interesting place for many reasons, including a beautiful natural plasma laboratory.
So I think I'll stop there and we'll open it up for discussions and I'm sure colleagues will help guide the discussion.

Kirk, Michael S. (GSFC-6700) 58:37

Great. Thank you so much.
This is this is amazing.
I I love the tour of the Solar System in magnetospheres because that that's something that, you know, I I have AI have a three-year old and he likes planetary science because, well, he's he's my son.
So magnetospheres are not covered in his books, so it's it's good to good to hear that.

Espley, Jared R. (GSFC-6950) 58:55
Yep, Yep.

Kirk, Michael S. (GSFC-6700) 58:57
Anyway, I'll just kick off a a question really quickly in terms of magnetospheres. I imagine when human spaceflight last.
Visited the visited the moon. Magniospheres were not, you know, part of the mission planning.
Exactly, maybe slightly.
But not not significantly.
How's that changing?
Thinking about a return to Moon or Mars in terms of human Space Flight interactions are is a possible Mars landing site going to correspond with the stronger magnetic fields? The intrinsic magnetic fields or I should say the baked in ones, yeah.
Yes.

Espley, Jared R. (GSFC-6950) 59:33
Yeah, the crustal ones. Yeah, absolutely.

Kirk, Michael S. (GSFC-6700) 59:34
Yep.

Espley, Jared R. (GSFC-6950) 59:35
Yeah. So yeah, you.
I'll answer the March part of it first, because that is easier because there is lots of things that we could say about what we would eventually want to do with humans at Mars.
I mean, first and foremost, I think it's really important that we, we continue to explore space weather at Mars for exactly the many of the same reasons that we're interested in space weather at Earth. It has impacts on.
Technology, infrastructure and also potentially as impacts.
On.
Humans, they explores in fact.
This here is a schematic diagram of a of a project that we've been working on with a colleague of mine. She's been doing the modeling of the high energy radiation Seb solar energetic particles, and even galactic cosmic rays, and how they would interact with a

strong crystal magn.
Field here at Earth there's crystal.
Magnetic fields are not strong enough to appreciably change the trajectories of those particles at Mars. Those crystal Manning fields are so strong, probably because of the meteorology of the of the Martian.
Rocks is different than the detailed mineralogy of the Earth. Rocks that there is an appreciable deflection of the energetic particles, and so in fact I don't know that it would be the determining factor, but I think it's absolutely worth important consideration for mission planners. Future mission planners about.
The idea of that there could be places on Mars that are more susceptible to radiation at the surface and there are places at Mars that are less susceptible to radiation, so that would be important for humans. We of course would love to do exploration of the crystal magn.
Fields of Mars on the surface from a science point of view, and whether it's the astronauts would be involved or we would just use Rover's or drones flying aerial vehicles. That's something I would love to think about more.
So definitely want to think about magnetospheres in human exploration for sure. To answer your question, sure.

Kirk, Michael S. (GSFC-6700) 1:01:28
OK.
Thanks other questions.
Yeah, Rebecca.

RR **Rebecca Robinson** 1:01:41
Hey, Jared, this was so good.
Thank you so much for this presentation.
This is Becca from Muse outreach.
Could you update me on is there any consensus on why the Martian core froze out?
Was it the collision theory or what's the updated consensus?

Espley, Jared R. (GSFC-6950) 1:01:57
I don't think there's been really substantial changes over, you know, the past many years, but but I'll just, so I won't say that there's necessarily updated consensus.
I'll just tell you what I think the consensus is, which is that it just basically comes out to the, to the physics, the thermodynamics of it.
It's just that there just wasn't enough heat in the Martian core to keep it molten over billions of years, unlike Earth.
So I think it's literally just society.

RR **Rebecca Robinson** 1:02:28

That's great.
Thank you.

Espley, Jared R. (GSFC-6950) 1:02:30
Hmm.

Kirk, Michael S. (GSFC-6700) 1:02:35
Arrest.

Reale, Oreste (GSFC-610.1)[SCIENCE SYSTEMS AND APPLICATIONS INC] 1:02:40
Thank you for this great talk. I have a question concerning the dust on Mars.
So what is the impact of the role of the having higher or lower global dust concentrations in the Martian atmosphere during a major solar event?
How the dust work and how it interact with this within this concert of the induced?
Magnetosphere.

Espley, Jared R. (GSFC-6950) 1:03:06
Yeah. Great question that that actually is a topic of very active interest in, in the Community right now.
The short version is that it has a very to several unexpected effects.
One is that as the dust activity seems at least as unexpected to me, it has several effects. Let me say that.
The as it does activity increases as as many of you will know there are. You know there are small dust storms at Mars.
They're occasionally regional dust storms.
Kind of like corroange.
And occasionally they're global. Planetary Sky sized dust storms that develop the literal planet as you go up and down this food chain of of sizes of dust storms and more and more dust gets elevated into the atmosphere.
And more and more then what happens is that it then facilitates even more atmospheric escape as the solar wind gets more and more access to the water that is being lofted by the dust along with the dust.
Then even more atmospheric escape.
Seems to be occurring.
As as a dust is elevating and there's all sorts of interest in trying to understand how does that.
Under what circumstances?
At play in the exact pathways that that occurs, and how does that you know when this?
Orange exosphere at the very edge and the primary atmosphere is lofted up.
What happens to the plasma interaction?
Does the bow shock itself care about the fact that there's a little more neutral?
Material. I think that's very openly.

Being investigated.
There's also really interesting.
Evidence that's pointing towards the idea that there's dust that's escaping from dust from Mars all together and getting into near Mars orbit in orbit around the sun.
And there's there's evidence from the Juno spacecraft, which you might be thinking, well, how would Juno, since that's a Junoon.
It's way too Jupiter encountered what seems to be a.
Dusty environment and it was able to see that because there's these huge solar rays.
So basically it was an accidental dust detector with these gigantic solar rays as Juno flew out to the outer solar system.
And it happens to be that Ware that found the most dust was a band.
That is where the Martian orbit is.
So it's not dust that's any longer connected directly with Mars, but presumably originated from.
From Mars, this is all super brand new cutting.
There's, you know.
I would not say this is a settled topic at all, but there is pretty strong evidence in favor of this at the moment in in, in the in the literature.
So there's the aspect of the dust environment, and there's also this idea of the dust wafting the atmosphere itself. To answer your question.

Reale, Oreste (GSFC-610.1)[SCIENCE SYSTEMS AND APPLICATIONS INC] 1:05:50
Thank you.

Kirk, Michael S. (GSFC-6700) 1:05:53
Alright, one last short question before we we turn it on to over to Hillary.

TP **Timmins, Sidey P. (GSFC-695.0)[ADNET SYSTEMS INC]** 1:06:00
Say Jared, thanks for the talk.
What's the effect of the, you know, on the moon when an astronaut is standing there and the solar wind hits him?
Or her.

Espley, Jared R. (GSFC-6950) 1:06:13
So on the on the moon, under the direct solar wind, it's not tremendously like the the typically you talk about radiation dose and the solar wind itself is not a tremendous radiation hazard intrinsically. However, whenever there's a solar event where there's a large amount of energized solar en.
Particles and that is absolutely detrimental to an astronaut if they're standing on the moon.
This is something that's very key.
For lunar exploration, but we'd be even more challenging for Martian exploration,

cause in the lunar case, if you knew that there was a large solar event coming.
And we typically would have a few days notice, one to several days notice. Then you would take measures to protect yourself. As an astronaut. You know, go inside a habitat.
We, you know, try to leave the moon, et cetera.
On the way to Mars, you're committed, so you have to have a plan.
For what you're going to do there.
The typical plan is that you would hide inside your water canisters here spacecraft on your way to moon. You put your human astronauts inside inside the water and hide while the storm passes over you on the Martian surface.
I think this is super interesting.
Open question.
Like I mentioned, Crystal Mountain feels might actually be your solution.
Of course, if you're on a different part of the planet, then that doesn't help.
You might be able to also hide in a in a cave in a lava tube if you could find one at Mars.
So that's a great interest.

Kirk, Michael S. (GSFC-6700) 1:07:42
All right.
Thanks Jared.
I think we could probably, you know, pick your brain all day long because there's a lot of fun, interesting follow up questions. I I wanted to ask about Venus Nightglo. But you know, we're not going to even get to that one. So thanks again.

Espley, Jared R. (GSFC-6950) 1:07:52
Yeah.
Yep.

Kirk, Michael S. (GSFC-6700) 1:07:54
We'll have you back another time to talk about all things magnetospheres, but Hillary, I'm going to turn it over to you to talk a little bit about planet, about the curriculum, alignments to Magniospheres and planetary science.
It's.

Hilarie Davis 1:08:09
OK, great. Can you hear me and see me?

Kirk, Michael S. (GSFC-6700) 1:08:11
I can thank you.

Hilarie Davis 1:08:12
OK.

Great. Thanks so much for that great talk. I was of course doing some background research on your work and the topic itself, because what we do is we create these slide decks which have investigations and connect to our framework for heliophysics education, which is something that the team.
Created because it was incredibly important to have a definition and an overview that connected to the science standards. If we're going to get it into.
Education and outreach. So.
These slide decks have summaries of the key ideas which I took from your announcement. So you've covered all of these things, but this is meant to complement your talk. When we save it in our resource database.
And this framework for heliophysics education. Many of you are familiar with it.
By now it's structured around Nessa's big heliophysics questions. The impacts of the Sun on humanity.
How the earth, solar system and heliosphere respond to changes in the?
Son, which you've talked about and what causes the sun to vary.
So this framework for Helio physics education took these big ideas and then made sub ideas and what you see in parentheses are the the national standards in science, the next generation science standards in P for physics, ES for Earth science, and L for LS, for life science. So.
There's lots of great connections here that we think can be parlayed into educational and outreach.
Environments, so the ones that apply to your work and in my estimation, and please feel free to to e-mail me later and say not really.
Are the impacts of the sun that it's active and can impact technology and other things that the Earth, solar system and heliosphere respond to changes in the sun and what causes the sun to vary now, as you said earlier, this is very terrestrially oriented, but I think your.
Your work would be complementary.
We've heard these areas.
So the inter we have 3 levels of investigations that we have collected and tagged resources for.
There's introductory, intermediate and advanced, and these are just quick investigations, a question and a couple of resources.
So if we just want to draw people into this, they might want to do this.
An introductory could be a naive adult audience, or it could be an elementary audience.
So it's just people who don't really have any background.
So does Mars have a magnetic field like Earth?
And how did the differences affect if and how we could live there? And here are some resources that they can just click on or use with themselves for their backgrounds that if they're that is, if they're an adult facilitator or give them to the students.
Intermediate level investigation might be when was Mars habitable and how did it lose

its water.
And could we lose ours?
Which you went into nicely today.
What is the role of the magnetosphere and a planet being habitable?
And again, we try to mix in.
Both interactives and background and activities.
An advanced level investigation might be how do the magnetospheres of Mars and Jupiter compare?
Is one more habitable than the other due to its magnetosphere and that was getting more into?
Comparison which I had read that you all do so For more information.
Obviously you're a great resource as well as our framework for heliophysics education.
And that's it, Michael. Thank you.

Kirk, Michael S. (GSFC-6700) 1:11:39
All right.
Thanks, Hilary. I appreciate that.
We'll have resources posted online and out to everybody who needs them.
Otherwise, TuneIn again next month, our first Tuesday of every month, this time slot we meet here and discuss everything.
Healy physics education. Thanks again.
We'll see you next month.

Kirk, Michael S. (GSFC-6700) stopped transcription