Transcript

October 15, 2024, 5:08PM

KS **Kirk, Michael S. (GSFC-6700)** 0:19

I met Kevin up at the National Observatory when it was up at Sunspot, New Mexico.
So this is an observatory perched on the top of a hill. And I, I I don't know if I met him before a volleyball game, but I certainly met him during the volleyball game because Kevin came off with skills that I wasn't prepared for, and certainly it showed.
Us all up in terms of his his prowess on the volleyball court and then was humble about it the same time.
So that's that was my introduction.

KR **Kevin Reardon (he/him)** 0:48

I think you're overselling a little bit, but.
But yeah.
But yes, volleyball was a yeah, that was the the Gathering.
Motive out there at at Sunspot?

KS

So yeah, as I said, I'm at the National Solar Observatory.
It's my e-mail address.
Feel free to get in touch with me with any questions.
And as I said, NSL.
We have these two sites, you know, our two staff are split between Boulder and Maui.
We also are sort of split or have two prime components in our in our sort of scope and and mission one. And I'll be talking about these later. But one is is deekist where we're sort of studying the the sun at very high resolution.
And you know, trying to understand this, this star that we have in our backyard and the other component is NIST, which is the synoptic program where we're trying to obtain continuous global solar observations that help us learn about the interior of the sun through Helio seismology and also.
You know, space weather, how the sun is affecting earth and all our technology.
So first I'm going to, yeah, talk a little bit about about NIST, about our synoptic program.
The way we do that, we actually have in order to get continuous coverage from the ground, you know, we don't have the.

Instruments in space, but we have a series of six sites around the earth where we observe.
With all these sites simultaneously, each one has its own day night cycle.
But if we sort of piece them all together, how they're spread out, we can get nearly, you know, continuous observations of the sun from the ground.
And we can.
You know, nice thing is we can keep these sites running, you know through maintenance and so on.
Almost indefinitely.
You know there it gets challenging with, you know, keeping old technology running sometimes.
But we're able to use, as I said, Helio Seismology lets us probe the interior of the sun.
We can actually use that Helio seismology to determine to, to measure what's going on in the backside of the sun.
And so, by the way, these waves travel through the sun.
We can detect whether there are active regions on the opposite side of the sun that we can't see.
We still see their signature in some of the the waves that are propagating and so we can actually see if a new active region is going to be coming around on the sun if it's growing and so on.
And so that's really a neat trick that allows us to, you know, get more information on on the sun sort of global.
Activity level at any given time.
This data that we take with these the gong sites, the gong is the global oscillations network.
It's sort of some of.
It's sort of like HMI where we get continual images and magnetic field maps of the whole disk of the sun. With gone. We get those with about a a one minute cadence.
The other neat thing that GOG has that isn't replicated on on SDO or anything.
Is the H alpha images like that one you see there in the in the center showing the sun?
You know the very chromos, the chromosphere, nature of the sun, where you can see sunspots and filaments, and active regions, and the prominences at the limb. And so those are also obtained with A1 minute cadence.
And you can see movies of this and evolution and it's great when there are those players like Michael was saying last week.

You can see you know H alpha is a great way to to see those flares and their.
Effect on the chromosphere.
And there's a couple links there to the the sites where you can access this this data and it comes down in nearly real time and is available.
You know, freely available.
For to be accessed there.
And so as I said, we can operate these these sites and take data you know continuously over over many solar cycles. And so this goes back.
All the way to the.
When they had the first vector magnetograph.
First magnetograph on on Kit Peak back in the 70s.
And they were able to measure this global magnetic field and this is now continued on through through four solar cycles. And so we can now make these these maps where we sort of unwrap the sun and we see from the North Pole down to the South Pole.
And we measure the magnetic field and we encode the magnetic field as blue as the negative field.
So it's sort of going into the sun.
And red is of the positive field and coming out and you can see all these interesting things that go on during the solar cycle.
You see the the trend, the butterfly diagram as active regions at the beginning of the cycle started high latitudes and move down.
And you also see that while those sunspots are in active regions are forming at lower latitudes, there's also these.
Flux that's being spread up to the poles at the same time.
There's other flows on the sun that are that push, some of that flux up to the, you know, the poles, opposite polarities in each direction.
And then you see the next cycle comes and you see very clearly what we call the the hail cycle, where you see the solar cycle again, the sun spots look similar, but if you look at the polarity now, you see the signs have changed.
So now what was red is blue and blue is red.
And then the next cycle that swaps back again.
So we have this.
You know magnetic cycle that that has a sort of a 22 year period instead of just the 11 year period of the sunspot and active region appearance. And so this is the kind of thing with, you know, a long term synoptic program getting sort of very Ste.
Continuous observations of the same type. We're able to really start to see this.

You know, the solar cycle in in all its glory, you know.
The magnetic fields flowing towards the poles and towards the equator, and this is all.
What learning what drives the Dynamo and what creates the solar cycle in?
You know, in the end, you know why.
How does the sun keep turning over this magnetic field and regenerating it, pushing it to the pole? And then you know, recreating that that field and that cycle on this regular pattern?
So you know, that's something that I think we're proud of it.
We we do with NIST and this, you know, synoptic network and we hope to you know continue that in the future for.
Another four solar cycles at least.
But the other you know, new thing that we like now that we are are are very much enjoying is the the dekus, the NS FS, Daniel K in a way solar telescope.
And here's a picture of it.
It's actually out on Maui, which is why we have a lot of staff out there.
It's located on the summit of Haleakala up at above 10,000 feet 3000 meters.
Where the skies are very clear, it's away from the the jet stream and a lot of dust.
So it's very good skies for for solar observing.
And you see a little cutaway there on the left.
Now sort of trying to peer inside what's inside the Dome, and it's a four meter telescope, so it's the largest solar telescope by far, pointing this, you know, giant mirror at the sun.
It.
You know, with that 4M aperture the you know one goal is to be able to resolve the very fine structures which we'll see down to about 2025 kilometers on the solar surface.
And the other is to get a lot of flux.
Strangely enough, in the ways we observe the sun, sometimes it's just too dim.
We need to do some of the measurements.
We'll see of of the magnetic field. We just need as much light as possible, and even you know.
The sun as bright as it is, you know we we need to get that big aperture as a sort of a light bucket sometimes and just try to get the highest signal.
They're always possible.
And so, you know, those are the two reasons we needed that that big aperture.
And So what does this, you know, actually look like in inside, in, in, in real life?

Here this is the the appearance of the telescope and its structure.
You see that the mirror is down here on the on the lower left you see just sort of part of the mirror exposed and you see all that Truss work that supports the mirror and also supports the secondary up here at the top end.
And that's where the light is then focused and that lower image shows what it looks like when you take a four metre mirror.
And gather all that sunlight and focus it up in in one image, and that's about 12 kilowatts of energy focused up there in that bright spot in the middle.
And so one thing at NSO, you know, try to explain this to people.
We we we've, you know, made infographics.
You know, try to, you know, help the public understand what 12 kilowatts means.
So things like, you know, you could, you know, pop a bag of popcorn in three seconds, right?
You know, compared to your one kilowatt microwave microwave.
Kilowatts is a lot faster.
Or you can boil that water in about a liter of water in about 27 seconds.
So you know, just a ways we try to, you know, convert these numbers into things that you know the public can understand in a, you know, easy, easy way.
But the other thing here is so you see the the sun is focused here on what we call the heat.
Stop that shiny spot.
And that actually reflects some of the light off most of the light gets reflected off and forms this big image on the Dome where it's, you know, not nearly as concentrated.
Doesn't heat anything up.
But early on in operations, there was a a strange configuration and and one time.
The tracking stopped inadvertently for the telescope, and that focused beam moved off of the heat stop where the light was, you know, safely managed and moved off onto the telescope structure.
And now you can see what 12 kilowatts starts to do as it starts some smoking there and the paint.
Started.
Being bladed away by the heat.
Turns out nothing you know wasn't too bad.
You know, it hardly affected anything. There was one pipe there. But anyway, that's a much very visual demonstration of what, you know, 12 kilowatts will do.

So it's very, you know, it's one of the big challenges with decisive managing all that heat because what you see here is it's that little black spot right in the middle.
We only admit a tiny amount of the full disk of the sun down to the instrument.
And so we don't need the entire light of the sun on the instruments.
We just take a small amount, just a few 100 watts goes through that that hole and so it becomes much more manageable once we've selected out the portion of the sun we actually want to to observe.
And so as you saw in that that cutaway before the light actually goes down to what we call the the coudet laboratory, sort of the instrument platform where we have all the instruments arrayed out here.
And so.
You know, this is all, you know, a lot of acronyms to different instruments you know, here's another infographic, you know, showing how the light comes down and there's mirrors that split the light off to different instruments.
So we can observe.
At different times, these instruments are quite large.
This whole platform is about 54 feet in diameter and it all rotates with the telescope.
So it's a another engineering challenge there.
And so with these instruments, we measure the light in different ways, some with Spectra, some with imaging.
And now I'm just going to, you know, wanted to run through and look at some of the different.
Types of data.
We get the images and you know show you some some.
Of the early results we've been getting now with with Dekist. And so we're going to step through the the solar atmosphere and look at how dehisto observes these different parts of the sun starting down here in the in the photosphere where we, you know, classically see sunspots and.
The granulation, the convective patterns.
Away from active regions, and then we'll move up into the the chromosphere.
Here and see some of the the structures from the chromosphere.
It's just sort of the the set the scene of of how we'll be looking at some, some different layers of the atmosphere and what decis can reveal.
So you know, as we said, one key part of you know, the DKA science is to resolve some structures at their very fundamental sizes, trying to get down to these, you know 1020 kilometers sort of scales because we believe there's

some interesting physics that goes on in.
How magnetic fields and the you know the the motions of the plasma and the sun.
Interact and maybe the source of you know.
Energy transport. How that you know, coronal heating and so on.
And so here's, you know, one example of an image from decisive at very high resolution.
So you see, we we take this small part.
You know, we just look at a small part at the, you know, at anywhere on the sun, but it's just a small cut out that we're able to observe at any given time.
Fact some people call dekista a microscope rather than a telescope because, you know, we're zooming in so much.
And here we see.
Yeah, these sort of convective patterns.
These, you know, large sort of white blobs indicating they're hotter rising up and some of these are, you know, typically on the size of of Texas. And then we look at some of these smaller bright features that are interspersed in between.
And those are, you know, more on the scale of of Manhattan, you know just.
You know 20 kilometers across or so.
You know, so we, you know, are able to really probe that.
And try to measure these and we're seeing, you know, fine structure and details at this resolution that you know that are are very exciting and trying to interpret those.
But as you know, you know a static image of the sun is nice.
But the best thing that about you know about being able to observe the sun and you know the star right here is that we see it evolve. You know, these type scales just as we're sort of very easily, you know, can get a time sequence and see how.
These structures evolve and so now we, you know, take that step.
The image and now you can see the the evolution of these convective cells that move is playing right, able to see that.
People able to see the the movie, make sure it's.
And do you see all these? You know, how they push these bright features?
These bright features are indications of the the presence of concentrated magnetic field. And so yeah.
This is, you know, really exciting to be able to see how these magnetic fields and the plasma interact, how that changes with the, you know, different locations on the sun, different conditions.

But you know, now we are getting, you know this is the the quiet sun that's always there. Right now we are near the the peak of the the solar cycle.
And so we get to observe a lot of sunspots, and this is sort of what, you know, we start to see at the very high, this very high resolution. When we look at these active regions and we start to see the details of the sunspot.
We see the bright points features and you know.
Sunspot is not a uniform, you know dark structure.
We can actually, you know, pick out bright dynamic features in the in the umbra of the sunspot, and we can see the the details in the penumbra, how they're very finely structured.
And, you know, indicate this sort of twisting magnetic field emanating out of the sunspot.
And of course, you know, like that quiet sun it. It gets neat when you know we can actually start to then make a movie of a sunspot and see how the penumbra, there's both outflowing material and inflowing material in the penumbra.
And you see the, you know, the evolution of this, of the spot. And you know, just over the space of half an hour, you see the over here on the right.
You see some flows.
And so yeah, we can, you know, with this highest resolution imaging we're able to obtain, we're able to really start to look at the details of these sunspots.
You know, sunspots are of course, also where we see flares sometimes.
And you know, though, it's complicated when you have these sort of targeted instruments like dekast or like iris or or hinoda or these other, they'd only observe a small part of the sun at a time.
You have to pick the location to observe and hope the flare you know occurs while you're while you're observing.
But we have been lucky a few times, and so here's an example of this active region. You see some context.
Over here on the right.
Sort of.
These two spots in in between the two larger spots of the active region.
There, the HMI magnetogram shows the sort of complicated magnetic field there.
But.
You should see here.
Around that sunspot.
Right about now, you see that sort of brightening and the and the

chromosphere.
And so you know, we're able to catch this flare again, very high resolution.
And you know very high sensitivity measurements of the of the magnetic field.
If we go up to the chromosphere, we can also do this.
Look at some of the the details that we start to see.
This was an observation that was done. Actually coordination with Parker. Solar probe of this, you know, large region on the solar surface.
This is actually a mosaic of, you know, almost 20,000 by 14,000 pixels. So it's, you know.
Doesn't all show up, you know.
I'll explain on the screen here, but we can sort of zoom in and we'll step step in a few times.
So this is, you know, zooming in now to lower portion where that?
A black box is and I will zoom in from there onto this green box and we can see for example.
These structures, now in the chromosphere.
And how finally you know these details are again, we're seeing things at resolutions.
We've we've never had before in the chromosphere. Down to, you know, 20 or kilometers or so. So.
And this is hard to explain from our you know models.
Of the chromosphere. Why these things would be so finely structured, and so, so columnated and everything like this.
It's so it's very interesting.
And we have, you know, work to do, to understand it.
But the thing that decisive gives us now is we can actually, you know, measure the chromospheric magnetic field. Our measurements from gone or the ones we see from HMI or from the Hino dei, we're all photospheric measurements of the magnetic field. It gets much harder to measure the.
The magnetic field up actually in the chromosphere.
The signals get weaker.
And the line formation makes it harder.
But so with that sort of that light bucket gathering enough photons, getting a high enough signal to noise, we can actually now.
You know, tease out and measure the magnetic fields of these these fibers, these, the structures we see in H alpha or in H beta that indicate that, you know, that indicated where the magnetic field was in the chromosphere.
But now we can actually start to measure that both the vertical field.

Which, you know, we had some work on that before, but now this horizontal magnetic field where we can see, you know this is, you know, trying to, you know, pull things.
You know, understand things at at the at the edge of our our our signal here. But those bright yellow streaks indicated by the arrow or sort of an indication of the magnetic field that we're seeing for the first time so.
You know, this is a great.
Advancement with decis.
You know, we'll continue pushing that.
To measure the velocities there that little inset you know shows you see up and down flows in the same in the same location.
And the the most recent result that is, you know, really groundbreaking from Decist is actually being able to measure the coronal magnetic field, right?
This is sort of.
Been been the goal and you know it's extremely important to understand what the magnetic field is in the corona.
That's where the energy builds up for flares and CME.
That's where the solar wind is sort of being driven from.
And so, but we haven't had a A, you know very good ways to directly measure the coronal magnetic field. But now with Decis and again, the corona is very faint, much fainter. Of course, in the visible.
Than the disk of the sun. That's why we only see it during eclipses, but with decis it can operate as a coronagraph, block out the disk of the sun and allow us to measure the corona outside of an eclipse from the ground.
And so this was a recently published paper here, picking out this target on the limb.
You see what it looks like in SDO in the 193 channel.
And then you know the red box here indicates really what the, you know what? What is amazing here that there's a magnetogram we can actually measure the magnetic field.
We actually get its, you know, field strength going.
You know, 10s of Gauss, so much weaker than the the field in the in the photosphere.
But much more diffuse.And.
You know, this is really gonna, I think, revolutionize our understanding of the corona and, you know, understand the the magnetic field structures up in this, you know, faint but but important region.
And so yeah, you know, sort of mentions earlier we'd done some coordination

with Parker Solar probe.
We coordinate observations with solar orbiter as well, and so we sort of.
You know these three facilities together I think are really gonna allow us to to probe this on in, in whole new ways and.
Make the best use of of all these data so.
A lot more exciting things about the sun to come, but.
Happy to take any questions or.
Either before Tesla or or after.

Kirk, Michael S. (GSFC-6700) 26:22
Because how much do those two programs actually work together to create data products? To refine things?
Or are they pretty, pretty well independent because they have very different sort of view of time and space?

KR
Kevin Reardon (he/him) 26:35
You know, they've that that view is is very different, right?
You know, time scales of seconds to minutes, you know, and gong is, you know, hours to days and, you know, over solar cycles.
But I mean, I think there is a lot of room there that.
To to sort of build off each one, especially you know we're talking about using the gone data for the context. You know, because we'd look in and and see.
You know that flare right in this, you know, very small region.
You know, this one sunspot already where you know, as we're using HMI, you know as sort of context, the gong data I think will also provide context. And we're also another component coming online will be the SOLAS instrument which is now being installed in Big Bear and so.
That will have some innovative things also.
Sorry, the chromospheric magnetic fields again over the full disc, which is will be great context again for the DKS observations.

SO
Sten Odenwald` 27:56
Yeah, I'm. I'm curious at a resolution of 25 kilometers of the solar surface. Is that still too coarse to actually study the details of magnetic reconnection?
I mean is that is it?
Are we still not quite there yet? In order to really define how that process works for magnetic filaments and all sorts of other things?

Kevin Reardon (he/him) 28:22
Right. I mean, yes and no.
I'll hedge there.
You know some of that.
The you know the actual.
The physics of that reconnection, you know, may even be happening on spatial scales of of meters, right?
Which will will never resolve.
You know, both as a resolution but also.
Just you know, what's the information available from the Sun? So in in that sense, you know, it's not enough, but.
You know those signatures of that reconnection that may be happening on those small scales you know do propagate.
Up to to some you know these you know the 10s of kilometer scale, right. And we can you know certainly see indications of reconnection happening in some of these events.
We there's a recent paper that that came out.
That suggests we're seeing.
Evidence of.
Electric fields in a in a small reconnection event and so you know not at the scales of the reconnection itself, but you know because of the resolution is is high enough not to completely smear it out, and because the signal to noise is high enough, we're able to.
Pick out some signatures of of these you know physical processes like reconnection.

Sten Odenwald` 29:46
Can you actually do some elementary calorimetry and figure out from a reconnection events how much magnetic stored magnetic energy was released and then follow that into radiation, thermal energy and kinetic energy? I mean, are you able to do that energy calculation yet?

Kevin Reardon (he/him) 30:05
There's some of that right. We do have, you know, we can sort of.
Look at the volumes, that of of material that are sort of involved in that reconnection and you know we have estimates of the density.
We also use.

3D simulations now, and there's a lot of our interpretation and we we have these, you know, increasingly accurate.
You know fully maneto hydrodynamic simulations of, you know, small boxes on the solar surface. But we can see.
Know how a processes evolve and you know with that simulated queue we can, you know, look at different scales and different directions and and try to sort of calibrate our observations against.
You know what we what we see the signatures we see coming from those simulated.
Observables so.

KS **Kirk, Michael S. (GSFC-6700)** 31:33
And then tashaunna, I think you had a few things to to follow up on. On the education side.

TB **Tishanna Ben** 31:40
So I'll just quickly go over some of the recent outreach that we've been up to.
So I'm tishana.
I'm with the National Solar Observatory, education and public outreach team.
We're a small but mighty team, so there's four of us.
Jorge is our director. I'm the education specialist.
And then we also have a communication specialist and our Webmaster, John.
Jorge and John are in Boulder. Evan and I are in Maui.
So I'll just talk about some recent collaborations that we've done with the community, the educational program that we lead and then I'll end with a couple of links to some of our online resources.

1) So the first is shadow the scientist. So this is through UC Santa Cruz. But their program leader Jamea actually is located on the Big Island. And so what that is is it gives the public and students an opportunity to sort of see what science looks like behind the scenes. And so we do a live stream from the telescope with a couple of our operators and our observation scientists. Explaining the experiments that they're doing on that day. So that was recorded and then it's uploaded onto YouTube and they have a nice playlist from up a bunch of different facilities and observatories throughout Hawaii.
2) The second is excite camp and that's run by the Maui Economic and Development Board and it targets young women or females that are under from underrepresented groups.

And so we bring them on a field trip up to Haleakala National Park and then on to our site at the summit and they get to do activities with our engineers, with the Park Rangers. They look through solar telescopes.
So they get to see the sun from atop Paliak Allah, and then they come down to our offices later and they meet a few more of our staff and listen to presentations and get a tour. And all of those things.

3) The third one is pretty unique. It's not finished yet, but we're working with the Sheraton to have what's called a living portrait. So this is actually a series that they'll have throughout the hotel where there's these posters and people can scan the QR code and the subjects of the posters come to life and they start to talk about whatever topic that. They're focusing on so our poster is all about the sun on Maui and we partnered with a group called Ohana Kilohoku. And so we have a cultural side and Us at the DK. So basically science Sarah talks about.
The sun from her lens as a solar physicist and then Keiko will talk about the sun through the lens of the story of Maui, who was a demigod.
That captured the sun from a top Holly akala.
4) The Solar Fest is led by the National Park and it's just a day of fun activities. Public can come look through telescopes for free.
Learn about us at National Solar observatory. Learn about the sun and then we have science talks. I think every hour throughout the day and it's pretty neat because our telescope is in the backdrop of the.
Event so it looks really good.
We'll also talk about our education program, so.
This program's called Journey to the universe. It actually started on the Big Island, and over there it's led by Mauna Kea observatories. But over on Maui, we lead the program and they're very similar, but a little different in a few ways too.
Ours includes a community event component, so that happens over the weekend.
It's a week-long event.
This past year, we held it at the Maui Ocean Center, so they have a a nice planetarium.
So we were able to screen the film called Space Hope and Charity. You may have heard of it.
It's a documentary, and it's about charity. Who actually, I believe is a NASA astrophysicist now.
Looking on the James Webb telescope team.

So that was really neat.
So she came down to Maui and they were able to answer questions after the film and.
It was received really, really well. And then following that, we had a stargazing event at the same venue.

5) And then the week, either prior to or after the weekend depending, is the classroom visits.
So for elementary school students, we have different volunteers go into the classroom, do activities with them, talk about space, talk about STEM or the sun.
And yeah, just two activities allow them to to meet professionals in STEM industries.
2nd component for the older students.
We have, umm, career panels, so these are popular amongst middle school and high school students. But we over the years have gathered a network of different stem educators from the community that will sit on a panel and talk about what they do in their field and let stud.
Q&A With them. This is all kind of just to give them exposure of what's available out there in terms of career choices, what's available in terms of science, technology, engineering and mathematics in general.
Give them an idea of what different things could look like. So on the right I just put a list as examples.
Our community is very diverse in terms of what they do within STEM and it's not only people who directly. Use STEM, I guess in their role, but also people in STEM industries like for example communicators and. You know admin from our observatory, so we invite anyone who wants to join and help out and visit with the students.
To come and share about what they do.

I just wanna take too much time, but here are a couple of online resources.
1) The first is our educator web page. So there we have things like our Google Classroom where we house a lot of different stem activities.
2) And then there's also links to our journey web page and our Journey Workshop page.

HD

Heliophysics Student Investigations Hilarie Davis 42:06
Hilarie Davis 42:32

What we've been doing in the HEAT team you'll be interested in, we created a framework for education for heliophysics, so we took all the concepts that we could make good connections with and create investigations at 3 levels, introductory, intermediate and advanced.
The three big questions that NASA heliophysics investigates.
1) What are the impacts of the sun on humanity?
2) How do Earth solar system and heliosphere respond to changes in the sun?
3) hat actually causes the sun to vary?
So we had great insights into that from Dr Reardon today.
Very interesting about what they're learning about how these things happen and how we can track them.
So here's the framework questions. The Big three, and then the big ideas for education. You'll see there's three for each one, and then for each one of those, there's a narrative describing what you would teach an introductory level learner of any age or elementary school.
Question One is what are the impacts of the sun on humanity and the 1.2 is that the sun is active and can impact technology on Earth via space weather and then in question three, what causes the sun to vary is about the life cycle.

At the introductory level the investigation question might be how does the Earth keep us safe from the harmful effects of the sun? Including radiation, space weather, and I've listed three resources here that you could use with students or use for background. Educators could use her background, and these are both formal and informal educators. So one's on what is space weather. Another one is on magnetic earth and then another one is on the Earth's magnetosphere.

At the intermediate level- middle school or people who have some background. They might begin investigating what plasma is and how it contributes to sunspots, solar flares and coronal mass ejections. What are the relationships there? There's a nice resource from Stanford solar on tails.
It's a really nice graphic kind of presentation. There's a space weather Living history podcast which Carolyn spearheaded a number of years ago.
These are the original people who were founders essentially in that field.
They're just fascinating to listen to. Then there's a solar plasma collage, which is an activity that students or learners can do something on. Plasma from UCAR and then stand at this wonderful collection of four parts on space weather and in the second one he talks about Hinoki and solar storms and he.

Interviewed George Joshuk, so there's some nice resources.

At the advanced.
Students or advanced learners can get into what causes solar weather and how do we know when it's going to happen and how it happens on the surface and below the surface and all that helps us understand and prepare. There's a nice resource here on tracking high energy protons from coronal mass ejections. There's a whole activity booklet by Sten Odenwall, our astronomer on space weather math, which just has a wonderful collection of math problems and then solar wind. Mad science at the lunar surface. That's a really fun one.

KS So For more information you can check out like I said, just just Google NASA heat or this is the direct link to the big ideas.