NWX-NASA-JPL-AUDIO-CORE

Moderator: Michael Greene
May 22, 2013
8:00 am CT

Coordinator: Welcome and thank you for standing by. At this time all participants are in a listen only mode until the question and answer session of today's conference. At that time you may press star 1 on your touchtone phone to ask a question. I would like to advise all parties that today's conference is being recorded.

If you have any objections you may disconnect at this time. I would now like to turn the call over to Ms. Vivian White. Thank you. You may begin.

Vivian White: Thanks so much. Hi everyone. This is Vivian White calling in from San Francisco from the NASA Night Sky Network at the Astronomical Society of the Pacific. I'm very pleased to be hosting this teleconference with Dr. Lynn Cominsky.

And I have a feeling you're going to really enjoy this high energy talk about blazing galaxies and exploding stars and monstrous black holes. She's going to talk to us tonight about the x-ray and gamma ray visions of the universe.

Vivian White: Just follow along with the slides and there's going to be time for Q&A at the end of the talk if you stick around. There's also going to be, after the Q&A we're going to give away a copy of the new hardcover book, The Life and Death of Stars by Kenneth Lang, to one lucky listener.

So stick around to the bitter end and we'll tell you more about that when we get there. So now I would love to introduce Dr. Lynn Cominsky who keeps very busy wearing many hats. She is an award winning professor and the Chair of the Sonoma State Physics and Astronomy Department.

Where she is among many other things, developing an online cosmology course for undergraduates. She's also a lead scientist on many high energy missions like Swift and NuStar and Fermi which she'll tell us all about in a minute.

She's been studying the high energy phenomena of black holes and pulsars and neutron stars for I think more than three decades, since the first x-ray satellite data came in to the Harvard Center for Astrophysics.

So I read an article that described her as a serious scientists with a sense of humor which I can attest to. And it's one of the reasons we've asked her back to speak with us. I believe it's been about five years since you last spoke with us Dr. Cominsky.

We were talking then about the upcoming GLAST launch which was soon renamed the Fermi Gamma-ray Telescope. And this is where all the record setting GLASTs are being detected right now I hear. So I'll stop talking now and you can tell us more about them.

Thank you so much for joining us tonight Dr. Cominsky.

Dr. Lynn Cominsky: Well you're very welcome. I assume my line is open?

Vivian White: It is open.

Dr. Lynn Cominsky: Okay, good. So - and I also assume everyone's looking at the slides. It's great to be here. Right now you should be looking at the title slide. It has on it an artist's conception of a galaxy with a supermassive black hole shooting juts of particles and light out of it.

If you will please turn to slide 2 - these are the satellite missions that my group supports, four different satellite missions. Pretty much every high energy mission that's up there right now except for Chandra, the really big one.

That's done by folks at Harvard where I used to work, as Vivian just told you. So I'm going to concentrate tonight in telling you some results from Swift which I got to see the launch of back in 2004. It's a medium sized satellite that looks for gamma-ray bursts.

Fermi which used to be called GLAST, which I also got to see the launch of in 2008 and that is very high as energy gamma-ray sky survey. Plus it also seeks gamma-ray bursts. And then most recently, NuStar got launched, just about a year ago.

I did not get to see the launch of that one. That was launched in a very unusual way which I won't have time to talk about. But it wasn't launched from Cape Canaveral. It was launched from the Marshall Islands. And so hardly anybody got to see that one launch live.

If you'll change to slide 3, this is the conical diagram of the electromagnetic spectrum, all of the different forms of light that we can and visible light is right in the middle.

And I've illustrated on this by different color boxes and lines, the energy band passes of three of the satellites that I'm going to be talking about. So if you look at the big purple box I made just one big box for Swift. Swift has three different telescopes on it.

One that looks at ultraviolet and optical light, so that's the UVOT, one that looks at x-rays, that's the XRT and then the one that looks to the gamma-ray burst which is called the Burst Alert Telescope, BAT. And that spans basically from the visible light range up to about 150,000 electron volts.

When we talk about x-rays and gamma-rays we usually use energy units and not wavelength units or frequency units because we are detecting individual photons for the most part and measuring their energy. So a visible light photon is typically about two or three electron volts.

And Swift goes up to 150,000 electron volts. NuStar is the little red box, the skinny red box and that has a narrow band of energy starting at ten and ending at 79,000 electron volts. Now Fermi has two different sorts of detectors. Its lowest energy range is about 10,000 electron volts.

But it goes all the way up to 300 approximately billion electron volts. And so that's why I have the black arrow there pointing to the right. So if you'll change to slide 4, this is a little graphic that shows what happens when you try to look at the space environment with x-ray light.

So in general the wavelengths of each - on an individual x-ray are about the size of an atom. We usually define the x-ray band as between 1000 to 100,000 times the energy's invisible light or roughly 1 KEV to 100 KEV.

And when you're looking at things in the sky that put out x-rays what you're usually seeing is very hot gas or plasma. Things that are radiating thermally so they're radiating because of their heat, at tens of millions of degrees to say 100 million degrees or a little bit more.

And those kinds of things that make those high temperatures include supernova remnants, so the leftover gas after a star explodes or the discs of gas that are orbiting black holes. Now if you turn to slide 5 you'll see a little picture of NuStar and a link for the NuStar Web site.

NuStar looks at the high energy x-ray sky so higher than Chandra Observatory that you may have seen lots of pretty pictures from. And it's the first x-ray telescope on orbit to every focus these x-rays at wavelengths higher than what Chandra can observe.

Chandra pretty much stops at 10,000 electron volts and that's where the NuStar energy band starts. Now if you'll turn to slide 6, you'll see a little graphic of how we focus x-rays. And this is true for Chandra as well. Both NuStar and Chandra have a focal length of about ten meters.

And those - the cutaway, conical gray things on the left hand side is a cutaway view of the nested mirrors. So you use many mirror services nested inside each other, sort of like those Russian dolls.

And the x-rays bounce off one of the mirror surfaces, hit the second set of mirror surfaces and come to a focus at a point about 10 meters away. So it takes two bounces, sort of like skipping stones off the surface of the water, to focus the x-rays.

Not very similar to the way visible light telescopes are made. Now in Chandra these mirrors are highly polished surfaces of gold and the shapes are very exact, hyperbolas and parabolas. In NuStar which is a much cheaper and smaller mission, we basically approximated those services with just cones.

And the mirrors are made of multilayers of different materials to enable to focus the harder x-rays that you can't see with the gold coated mirrors of Chandra. The NuStar mirrors are coated. There's 133 layers of nested mirrors.

The outer 44 are coated with 200 layers of alternating tungsten and silicon. And the inner mirrors are coated with layers that alternate between platinum and carbon.

If you'll turn to slide 7 this is a photograph of the Swift Gamma-ray Burst mission before launch in the Goddard Space Flight Center clean room. And you can see all three telescopes on there.

The ultraviolet optical telescope near the x-ray telescope are just sticking up in the back behind that large, silver, aluminum thing that's on the top. You can see if you look carefully, two sort of round, cylindrical things in the back there. So those are those two telescopes.

But the Burst Alert Telescope is the one that I want to tell you a little bit more about. And also I should mention that Swift is one of the few NASA missions that's not an acronym. It's actually named after the Swift bird because it catches its prey on the fly like the Swift bird catches mosquitoes and bugs.

The Swift satellite swiftly turns to see gamma-ray bursts in less than a minute and catches the gamma-ray bursts on the fly. If you'll turn to slide 8, this is graphic that shows the parts of the Burst Alert Telescope.

Now this is another telescope that's very unusual and doesn't it all look like the kind of telescope that you use for visible light? It's basically made of the thing on top that looks sort of like a carpet is actually over 32,000 little lead tiles placed in a really random - sort of random array order.

And the tiles keep the x-rays from coming through. So if there's an x-ray burst that goes off the x-rays come down to the surface where the tiles are and they go through the spaces between the tiles. And they land on the detectors that are shown in the lower left.

And you basically make what's called a shadow mask and by doing some complex mathematical calculations you can invert that pattern to figure out roughly where in the sky the bursts occurred.

Then Swift gets that information and swiftly turns to put the two narrow field of view instruments - the ultraviolet optical telescope and the focusing x-ray telescope, onto that part of the sky to try to figure out what actually blew up and study the cooling embers and then there's the afterglow afterwards.

Now if you'll turn to slide 9, we're going to talk a little bit about gamma-rays. So gamma-rays are the most energetic band of electromagnetic spectrum.

And in contrast to x-rays where a wavelength was the size of an atom, the wavelengths of gamma-rays are about the size of the nucleus of the atom which is much, much smaller.

And usually people say that the gamma-ray band starts at about 1 million electron volts, 1 million times that invisible light and it just keeps going up. It goes all the way up as far as we've ever been able to detect photon energy.

Now if you were going to create gamma-rays by the temperature of the matter, thermal gamma-rays they would be called, you would have to have things that would be billions of degrees. Remember x-rays were tens of millions of degrees.

So gamma-rays being much more energetic, you need to have billions of degrees. And really there are just not that many things out there in space that are billions of degrees.

Perhaps a star, right when it blows up is that split second of the actual explosion, you might see thermal radiation that's a billion degrees. But then it starts to cool down. So most of the things that we see in the universe that emit gamma-rays are not emitting thermal gamma-rays.

They're not emitting the radiation because they're hot. They're emitting the radiation because you've got charged particles that have been accelerated to really, really close to the speed of light.

And when you do that to an electron or a proton or that charged nuclei of atoms, those atoms will emit gamma-rays.

And the things that can accelerate those particles include really, really strong gravitational fields like you see near a black hole; really, really strong magnetic fields like you see near the surfaces on the neutron star; and other things like that, collision excitation, shockwaves from things blowing up also accelerate charged particles.

So in general the objects that we look at with gamma-rays are emitting them for very different physical reasons than the ones that we see when we look with x-rays.

And gamma-ray astronomy is actually a lot closer to radio astronomy where the radio waves are coming from things also by virtue of charged particle acceleration than it is to x-ray astronomy which is a little bit hard to understand at first but I've gotten used to it over the years.

Okay, so let's change to slide 10. Here's a little image of Fermi and a good Web site to go to, to get educational materials from Fermi. And slide 11 has a picture of the Fermi gamma-ray space telescope in the Goddard clean room before launch.

Now it has two different instruments - the Gamma-ray Burst Monitor which actually consists of 14 different telescopes. You can see three on the left side that - by one of the red arrows and another three on the right with no arrows pointing to it.

And then a big cylindrical one across the bottom. Those make up the Gamma-ray Burst Monitor. And there's an identical set of six and another long, skinny one on the other side of the satellite that you can't see in this picture.

But that thing on the top that looks like a big square aluminum box, that's probably the weirdest telescope that you will ever see, it's called the Large Area Telescope. And it's what detects the very highest energy gamma-rays.

So if you turn to slide 12 you'll see what this looks like when you take the aluminum mylar shielding off of it. It looks like a bunch of suitcases. It's not possible to actually image your focus gamma-rays the way you can do with x-rays.

So instead we have to use special detectors such as scintillating crystals or silicon strips which is a form of (solid space) detector. Scintillating crystals are crystals that put off visible light when they're hit with gamma-ray light.

And this thing that looks like a bunch of suitcases over here is the Large Area telescope which is what we call a pair-conversion telescope with a calorimeter. It's a 4x4 array of these pair-conversion telescopes as you can see from looking at the image.

So now what did she just say? Well let's look at slide 13 and I'll try to explain this whole pair-conversion stuff. So if you start out with Einstein's most famous equation, E=MC2, what does that really mean? Well the E is energy, the M is mass, the C is the speed of light and the events square it.

So that's what it says but what does it really mean? What it means is that you can turn mass into pure energy and vice versa. And so in that process known as pair-annihilation you get two things that's mass, an electron and its antimatter partner, the positron.

You smash them together and out comes pure energy, two gamma-rays. That's called pair-annihilation. Now change to slide 14 and you'll run the camera backwards and now this is called pair-conversion.

We have the gamma-ray that comes in, it helps a heavy metal like tungsten in this example and it actually produces a pair of particles that has mass. Here we have our electron positron pair being made by converting the gamma-ray into this pair. So that's pair-conversion.

Now on slide 15 we see a cutaway of how the Large Area telescope works. A gamma-ray comes into one of those 16 towers. It is going to interact with the tungsten and it's in between a bunch of different layers of silicon strips. It's going to turn into an electron positron charged pair.

Those particles are going to travel through the layers of silicon and leave behind charge tracks and then deposit all their energy down at the bottom in the calorimeter. We then take the computer and reconstruct the path of these particles to figure out where in the sky the gamma-ray came from.

And I should also mention that the yellow stuff that's on top is the anti-coincidence detector shield which is used to separate the gamma-rays from the charged particles because charged particles will set off the detectors as well. But we don't want to know the information about those.

We only want to know the information about the gamma-rays. For every one gamma-ray that we get that we want to keep the data for, we get 150,000 charged particle hits that we have to throw out in the data from the anti-coincidence detectors.

So it's really like finding a needle in a pretty big haystack to get to the gamma-ray data that we want to analyze. If you turn to slide 16 I'll just show you a couple of images up close of the Gamma-ray Burst Monitor detectors.

These use the scintillating crystals - sodium iodide in the case of the lower energy ones and bismuth germinate crystals in the case of the higher energy ones. And they've shown the wavelength ranges there as well.

And by having those 12 detectors and the two big ones on the different sides of the spacecraft, we cover the entire sky so the Fermi Gamma-ray Burst Monitor can see bursts from anywhere in the sky when they occur. If you change to slide 17, this is the Fermi skymap.

It's slightly cut off at the right. Sorry about that. This just highlights some of the new discoveries made by Fermi. Now this is what's known as an (H-Off) projection.

It shows the entire sky sort of unpeeled and spread out like an orange peel flattened out with the plane of our galaxy running across the middle. And you'll notice that the brightest source in the sky is in fact our own galaxy.

That's because when cosmic rays which are charged particles, hit the gas in between stars and the galaxy they turn into gamma-rays and so our entire galaxy flows in gamma-rays. I've circled a few of some of the notable sources.

For example, a bright quasar in the middle top, a gamma-ray only pulsar on the left - I'll be talking more about those. A high mass binary with the neutron star and a big star orbiting each other. I don't have time to talk about that one.

A radio galaxy that's actually not a blazar, we've discovered making gamma-rays anyway even so we weren't looking right at the juts.

We discovered cosmic rays being accelerated in the supernova remnant W44 and a globular cluster probably just a sum of a bunch of pulsars in the center of a globular cluster. But we just see it as a single object.

And of course there's still lots of unidentified sources left in the Fermi catalog to try to follow up with ground based observations and associate with objects of known classes.

If you change to slide 18 I'll start to talk now about some of the highlights and some of the problems that we're trying to solve with all of these different satellites, looking at some of these blazing galaxies and monstrous black holes.

So here's our active galaxy drawing again. Active galaxies emit both x-rays and gamma-rays.

They emit x-rays from the hot gas that's swirling around the black hole and they emit gamma-rays from the juts of charged particles that are being shot out of the center of the black hole region, of course from outside the event horizon because nothing can get out from inside the event horizon.

So all of the x-rays and gamma-rays that we see are coming at us from right outside the event horizon. And the galaxies that are pointing their juts directly at us are the ones that we call blazars as opposed to quasars which is also another name for active galaxy.

And so that is the big scientific question that we would like to answer. If the black holes are supposed to be sucking in everything how is it that they can shoot out these powerful juts, a lot of them? So if you'll turn to slide 19 I'll show you an example of how we're trying to address that scientific problem.

Fermi scans the entire sky every three hours. So if a blazar flares we can see that on a pretty short time scale. In this graphic the top line shows a bright blazar above the Milky Way. And then in the bottom panel it got a lot brighter. I hope you can see it.

That's the part 1502 plus 106 source. In contrast, 3C454.3 down below, is about the same brightness on both of those days. And so there are many models for how it is that these blazars juts work. And the models predict different information about what kind of light should flare first?

Should the gamma-ray skip right before the visible light? Or should it be the other way around? Or should they both flare at the same time? There's a whole bunch of models out there.

And we would like to study a whole wide range of these galaxies and lots of different wavelengths to try to understand how the flares occur. Because when things change is your best chance to learn about the physical mechanisms behind how things work.

And so we have coordinated campaigns as many ground based visible light telescopes, a lot of which are operated by amateurs through our Global Telescope Network or through Skynet or both. And we've been trying to follow those and get information to try to find out both the nature of the charged particles and the juts. Are they positive particles? Are they negatively charged particles?

If they're positive are they protons or are they positrons? We don't even know those simple - the answers to those simple questions. So now if you'll turn to slide 20 here's the result - a little closer to home from NuStar.

This is some data that was taken by NuStar around January of this year. And NuStar was imaging the galactic center in hard (unintelligible). It's very hard to see the galactic center in the Chandra band because there's too much dust and gas in the way and the lower energy x-rays get absorbed.

And so you can see three snapshot images of what it looked like and then a flare happening and then after the flare. And that took place over the course of a couple of days when NuStar was studying this region for a couple of weeks.

If you'll turn to slide 21 here's another image of NuStar data, just the two purple dots are from NuStar. The background images of course are visible light image of this galaxy. And in this particular galaxy the black holes are not at the center.

And so that's something that has been taking a long time to try to understand. They're too bright and too big to be black holes that were farmed as a result of the supernova explosion. But they're not in the center so they can't be the massive black holes that grew up with the galaxy.

And so people have taken to calling these either intermediate mass black holes, black holes that are probably 1000 times the mass of our sun.

Or sometimes they call them ultra luminous x-ray sources because if they are small black holes that are the mass of our sun, say ten solar masses or more, you know, ten to 30 say. Then they're way too bright to go with that mass. They shouldn't be able to be making the amount of energy that we see.

So it's a puzzle. Okay. If you'll turn to slide 22 this slide - this graphic of the lifecycle of stars will hopefully look familiar to a bunch of you in the Night Sky Network because this is one of the graphics that we made with the Astronomical Society of the Pacific that was distributed in the supernova! toolkit.

And that is something that was funded by Fermi and Swift and XMM Newton and another mission that I don't work on called (Suzaku). And so this shows the lifecycle of stars starting from a big cloud of dust and gas called the Star-Forming Nebula.

And they want to concentrate on this cycle to the right for the massive stars. So we go from the Star-Forming Nebula to the massive stars to a red supergiant and then to a supernova. We get a big explosion. We have an endpoint that's either a black hole or a neutron star or maybe nothing.

Maybe it all got blown to smithereens in which case you're just back to the Star-Forming Nebula. But if part of the core of the massive star was left over and the mass of that core is around 1-1/2 solar masses then that's a neutron star.

If it's above three solar masses then we're left with a solar mass black hole. The ones that we've measured masses for in our galaxy usually have masses in the range of ten to 30 solar masses for the black holes.

And so they're pretty easily distinguished from the neutron stars because all the masses for those that we've measured, have been about 1.4.

If you'll turn to slide 23 I'll show - this is an image taken by NuStar of Cassiopeia A, a famous supernova remnant and the blue color here shows the highest energy x-rays that have not been seen before NuStar.

The green and the red colors show the lower energy x-rays that are also seen with Chandra which of course have made spectacularly high resolution images of this lovely supernova remnant. Now you notice from looking at where the blue light is, it's on the very outer edges.

That's because that's where the shockwave is interacting with the inter-solar gas. And so where the shockwave front - where the shock front interacts with the inter-solar dust and gas. Heats the material up to the highest temperatures due to the compression of the shock ramming into that gas.

And so the highest temperatures are seen on the outside limb and of course sometimes - I mean that limb is coming at us as well and so sometimes you can see a little glimpse of that on the part of the remnants that's in the middle.

If you'll turn to slide 24 I'll start to tell you a little bit about gamma-ray bursts which I've alluded to many times now in the course of our discussion. So gamma-ray bursts come in two types that have been most studied.

The long burst which lasts for more than 2 seconds, might be from something that's usually called the hypernova, sometimes it's called the collapse (R). But it's basically a super supernova.

So a supernova that's producing ten to 100 times as much energy as the normal supernova that we tend to observe more often.

The short burst, the burst that lasts less than 2 seconds, maybe coming from the mergers of two neutron stars or perhaps a black hole in the neutron star or maybe two little black holes making a bigger black hole.

But in both of these scenarios we believe that a black hole is created and each gamma-ray burst is the birth cry of a black hole. So in the case of the hypernova you start with the massive star and the chunk of stuff you have left is a black hole sized chunk.

So you get this explosion that collapses everything down to a point. That releases a lot more energy than if you just made a neutron star.

In the case of the short bursts merging the two neutron stars at one point for solar massive each make a black hole by the fact that once they merge they've made something that weighs three solar masses or more. And so you end up with a black hole in that result.

But what's really neat is that each gamma-ray burst emits as much energy in just a second or two as our sun emits in its entire 10 billion year lifetime. And we see one of these gamma-ray bursts happen from somewhere in the universe, about once a day.

Now please turn to slide 25. This shows eight years of gamma-ray bursts seen by Swift, 667 of them total through the end of 2012. And there's a superimposed little dot showing where the bursts are. It's superimposed on an infrared image of our galaxy just so you can get the projection correct.

And you notice one very important thing. There is absolutely no preference for the gamma-ray burst to be coming from our - the plane of our galaxy. And indeed we've discovered over the years from watching these afterglows, these cooling embers that are left over when - after the bursts occur.

And looking at the red shift of the visible light that is being emitted from the afterglow or the galaxy that the afterglow is located in, that the bursts are all at cosmological distances. The average distance to the long burst is about 7 billion light years.

So they're coming to us on average from halfway across the observable universe. Now if you turn to slide 26 you'll see Fermi's equivalent map, not quite so pretty because it wasn't made for a press release. But the same coordinate system.

The galaxy is right across the middle of the (ATAS) map. These are the Fermi gamma-ray bursts that have been seen just since Fermi's launched. It's about 1000 gamma-ray bursts at the time of this plot being made which was September of 2012.

And the large area telescope has discovered - has managed to detect a number of these bursts even though it's operating at much, much higher gamma energy since bursts were conventionally detected at.

Now you can learn more about each one of these individual bursts that are seen by Swift, Fermi and every telescope that's up there since 2004 by looking at this Web site, www.GRB.Sonoma.edu. We put up finding charts, we put up little write-ups about each - the properties of each burst.

And it's just a fun Web site to go to, to learn more about individual bursts that might interest you. If you turn to slide 27 I'll show you a typical strong burst seen by the gamma-ray burst monitor onboard Fermi. This is a time scale of about 50 seconds. You see lots of different spikes and peaks.

The one thing that we always say about gamma-ray bursts is when you've seen one gamma-ray burst you've seen one gamma-ray burst. They all look totally different. Some of them have fast (rise) and exponential decay. We call them FREDs.

Some of them are the opposite. We call them reverse FREDs. Some of them just have all of these crazy spikes. We don't have any good name for those.

But we've seen over 40 of these gamma-ray bursts with the large area telescope at energies over 100 million electron volts in the first four years of Fermi's operation. So we're quite excited by how many bursts we've been seeing at energies that we just did not expect.

If you turn to slide 28 I'll tell you something that might be a little harder to understand. But gamma-ray bursts can provide a really, really good test of Einstein's theory of special relativity. That's the theory in part that states that light travels at a constant speed in a vacuum. So how do we do this?

We take a short gamma-ray burst that's coming from really far away. In the case of the one that we wrote the paper on, 12.2 billion light years distant. And because it's a short gamma-ray burst all the photons arrive very close together.

And because Fermi has such a wide energy band we can detect photons at different energy by a factor of a million all within the same burst. And so we look at how closely together the lowest energy photon and the highest energy photon arrive in the burst.

And that is used to set limits on how the speed of light could change as a function of energy.

Because there are some theories of quantum gravity that predict that the higher energy photons will interact with the quantum foam of space time and will get caught up and travel slower than the lower energy photons, sort of like an ice skater skating over some rough ice.

If there is - if there are small ripples in it then the ice skater can get caught. If there are large ripples they can probably glide right over those.

If you turn to slide 29 you'll see a little cartoon illustrating this where our happy green, low energy photon, is skating over the ripples and the pink photon is getting caught up. But in fact we did not see any evidence for any deviations of the speed of light as a function of energy.

These two photons that differed in energy by a factor of a million arrived at Earth within one second. And so that's allowed us to set pretty good limits on the constancy of the speed of light. And Einstein has proven correct once again. It's very exciting.

Okay, so now for - I will wrap up with the latest news here. The latest news that we've announced from Fermi and also seen by Swift and also seen by NuStar and a whole host of other telescopes, is this incredibly bright gamma-ray burst that occurred on April 27, 2013.

And this shows the northern hemisphere sky as seen by Fermi with some background gamma-ray photons and some spaces where we weren't seeing any photons. And before and after. And here's the burst.

And it's outshone everything in the sky for just a brief few seconds while this thing was going off. It was eye-wateringly bright to quote the Fermi project scientist, (Julie McHenry). If you look on slide 31 you'll see some of the other records that this burst set.

It has the record photon energy, the single highest energy photon ever seen from a gamma-ray burst, 94 billion electron volts. Plus the bursts stayed really bright for at least a day. It was seen by many satellites and ground based telescopes.

It occurred at - in a galaxy that was 3 point billion light years distant and it was - so that's really, really close because remember, I told you that the average gamma-ray bursts occur about 7 billion light years away. So this one's pretty close as far as a long burst goes.

And so we have hope that as the gamma-ray emission and the rest of the supernova remnants start to clear out a little bit, that's a visible light that we get out, will show us that a supernova is occurring in this galaxy.

And this little image here is Swift data taken in 0.1 seconds of the burst while it was happening. I will close and leave you with resource slides. After this it's just followed some backup slides that I might use to answer questions. But here are all the Web sites that I've told you about during this talk.

If you don't want to remember all of those just remember the one on the top which is Education and Public Outreach, www.EPO.Sonoma.edu. And you can find links to all of our projects if you go through that one.

And there's a picture of me in case you were wondering what I look like throughout all of this talk. And with that I will close and I guess we take questions now.

Vivian White: Yeah. Thank you so much Dr. Cominsky. That was great. I'm sure there are going to be many questions out there. So Operator, could you help us open up the lines for the listeners?

Coordinator: Absolutely. We will now begin the question and answer session. If you would like to ask a question please press star 1, unmute your phone and record your name clearly. If you need to withdraw your question press star 2. Again, to ask a question please press star 1.

It will take a few moments for the questions to come through. Please standby.

Vivian White: I was amazed to hear that Swift could move so quickly. I mean what - that's a really aptly named telescope. Within a minute it can get the information organized and get pointed in the right direction. I think that's just wonderful.

Dr. Lynn Cominsky: Yes. Well Swift was built with extra reaction wheels. Reaction wheels have been in the news a lot lately because as I'm sure people have heard, Kepler is down to only two now and it's had to suspend operations. So two of its original four wheels broke.

Swift actually has six wheels onboard and so it is able to move more quickly and it also has extra spares.

Vivian White: Oh, I wish they had built Kepler with a couple of extras too. That's a great idea.

Dr. Lynn Cominsky: Reaction wheels are just one of those things that are known failure modes for satellites unfortunately.

Coordinator: One moment. Our first question comes from (Patrick O'Brien). Go ahead. Your line is open.

(Patrick O'Brien): Thanks for the presentation Dr. Cominsky. And I was wondering as an example on page - slide 23, take a look at that picture.

Dr. Lynn Cominsky: Okay. Slide 23 is a NuStar Cas A image.

(Patrick O'Brien): Well my question is I'm not as well intelligent as I was hoping I'd be. But I was curious what is the difference in the colors? Is that artificial colors or is that actual colors if you use a telescope to take a look at that? To my knowledge, those are artificial colors.

And if so, how - what is the color scheme determined and who determines that?

Dr. Lynn Cominsky: Okay, so I think you're doing really great because those really are in fact false colors. X-rays come in x-ray colors and those are not blue, green and red, right? Blue, green and red are visible light colors.

(Patrick O'Brien): Right.

Dr. Lynn Cominsky: So what you have to do is just assign a color to make a pretty picture. And take an x-ray energy range for the colors. And so the blue is the ten to 80 kilovolt x-rays that are seen by NuStar that can't be seen by Chandra. And the green and red are the lower energy ones that can be seen by Chandra.

And if I go to the Web real quick I can probably tell you I'm probably slightly wrong. But this is one of our press release images and so if you go to the NuStar Web site you can get to the press release or www.NASA.gov/NuStar, that one works also.

And you can actually get to see that - those actual images.

(Patrick O'Brien): Oh, is that right? Okay.

Dr. Lynn Cominsky: Yeah. And then it will tell you what the color scheme was. I'm trying to find it here quickly while I'm talking but right now...

(Patrick O'Brien): So if you look at two different...

Dr. Lynn Cominsky: ...I'm having trouble talking and...

(Patrick O'Brien): ...pictures...

Dr. Lynn Cominsky: ...typing at the same time.

(Patrick O'Brien): If you look at two different diagrams they might be - have different colors?

Dr. Lynn Cominsky: They almost assuredly will have different colors.

(Patrick O'Brien): But it's important to realize the color scheme because this slide 23 has what the color scheme is all about. And I was thinking if other pictures have different - alternative colors, each picture should say what the colors represent.

Dr. Lynn Cominsky: They do and I apologize for not putting that on the actual slide.

(Patrick O'Brien): Okay.

Dr. Lynn Cominsky: So - but if you find the press site where the actual image was first published, you will find the color scheme.

(Patrick O'Brien): Oh, okay. All right.

Dr. Lynn Cominsky: I'm trying to find it myself but I'm not having much luck. I know it's on there though. I'm just having trouble doing it and talking at the same time.

(Patrick O'Brien): No problem.

Vivian White: Great. What's the Web site again?

(Patrick O'Brien): Thanks a lot, Mr. Cominsky.

Dr. Lynn Cominsky: If you go to www.NASA.gov/NuStar...

Vivian White: Great.

Dr. Lynn Cominsky: ...and click on News and you'll see all of the different NuStar press releases.

(Patrick O'Brien): Okay. Well thank you very much.

Dr. Lynn Cominsky: And that image from Cas A is definitely one of them.

(Patrick O'Brien): Well that's good to know. Thank you.

Coordinator: One moment please. Our next question comes from Larry Jaeger. Go ahead. Your line is open.

Larry Jaeger: Good evening. My question is about the recent GRB on...

Dr. Lynn Cominsky: Oh excuse me. Now of course I just found the answer now that we have another question. So the blue was between ten and 20 kilovolts. The eight to ten kilovolts are green and the 4.5 to 5.5 kilovolts were red. Okay. Now I'll take the next question.

Vivian White: Thanks.

Larry Jaeger: It's about your latest GRB on 427. Do you have any hypothesis at all about the energy level and especially the persistence?

Dr. Lynn Cominsky: That is a really excellent question because it's really hard to understand how such an incredibly bright thing could last for days except it is close. So it's only apparently bright. It's not actually the most intrinsically bright burst that we've seen.

And we're even more astonished that we saw that really, really high energy photon. But higher energy photons are easier to detect if they're coming from closer to us in the universe.

It's a known effect that produces this other thing called the extragalactic background light which I didn't have time to talk about.

But if you have a quasar and it's making really, really high energy photons and it's, you know, 10 or 12 billion light years away, those high energy photons have more of a tendency to interact with intergalactic dust and gas on their way to us and be preferentially attenuated out of the signal that we got.

And so the closer the bursts are the more likely we are to see the higher - really, really high energy gamma-rays because they haven't had a chance to be attenuated by bumping into other photons from the extragalactic background light and other ways being removed from the signal.

So that might be part of the explanation but it still is a pretty amazing burst. So maybe because it's close and maybe that will also help with the higher energy photons.

Larry Jaeger: Do you have any idea about how long the remnants will clear out and will start being able to see what's left?

Dr. Lynn Cominsky: Well people were predicting that they should be able to see the supernova by now and I haven't heard any reports of it actually being seen. So maybe not. I mean that was the prediction.

Larry Jaeger: Okay, thank you.

Dr. Lynn Cominsky: I know people have been looking.

Larry Jaeger: Thank you.

Coordinator: Our next question comes from (Jim Smalls). Your line is open.

(Jim Smalls): Okay. So we use gamma-rays to detect black holes, right? Could you explain how we use the - might use the detectors to detect the energy like I guess it's positrons, around the center of the galaxy?

Dr. Lynn Cominsky: Okay, so yes we use gamma-ray detectors to detect light from black holes, from - and that light is being - the gamma-ray light is being made by the acceleration of charged particles. And what I was saying is we don't know what the actual nature of the charged particles are that are making the light.

And so we're trying to understand that by taking data in different wavelengths of light and comparing the variations that we see in flares from these central black holes and comparing those to model predictions for different kinds of charged particles.

And so, so far it's - we don't have enough results. The results that we do have are sort of all over the place. In some of the flares the gamma-rays come first and in some of the flares we've seen the visible light comes first. And some of them they vary together.

And so I think the verdict is still out on whether we're actually going to be able to figure out whether it's positrons or electrons for example, that are mostly responsible for making the gamma-rays that we see.

(Jim Smalls): Okay, thank you.

Coordinator: Our next question comes from (Laurence Quary). Your line is open.

(Laurence Quary): Hi, thanks. Dr. Cominsky, is there any significant correlation between the data you're getting and the high energy emissions that you're working on and the alpha magnetic spectrometer on the space station?

Dr. Lynn Cominsky: That's a really excellent question. So the alpha magnetic spectrometer is basically studying directly those charged particles that we've been talking about that also can be making gamma-rays if they're accelerated. And it has these little magnetic brooms.

And so by looking at which way the charged particle is curved around the magnetic fields you can tell if it's a positively charged particle or a negatively charged particle. Now Fermi does not have the ability - it was not actually built as a charged particle detector.

But I talked about the anti-coincidence shield. And the anti-coincidence shield does record information about the charged particles that we're mostly rejecting and not studying.

Now we have been able to do positron and electron spectra using the data into the anti-coincidence shield from Fermi that we have published.

And although the alpha magnetic spectrometer was specifically designed to do that and therefore has much higher sensitivity and can make prettier specter than we can, we published our positron and electron specter results already a year ago.

And the data that they've produced is in total agreement with what Fermi has already published although theirs has better signal to noise of course because that's what they were designed to study.

(Laurence Quary): Yeah. They've been a little tight on their releases I guess. Haven't they?

Dr. Lynn Cominsky: The alpha magnetic spectrometer? Well they did have the one big press flash. Now...

(Laurence Quary): Yeah.

Dr. Lynn Cominsky: ...it's interesting because as I'm - since you know about this I'm sure that you're familiar with the fact that their principal investigator, Dr. (Sam Chang), Nobel Prize winning (Sam Chang), claimed that perhaps the positron spectrum that they were seeing, the positron (expos) was a hint of a dark matter particle.

And the Fermi people had seen the same access and so did another experiment called (Pinella) that published even before Fermi did. And we are not interpreting it at this time as any evidence for a dark matter particle.

We are believing that work, you know, extraordinary claims require extraordinary evidence. And this does not yet rise to that level. It's much easier to explain the excess of positrons by a whole bunch of pulsars or other things that are making charged particles and juts.

And so that's basically the Fermi team's conclusions at this point. Now, you know, the AMS will keep running and it will keep making better and better resolution spectra.

What would be a clincher and what Fermi's been looking for as well is the sign of an actual annihilation line at a specific energy that would then be able to tell you using E=MC2, the mass of the particles that were colliding that could be the dark matter particles.

So when I talked about pair-annihilation and pair-creation before, and I showed an electron and a positron, when you annihilate the electron and the positron you get a hard x-ray of this very specific energy. It's 511,000 electron volts.

That is the rough mass energy of the electron or the positron. They're equal of course. So in some theories of dark matter particles, the dark matter particles, the ones that are call (WIMPs), they can be their own antiparticles.

And you can get two (WIMPs) annihilating with each other and making gamma-rays of the specific energy. And so Fermi has long been looking for any gamma-ray lines that could be the signature of (WIMP) annihilation, has not found any to date.

And so it's that kind of thing that's being discussed. But there's no good evidence at this time that anyone has been able to find a specific energy that's associated with dark matter pair-annihilation.

(Laurence Quary): What energy level would you be looking for, for that?

Dr. Lynn Cominsky: We're looking at everything in the entire layout energy range so 100 MEV all the way up to 300 GEV. And so that's, you know, that's what Fermi is sensitive to seeing. And so that's where we're looking.

(Laurence Quary): That's really exciting stuff. Keep up the good work.

Dr. Lynn Cominsky: It'll be even more exciting when we find something.

(Laurence Quary): Truly.

Vivian White: Okay. I think we've got time for one more question.

Coordinator: Our final question is from Linda Prince. Your line is open.

Linda Prince: Oh, hi Dr. Cominsky. You said that the average distance of these gamma-ray bursts is about 7 billion light years. How much would that radiation be red shifted over that time before it reaches us?

Dr. Lynn Cominsky: Okay, so that's a red shift of one. So basically that means the light's been stretched by a factor of two.

Linda Prince: So the wavelength would be stretched by - just doubled?

Dr. Lynn Cominsky: Yeah. Yeah, doubled.

Linda Prince: The gamma-ray could just as well stay a gamma-ray?

Dr. Lynn Cominsky: Right because the Fermi energy band remember, is so incredibly wide, right? We're seeing everything from 100, you know, 10,000 electron volts all the way up to 300 billion electron volts. So...

Linda Prince: And this is - how do they get a, you know, how do they get - I don't know how they measure the red shift. Do they look in the galaxy that...

Dr. Lynn Cominsky: They - the red shifts are measured by looking at visible light.

Linda Prince: Okay.

((Crosstalk))

Dr. Lynn Cominsky: Because you need to specter lines moving, right?

Linda Prince: Okay.

Dr. Lynn Cominsky: And so because you can't really image or focus gamma-rays very well it's also very hard to do really clear line measurements. And in order to see lines you need to have ionization states of chemicals and you need to see thermal emission like I talked about thermal versus non-thermal.

Linda Prince: Right.

Dr. Lynn Cominsky: So - and then gamma-rays it's almost all non-thermal so you don't see very many lines at all.

Linda Prince: Right.

Dr. Lynn Cominsky: In x-rays you see, for example, you see 25 times ionized iron. So you see an iron line at 7000 electron volts and you see a bunch of lines down at 1000 electron volts to 2000 electron volts come from silicon and magnesium.

Linda Prince: Yes.

Dr. Lynn Cominsky: Because there are still elements that have some electrons left at those temperatures that are ionizing those atoms. But by the time you get up to gamma-rays there's no semblance of atoms left at all.

Linda Prince: Okay, thank you.

Vivian White: Wow. Thank you so much Dr. Cominsky. We really appreciate your time and your excellent presentation. I'm afraid it's all we - all the questions we have time for this evening. But we wish you much future success and we'll be listening and watching. So thanks very much.

Dr. Lynn Cominsky: Well it was my pleasure. I'm glad everyone enjoyed it and I got - I really enjoyed the excellent questions that I got.

Vivian White: Before we sign off let's be sure to have the drawing for the copy of The Life and Death of Stars. Operator, can you let us know how to do that? I think we're going to take the seventh caller.

Coordinator: Absolutely. To win the copy of the book please press star 1 now.

Vivian White: Okay. We want to thank the Astronomical Society of the Pacific for donating this tonight. Let's see.

Coordinator: One moment.

Vivian White: Waiting for the seventh call. Two shakes.

Coordinator: And our winner is (Alan Davenport).

Vivian White: (Alan)? Excellent. Okay. (Alan) if you're not on the Night Sky Network go ahead and give us an - send us an email. Our email is NightSkyInfo@AstroSociety.org. And congratulations to you. That's wonderful. And that's all we have for this evening everyone.

You can find this telecon along with many others on the Night Sky Network Web site if you look under Astronomy Activities. Just go ahead and search for teleconferences. Tonight's presentation with the full audio and written transcript, should be posted by the end of next week.

Good night everyone. Thank you so much

Coordinator: That concludes today's conference. Thank you for participating. You may disconnect at this time.

David Prosper:

END