Astronomy Cast Student Questions
Collinsville High School

Dr. Pamela Gay: The Astronomy Cast's Student Questions program is funded through NASA's Gamma Ray Large Area Space Telescope. Get your class involved in high energy astrophysics by visiting www-glast.sonoma.edu or by e-mailing us at info@astronomycast.com

Fraser Cain: Are you there Pamela?

Pamela: I'm here Fraser.

Fraser: We do a weekly space astronomy podcast called Astronomy Cast where we explore the Universe one concept at a time. As you may recall a few weeks ago you submitted a bunch of space questions and we're here with your answers. So let's get started.

Hi. We're the Puffins from Collinsville High School, and we wanted to know can a gamma ray destroy a galaxy?

Fraser: I'm guessing that's a kinda gamma ray burst destroy a whole galaxy?

Pamela: Well, no, and this is good. Lots of galaxies experience gamma ray bursts maybe every few hundred years. It depends on the star formation. If you are a young galaxy and you are spewing stars constantly, you are going to have a higher rate of gamma ray bursts than an old sedate galaxy that is only producing gamma ray bursts when like neutron stars collide or something like that.

Now, since this happens and we don't see the galaxies destroying, we have pretty good evidence that gamma rays don't destroy galaxies. But they can destroy planets. They can destroy nearby friendly objects. So...

Fraser: Now when you say destroy, do you mean vaporize or just make unlivable? Like, if a gamma ray burst nearby, or relatively nearby gamma ray burst hit the earth, it could vaporize the planet?

Pamela: Yeah it would. Yeah it would.

Fraser: Like how nearby?

Pamela: Well let's say that we replaced our Sun with a star capable of having a gamma ray burst.

Fraser: Okay.

Pamela: And we moved all the planets out so that the Earth is now in the habitable zone of this ginormous, huge massive star that is capable of having a gamma ray burst and we wait. If that gamma ray burst went off and the planet had some bizarre land orbit that it took over the part of the star that has the gamma ray, because gamma rays come out the north and south poles of stars, and planets don't usually orbit there.

But say that some weird magic occurs and the planet got hit with another planet in its path or something that causes the planet to go right into the jet of the gamma ray burst. That planet vaporized…toast…gone. No more planet, atoms blown apart. That's kinda cool.

Fraser: Yeah. But further away, you don't get planets being destroyed. You just merely get them being wiped clean of life, right?

Pamela: You have them getting destroyed at, a light yearish distance. So you can get a pretty good distance away and still vaporize a planet.

Fraser: That's so much energy.

Pamela: [Laughter]…These are the most energetic things in the Universe. A gamma ray burst can give off as much energy in just like three seconds as our Sun would give off in tens of lifetimes.

So take our Sun, gather all its life for 50 times the time that it lives. Watch it get born, live and die. Repeat 50 times. Gather all that light up and spit it out in three seconds. That's what happens with a gamma ray burst.

Fraser: Wow.

Pamela: Yeah. So, yeah, you can totally blow away a planet. You can even blow away a small star.

Fraser: But not a whole galaxy. Not a whole galaxy because it is too spread out.

Pamela: It's too spread out.

Fraser: Right. If you could get a whole galaxy within a light year of the gamma ray burst, and all nicely lined up in the cone of where the burst is going to fire, you might get something really crazy to happen, but that doesn't exist, so…

Okay. Well let's move on.

Hi. We're the Quick Silvers from Collinsville, do black holes really absorb matter or do they have another purpose?

Fraser: So, I guess it's only mostly theoretical. Could we be pretty certain that black holes are consuming matter?

Pamela: Yeah, we can actually watch them do that. There are black holes in the centers of pretty much all galaxies as near as we can tell. And we can watch them, and we can watch them eat things occasionally. So we know this is going on. We see little black holes around stars and they occasionally eat things, and we watch.

Now, as far as another purpose, you read in science fiction books that black holes can be used to get to other Universes that black holes can use to travel through time. There is the whole Andromeda drama TV series where he is going around and around in the black hole and is pulled out and it's hundreds of years later. Well, yeah, if you were orbiting too close to a black hole time would slow down and if you somehow miraculously got out, yeah, you'd be in a different time. But that's not what they are there for. That's just a side effect of physics.

You get going too fast anywhere and that happens. Black holes in general just sit there. They are big and they are hungry and if you get too close, it's like a fly flying past a frog. If the fly gets too close to the frog, it reaches out and eats it. If a light beam gets too close to a black hole, it gravitationally reaches out and eats it. A planet gets too close gravitationally reaches out and eats it.

Now, you have to get pretty close. If you took our Sun and you replaced it with a same mass black hole, the Earth would continue to hang out exactly where it is. The Earth is not going to move. You would have to get so close to that black hole that you're within the surface of what used to be the surface of Sun before you have to worry about getting eaten.

Fraser: But I guess the second part of the question though, is there something else? Is a black hole a portal to some other dimension?

Pamela: No.

Fraser: No. We used this analogy on a previous show where we have a frog looking into a blender wondering if that's a portal to some other dimension. You know, maybe I should jump in and see. NO.

Pamela: The answer is no.

Fraser: No. No it's not.

Pamela: Do not step into the black hole. Step away from the edge.

Fraser: Yeah, it's just a blender. [Laughter]

Pamela: Stay behind the short shield limit.

Fraser: Yeah, exactly. Alright, let's move on.

We're from Collinsville High School and we're the Blue Light Special. And we want to know how we know that space does not stop?

Fraser: [Laughter] Well, actually we just did three shows to explain this concept. So once again Pamela, you're going to have to really compress this concept. How do we know that space doesn't stop?

Pamela: And the answer is we don't know for certain.

Fraser: We don't know for certain?

Pamela: We don't know for certain. But as near as we can tell, the Universe doesn't have an edge we can get to. And we think that the Universe is either infinite or if it's not infinite, it's a finite size, but in such a way if you move forward long enough you end up coming back to where you started.

Fraser: Right, so it's kinda like a ball where if you're moving along the surface of a ball, you go all the way around and you just come back to your starting point. So, if you traveled in one direction in the Universe, you might be able to come right back to where you started.

Pamela: But it's not a ball, it's some weird scary geometry. We will link to those shows.

Fraser: Right. It's not a ball, but it's some other shape that only works in four dimensions and [Laughter] it's very complicated. Essentially, astronomers have been able to figure out to this point that either the Universe is infinite so it never stops in all directions, or it is a certain size. But just like with a ball, where you go around the outside of the ball, you come back to where you start. In our Universe, if you go in one direction, you come right back to where you started so you can't ever get outside of…

Pamela: You can't stand on the edge of the Universe.

Fraser: Yeah, you can't stand on the edge of the Universe and look down into it. Alright, let's move on.

Hi. We're the Orange Shirts of Collinsville High School and would like to know does the Universe ever come to an end?

Fraser: So, will the Universe ever end?

Pamela: I guess that depends on what you mean by “end?” Um, will it eventually reach a point where there’s not any light shining and so you can’t have life as we understand it, because life as we understand it requires light to be kept warm?

Fraser: Well, no, I think it is like will there be a time when time ceases to pass?

Pamela: As far as we know, no. But there are a lot of weird ideas out there. Like, our Universe and another Universe might merge together or something like that.

But those are sort of we have no evidence, but you can do it if you try hard enough with mathematics. As near as we can tell, the Universe is going to be here forever.

Fraser: Forever. But at the same time, the Universe hundreds of trillions of years in the future is going to look very different from the Universe that we have today.

Pamela: And life as we are today probably won’t be able to live in that Universe.

Fraser: Why not?

Pamela: No light.

Fraser: We need light. I mean, obviously we need light from the Sun but, but how would that affect life way, way down the road?

Pamela: Eventually all of the nuclear materials that can generate heat will have all decayed away. Eventually all the stars that are generating heat will die.

With nothing generating heat, we freeze. Human life needs to be kept warm. Someday we are going to run out of ways to do that.

Fraser: So, someday all the stars will have used up all of their fuel and will all be cold white dwarfs, or black holes, and there just will no longer be any radiation, any light happening in the Universe that any life could use to get a start.

Pamela: Yeah.

Fraser: And, is that the end? Or does it kinda go further?

Pamela: No, I don’t think it’s the end of time, I think it’s just the end of life.

Fraser: Right. So, what will it look like further down the road?

Pamela: You’re going to have black holes slowly evaporating which means you’re going to have this crinkling of radiation. It’s getting spread out over such large spaces that it really can’t do anything effective.

It's like trying to heat a bedroom with a birthday candle. It's just too big of a space for the heat that is coming off that candle to do anything effective. So, eventually we're just going to end up with white dwarfs neutron stars and even the black holes will have evaporated, and there will just be nothing except for these giant dead stars floating around.

Fraser: Well, I think this leads into our next question. So why don't we move on to the next question and kinda wrap this up.

We are the Astronomers from Collinsville High School and we want to know how can there be energy death when energy is conserved?

Fraser: So, what does that mean? What is energy death?

Pamela: I have to say this is the best question anyone has ever asked. The idea of energy death is what I was just talking about with all the energy spread out so much that everything is basically cold.

If you try to melt a glacier with a birthday candle, you're not going to be able to do that. There's just not enough energy. If you try to heat up a soda bottle cap with a birthday candle, you can actually melt it. You can do some damage. That's because the soda cap is tiny so you're able to heat it up.

Our Universe right now, compared to trillion, trillion years in the future is tiny, and so the stars are able to heat it up. We also have a lot of fuel hanging around. We have these stars that are quite happy to burn. We have all sorts of radioactive material inside our planet Earth that as they decay they are giving off heat. We have all these different sources of energy and all these sources of energy are in a fairly small space.

Eventually, we're going to use up most of these sources of energy and what few things are still giving off little bits of radiation are going to be spread out over so much space that essentially everything freezes. Everything is cold. Atoms all but stop as the Universe just becomes a cold, dead, dead, dead place.

Fraser: So, the amount of energy in the Universe is actually staying the same from the big bang, it's just that the Universe is so big that for every chunk of space, there is just so little energy there that it doesn't really matter.

Pamela: And the energy is getting spread out and little concentrated sources of energy stars, pockets of nuclear materials are getting used up. So what energy is left flying around the Universe is just spread out in this non-useful form because it's so diluted.

Fraser: That's right. Astronomers call this the heat death, right?

Pamela: Yeah.

Fraser: Where every reaction that you have, any time you have energy you have a little bit of waste heat that comes off. Eventually, the entire Universe will just end up at that exact same level of waste heat. A point at which no further work can be extracted from this heat.

The Universe will end up at some temperature and that temperature will go down as the Universe continues to expand. There is no way that anything can ever exploit that energy.

But it is still following the law of conservation of energy. The energy is still there it's just all heat and it's all the same.

Pamela: One neat little way to think about this is if you take a can of compressed air, the can is just hanging out at room temperature. When you spray air onto your hand it's really cold. That is because as the air expands the energy in that air gets diluted. The temperature drops.

As the Universe expands, it's just like that gas coming out of the can, and so the Universe cools. It's all thermodynamics and eventually kills us.

Fraser: And that's sad.

Pamela: It is.

Fraser: Alright, let's move on then. [Laughter] So, Team Einstein has this question.

Hi. We're Team Einstein from Collinsville, and we heard that time slows down for an object entering a black hole, and we wanted to know how and why this happens.

Fraser: That is a bit of a puzzler. Why does time slow down for an object entering a black hole?

Pamela: This goes back to what we were talking about earlier in terms of the faster you move the slower time seems to go. In general, when you're headed into a black hole, as you get closer to it, it pulls on and you go faster. As you get closer to it, it pulls on you more and you go even faster. And the faster, and faster, and faster, you go, the slower your time gets. So eventually for people watching you, your time has now stopped.

You have ceased to live, you've ceased to move. You're just this frozen thing. Now as far as you're concerned, you don't perceive this slowing of time because it's your heart slowing down. It's the rate at which things go through your brain that's slowing down.

So if you were able to hold your body together as you were flying into the black hole which in reality you'd be dead because your body would have been torn apart. That's just gruesome so we're going to ignore that for now.

So, if your body was able to hold itself together as you fly into the black hole, the way you would perceive time wouldn't change. You'd say to yourself, "oh my God, I'm going to fall in, I'm going to fall in" and then you, you die.

Fraser: Bang.

Pamela: Yeah.

Fraser: You whomp into the black hole.

Pamela: Yeah.

Fraser: Yeah. Get added to everything else that came before.

Pamela: And, as far as your poor friend who is outside the black hole watching you go in, they see you basically freeze and then over thousands of years fade away.

Fraser: So they wouldn't actually see you whomp into the black hole.

Pamela: Nope.

Fraser: But does that have anything to do with the fact of the light that is coming off of you is also getting sucked down?

Pamela: That's part of it as well. You have the light getting red-shifted. That's what causes you to fade away. The light doesn't actually ever change speeds according to anybody.

But, the color that we perceive the light is gonna get changed, so basically as you fall in someone observing you is going to see you slow down, slow down, stop, and then fade to red.

Fraser: Right. And then eventually just fade away.

Pamela: Yeah.

Fraser: Wow. Alright, let's move on.

We're the Astronauts from Collinsville High School and we wanted to know why don't black holes emit light?

Fraser: Alright. We've said this many times. Black holes pull gravity so strong that nothing, not even light can escape, but that sounds pretty weird, right? How can light not escape gravity?

Pamela: One of the things we don't usually realize is light just like everything else is affected by gravity. When you turn on your flashlight beam, it's not shooting in a straight line. It just looks like it's shooting in a straight line.

It's actually getting curved ever so slightly by the Earth's gravitational pull. Now because it's moving so fast it gets a long ways away while it's going so you don't see it fall straight to the floor. You don't turn on your flashlight and see the beam plop to the floor the same way if you drop a marble, it plops to the floor.

Fraser: But if you could turn up the gravity of the planet…

Pamela: You'd be able to see the arc of the beam hit the planet.

Fraser: It would almost be like a jet of water coming out of a hose. It would make that shape right? It would be bending down just like a hose of water and crashing into the planet.

Pamela: But you can imagine taking it the opposite direction. When you have that hose in your hand and you first turn it on, the water pretty much goes straight down to your feet. But as you turn up the pressure in the water, and the water shoots out at higher and higher velocities, it's able to get further and further away from you before it hits the ground.

If you could shoot the water out of the hose at say 12 kilometers per second, that water would never fall back down to Earth. It would actually shoot away from the planet Earth and travel across the Solar System.

Now you can't ever crank a hose up so that the water is coming out at 12 kilometers per second, but you could imagine how this would happen, just a little bit faster the water goes further, a little bit faster the water goes further, a little bit faster water leaving planet Earth.

Fraser: So, you've turned on your hose so strong that water is going into orbit.

Pamela: That's kinda cool to think about.

Fraser: Yeah.

Pamela: But, sadly we can't get there. But the light coming out of the flashlight it's going fast enough. It's going 300,000 kilometers per second.

Earth bends it a little bit but it's on its way to Mars. It's on its way to Jupiter or wherever it's pointed toward because it's moving so fast.

Fraser: No problem. You can, send stuff out into space just by turning on a flashlight.

Pamela: And you're just sending particles of light. Now in the black hole, you turn on your flashlight and the light goes straight down to your feet the same way the water hose does in your back yard. In this case, the gravity is so big on the black hole that it pulls the light straight down to the surface of the black hole.

Fraser: Imagine holding your flashlight standing on some object and you're turning up the gravity the beam is going out into space and then the beam is if you're aiming, it sort of horizontally, coming closer and closer. Eventually it's making it halfway across around the, the planet.

Then it's bonking to the ground, and it's getting closer and closer to you and eventually when you hit a black hole it's where you turn on the light and it just goes straight down. No matter what direction you point your flashlight in, the light just goes straight down.

Pamela: And that's how the Universe works.

Fraser: And that is a black hole. Alright, let's move on to our last question.

We're the Zealand from Collinsville High School and we want to know what a black hole does with everything that it eats.

Fraser: So where does everything go? Does it, as we said, does it go into some other dimension? [Laughter]

Pamela: No. Unfortunately, the black hole does the same thing a quarter-pounder does. Just like a quarter-pounder may make my jeans a little bit tight, when a black hole eats a planet, it makes the black hole a little bit more massive.

Now, what is kinda weird about the physics though is the more massive a black hole is in some ways the smaller the black hole is. We're not…

Fraser: Well, I was gonna ask you that. How big, like if you could ignore the gravity and go down with your ruler and measure a black hole, how big would it be?

Pamela: And this is where physics actually breaks.

Fraser: Does physics break or do we just not understand?

Pamela: Physics as we know it breaks.

Fraser: Right.

Pamela: This means stuff going on that we don't understand.

Fraser: Yeah. Physics is doing just fine. It's just that we don't understand it. [Laughter]

Pamela: We know with neutron stars, and white dwarfs that the more massive they are the smaller they are in radius because the stuff inside of them just packs together closer, and packs together closer, until it can't pack together any more closely.

Well, in black holes, as near as we know, there is nothing pushing the mass apart so it just collapses down to a point.

Fraser: Like a, like an infinitesimally small point?

Pamela: Yeah. And what's weird is it is sort of like, how do you say, one infinity is bigger than another and you really can't. But there are still an infinite number of points between one inch and one and a half inches. And an infinite number of points between one inch and 10 bazillion miles. They are just two different infinities.

Now, what we don't know and what could be true is that that infinitesimally little tiny point gets smaller as you throw more mass into the system and that's just crazy silliness.

Fraser: Whoa…whoa…whoa…wait. Hold on. So you're saying that it's infinitely small…And yet, the more massive it is the more infinitely smaller it can be?

Pamela: Because it's being pulled together more tightly.

Fraser: But even though it's infinite in both situations?

Pamela: We're not entirely sure. This is where it sort of gets into the "well the math could save us". We're not really sure. But it's cool to think about.

The reality is, that the point of no return that we call the short shield radius, the point at which if you get any closer than this you die and you don't escape even if you're a light beam, that point gets further and further and further out the more mass you throw into a black hole.

Fraser: Right. I know, with a regular stellar mass black hole that short shield radius could be very tight end. But with a super massive black hole it could be light years across right?

Pamela: As if you get big enough. Now we don't actually know of any black holes so big that you can't get within a light year of them. But, it's possible.

As the Universe gets older and black holes get bigger and bigger it could be possible some day in the future.

Fraser: Right. And with a stellar mass black hole, you're torn apart in an instant. You get into the short shield radius and whoop; you're turned into a stream of spaghetti.

While with one of the super massive black holes, it could take you weeks of space travel and you're noticing that your feet are tugging a little stronger…[Laughter] Huh, my feet are kinda heavy, different from my head. And after a while it would take before you would actually get torn apart.

Pamela: Yeah. It's, it's one of those sad stealth death problems in the Universe.

Fraser: Right. But once you cross that line you're never getting back out. Earlier on in the show we talked about black holes evaporating so material comes back out of a black hole?

Pamela: Sort of.

Fraser: Mayb?. [Laughter]

Pamela: There are many things in cosmology that hurt to think about and black hole evaporation is one of those things that most definitely hurts. So, when you throw matter into a black hole, it goes in, falls to the center, thrump, it sticks.

But there's all this energy. There's all this stuff boiling in the energy around the black hole. If you have this energy turn into a particle and an anti-particle, say a positron and electron, right on the edge of that short shield moment where say, the positron, the anti-particle of an electron, decides that it's going to fall back into the black hole, but the electron flies off into some other direction. Well the black hole just lost the electron's working mass.

We think that this is sort of the energy of the black hole, and energy and mass are just two sides of the exact same thing. We think that if this black hole's energy can convert itself into mass and some of this mass can fly away that the black hole can slowly evaporate.

Fraser: Wow. So you could end up millions, trillions of years in the future that the black hole would eventually give off all of that mass that went in could come back out again and the black hole would disappear.

Pamela: We're talking really far into the future.

Fraser: Yeah. Trillions, hundreds of trillions, quadrillions of years into the future.

Pamela: Yeah. One of the things that prevents big black holes today from evaporating is they're losing matter at a rate that is slower than the rate that just the cosmic microwave background light falls in. So light from the Universe shining on the black hole is able to give it more energy than the amount of energy it's losing through evaporation. But some day…

Fraser: And you could…right, so we talked about that heat death that some day there will be less energy in the Universe and finally the black holes will be giving off more radiation than they are consuming and they will slowly evaporate away to nothing.

Pamela: Astronomy in many ways is the science of how the Universe dies. But we have trillions of years to get there and a lot of interesting things to try and understand in the interim.

Fraser: Alright. Let's hope that we're still around to see it then.

Pamela: Exactly.

Fraser: Alright. Well, thank you Pamela. And I hope that everyone from Collinsville High School found this educational. I hope this helps you all get an A in your astronomy class. So thanks again for asking all your questions it was a pleasure to answer them. Thanks Pamela.

Pamela: I'll talk to you later Fraser.

This transcript is not an exact match to the audio file. It has been edited for clarity. Transcription and editing by Cindy Leonard.