Astronomy Cast Episode 54:
Questions Show #6

Fraser Cain: It's been a while, so let's catch up with the listener questions. We've got some easy ones, we've got some hard ones, and I think we've got some impossible ones, so… I won't tell you which is which ahead of time.

We actually get this question a lot. I've got two different people, Steven Williams and Lon Blumenthal asked this question: "has it occurred to anyone that we live inside a black hole?"

Dr. Pamela Gay: The question has occurred, and the answer is no.

Fraser: No.

Pamela: No.

Fraser: Why do people think we might live in a black hole? That seems kind of crazy to me.

Pamela: It's a lot of science fiction. There's this idea in science fiction that you can fly into a black hole and emerge in a completely different part of our universe, in an alternate universe… and so from these fiction writings, the idea has gotten into the zeitgeist that you fly into a black hole and you fly into a different universe – which means a universe can be inside of a black hole.

The problem is real black holes just lead to death.

Fraser: I guess that's the question – it's like a frog asking if I hop into that blender, will it lead me to another universe?

Pamela: Exactly

[laughter]

Fraser: No, no it won't – a universe of pain.

Pamela: It will lead to death, and yeah – where death leads to is a personal question not based in facts and not addressable in this show.

So no. We know we don't live in a black hole because we have atoms that are whole atoms with spaces between them. In black holes, atoms can't exist. The densities are so high that not even neutrons can hold themselves apart.

An example I like to use is a normal universe is fridge with a bunch of randomly displayed cans of Coke in it and you have to dig around the butter to find the soda. A white dwarf is where all of the cans of soda have been packed in using the Coca-Cola shipping cases to completely pack your refrigerator and you can't fit one more can of Coke inside.

A neutron star is what happens when you put all those cans of soda in a can crusher and make them really small (and the soda sprays in all directions). Neutron star formation gets you a supernova.

If you then squish those leftover remains of cans such that every single molecule in the cans has now been broken, you're nowhere near as dense as a black hole. You have to keep squishing until the atoms in the cans fall apart in order to get to a black hole.

So yeah – real life can't exist in those conditions.

Fraser: Right, so it's almost like it's become a kind of philosophical question and it goes back to that extra-dimensional conversation we had in a well-received episode we did back in the day. I guess it's kind of like it's different – could it be so different that it's not really a devastating matter crusher? Could it be a bold new universe we could explore? (Says the frog hopping into his blender.

Pamela: No.

[laughter]

Fraser: All right. I'm sure we'll get this question more, so maybe we'll address it again later on.

Pamela: We're not going to do any experiments to test this one. Really – you will die if you enter a black hole.

Fraser: But if you do, let us know how it goes.

Next up, Nathan Dye wants to know (this is based on our tidal-locking episode): "would it be possible for a planet with an axis like Uranus to become tidally locked with its star?"

First I want to say I'm going to say urAnus – I don't care what anyone says, that's how I say it.

[laughter]

I know it's one of the legitimate ways to say it, and there's the more "family-friendly" URanus version, but this is how I'm saying it.

So I can imagine you've got a planet like Uranus and it is spinning, unlike the rest of the planets, it's actually spinning like it's been pushed on its side and it's kind of rolling around the solar system. Could an object like that become tidally locked to the star?

Pamela: Only if it agreed to have its axis rotated again – and that's actually possible.

You can start off with a top happily spinning with its bottom facing the table and its top facing the ceiling and over time it will flop on its side and commence rolling around on the surface of the table. That's because gravity exerted a torque, it became unstable, and it fell over. It was rotating about its axis the entire time, but how that axis was aligned changed.

In order to tidally lock a planet like Uranus, you have to rotate its axis of rotation; you have to pivot it around so it looks more like a normal planet. As long as its axis of rotation isn't perpendicular to its orbit, as long as its equator and its orbit aren't lined up, you can't really tidally lock it. There's nothing to really grab onto and slow down.

We've learned in studies of planets like Venus that it's possible for distributions of material on planets to cause the planets axes to pivot. There are people who have gotten computer models to actually flip Venus over on its head just using gravity.

Now, since Uranus is a gas giant, it's kind of unlikely that you could flip Uranus enough to tidally lock it, but if you had a rocky planet that got knocked on its side through some sort of collision and it had the right distribution of mountains and it was close enough to a star, (if, if, if, if, if…) it's possible that you could end up torquing the planet (that's another really fun word to say).

So we're torquing Uranus (and we still manage to be a family friendly show). If you torque Uranus correctly, and if it had a mountain or something (which it doesn't have), you could tidally lock it.

Fraser: Isn't the question kind of meaningless? Think of the case of a tidally locked planet. Its rotation period is exactly the same as its orbital period. So one big lumpy bulge is always facing toward the star, and it's always facing that way as it goes around the star. I guess if you're up above looking down, you're going to see the planet slowly make that orbit, but if you've got the planet on its side, and yet it's got that one face – it's very top – aiming toward the star, couldn't it still be almost rolling around the solar system?

Pamela: This is where it starts to become a two-step process. As long as Uranus (or a planet like it) is oriented such that its north pole always faces the Sun and Santa Claus is always experiencing sunburn… in that situation you can't just tidally lock the planet.

You actually have to find a way to pivot the planet so it looks like all the other planets. Step one is change the axis of rotation. Step two is tidally lock it.

Fraser: I imagine I've got a ball on a string, and I'm spinning it around my head. The ball is tumbling as it goes around, but its north pole is still going to be facing me as I'm spinning this ball around. Wouldn't there be irregularities around the top of the planet so that it would eventually slow down its rotation, because it's always getting grabbed in certain ways, until it stops and is on its side and always facing the exact same face to me. At that point it doesn't matter anymore.

Pamela: So what you're envisioning is the north pole always facing the Sun, and equatorial Africa is always facing the north star?

Fraser: Yeah. And then it doesn't matter anymore, because it stopped moving because it's turned into a tidally locked planet. With a tidally locked planet, one chunk of it has to be aiming toward the star, and that's that.

Pamela: The problem here is if you start off with a situation where now we have knocked the planet Earth over so the north pole is facing the Sun, but it's still rotating around. At the beginning of this problem we have equatorial Africa facing the north star and then twelve hours later (or some period of time later) we have some place in equatorial south America facing up toward the north star. So the planet is still rotating about its axis, but the axis is pointed toward the Sun.

If I want to tidally-lock the Earth to the Sun in this situation, I somehow have to be able to grab the Sun at its equator and slow it down. That requires a force that's either up toward the north star or down toward where the current south polar area is.

Fraser: What if the most mass is at the north pole?

Pamela: If the most mass is at the north pole, the Sun may be able to knock the planet over so the rotation axis is facing the Sun. It's not going to be able to grab onto that and stop the rotation, because there is symmetric torque all the way around. It doesn't slow down the rotation, it just pivots the planet around.

It's sort of like if I want to close a door, pushing on the door along the door – sticking my hand on that little catch that keeps the door closed – if I push on that catch, the door is not going to move left or right, it's just going to hang out going "you're pushing me into my hinges, what are you trying to accomplish?"

So you can't really torque a rotating planet that has its rotational axis pointing at the Sun, to get it to stop rotating. You have to exert the force from either below the planet or above the planet. So it's one of these things where the angles don't work in your favour.

Fraser: I guess the point is in the end the Star will wrench the planet into its happiest place, and that will be that.

Pamela: Exactly. Sometimes rotations are allowed to keep on happening.

Fraser: Okay! This is going to be the whole episode just on this one question, so let's move on.

[laughter]

Pamela: But it's a good, complicated question!

Fraser: It is a good question, yes – I like it, that's why I had more to talk about.

Okay, so Damon asks us, "why are young stars blue? Why are there red giants, blue giants and dwarfs of different colours? What determines a star's colour? Was our Sun born blue?"

Pamela: This is one of these things where I have to admit I'm one of the people that have helped get the concept out there that young stars are blue.

Now, not all young stars are blue, but all blue stars are young. A star's colour is determined strictly by its temperature. Really hot objects are really blue, and cold objects are really red (the exact opposite of when you draw a thermometer). To get a really, really hot star, you have to be blowing through fuel at huge rates.

So when you look at a population of stars, if that population of stars has blue stars in it, you can say the population is young. Some blue stars only last a couple of million years. A little tiny baby red star can live for tens of billions of years.

That little baby dwarf red star is born red. It stays red, it just keeps going red. That blue star was born blue, it will go through phases of different colours as it gets rid of mass and all sorts of other craziness. It lives for only a brief period of time.

So if you look at a population and there are blue stars in the population, the whole population is young. If you see a population where all the stars are red, that means all the hot stars have died. Colour comes strictly from temperature.

Fraser: So our star, did it start out yellow?

Pamela: Our star started out more blue than it is currently, but it didn't start out blue, blue, blue. It went through a period where it was warmer than it is today (so it was blue-er than it is today), and settled down to the current colour. It's heating up again such that it's slowly going to get a little more yellow. We're never going to get to be a true blue star like Rigel, we're just going to vary through different shades of yellow or orange depending on how your eyes perceive colour.

We're also going to eventually bloat up, cool off and become a red giant star. Cool stars are red. It's through these different processes – how much light a star gives off and what colour it is – that the names come from. So a big, bloated star that's not burning through a lot of fuel but is burning helium in its core, that's a red giant star. A star that's burning hydrogen in its core and has a red colour is a red dwarf.

"Giant" refers to what's being burned in the core. Giants can be burning helium or carbon – but they're not burning hydrogen. Dwarfs, they're burning hydrogen in their core. The colour is telling us how much stuff they're burning. Blue giants are burning huge amounts of stuff – it's like a really well stocked fire will get yellow-er, and whiter and if you stock it hot enough (not that I've ever done it), you can get a fire white-hot/blue-hot.

Fraser: Is there a limit? Could you have the perfect star burning at the hottest possible thing that it shifts right out of the visible spectrum and straight into ultraviolet? Would it disappear from our eyes?

Pamela: Not so much, because stars are actually giving off not just one colour, but a whole variety of colours in what's called a blackbody spectrum. When we talk about the star's colour, that's the colour of photon that comes off in the highest number. So, our Sun is currently giving off light in the infrared, the ultraviolet but most of it's light in the visible spectrum. That's why we perceive it as a yellow-orange star – but all those colours are present, just in lesser numbers.

You can conceivably have a star that's gotten so hot that it's giving off most of its light in the ultraviolet. We can't see that in our eyes, but we can see the other colours it's giving off. We can see the blues, the reds, and the infrareds. Because our eyes cut off in the blue, we'll perceive that star as being blue.

Fraser: All right. So it's an average, but it's the average of what we see most of the time. Okay.

Pamela: Yes. It's a weighted average – if you look at a room with 80 brown-haired girls in it, you might say the room is full of brown-haired girls even though you might have one red-headed boy, three brown-headed boys and one red headed girl... what we perceive is what there's the most of.

Fraser: Moving on, we'll get another question here. This one is going to break everyone's brains – I guarantee this ahead of time. So if someone asks you why you're looking a little numb, blame this question. Dave Stites asks, "my birthday is September 30th. (happy birthday, Dave). Can the universe be said to have a birthday, or due to the deformation of space-time, does it transcend this notion?"

So I guess what Dave's getting at is we know that relativity means people experience time at different rates. Even though the big bang occurred in one moment, has the movement of all of the objects in the universe through relativity changed the time? Could there be a time that would be considered the birthday or is that lost in motion?

Pamela: This is such a wonderful question. I'm going to walk up to someone who does a lot of relativity later today and ask this question and watch the twitchy-ness occur.

What's so cool about this question is there's two different ways to look at it. First of all, there's the question of when do I celebrate the universe's next birthday, when does Andromeda celebrate it?

If I assume the Milky Way and Andromeda Galaxies have been chewing through space side-by-side for the past 13.7 billion years, then as long as both systems have been moving at the same velocities the whole time, my individual perception of time and the individual perception of time of someone in Andromeda, should be the same.

But it takes time for light from Andromeda to get here. I might decide I'm going to celebrate the universe's birthday on one day. If someone made the identical decision in Andromeda, and celebrated on the exact same day I did, I wouldn't know that for over 2 million years, because it takes time for the light from Andromeda to get here.

So we can't watch people celebrate at the same time, because we can never see anyone else as they are in the moment that they are.

So that's the way it breaks you once.

Fraser: Sure, but let's go with a theoretical thing. Say I'm running around in circles at close to the speed of light and you're standing there, and we decide to celebrate the universe's birthday from our relative positions.

Pamela: This is the way it breaks you twice.

Andromeda and the Milky Way may have been ploughing through the universe at the same rate for the past 13.7 billion years, but there are other systems out there that have been orbiting faster. There are individuals, presumably, somewhere out there on planets that are orbiting high-mass stars that are orbiting systems where they orbit significantly faster than we do. The faster you move, the slower you perceive time. There are all these different potential motions, and every time you change your velocity compared to somebody else, you change how time is ticking for you compared to somebody else.

So a part of space that has been orbiting a supermassive black hole, or a part of space that's just been orbiting a neutron star, those parts of space are going to perceive the passage of time at a different rate, so they'll be ready to celebrate the anniversary of the big bang at a different point in time, than somewhere else in the universe that is maybe completely isolated and sitting there going, "the universe is expanding around me but I'm not going to move."

Fraser: Wouldn't they be celebrating before we did? And be sending us their happy birthday celebration announcement, and we'd be all "what're you talking about? We've got to wait another billion years."

Pamela: The dude who's not moving is the one that celebrates it first. Then it's the people who are moving faster and faster and faster – for them time is slowing down. So they'll be ready to celebrate a little bit later.

It's all a matter of how fast you have been moving that tells you when you're ready to celebrate the anniversary of the big bang or the birthday of the big bang, however you want to look at it.

Fraser: That's cool.

Pamela: It's very cool.

Fraser: All right. Moving on. Damon Harvey asks "whenever I see a re-enactment of the big bang on TV science shows, they always show the familiar explosion with lots of light. Was visible light – or any light – a real component of the big bang at the time before the release of the cosmic microwave background radiation?"

In other words, if I was inside the big bang while it was going off, would I be able to see anything with my eyeballs?

Pamela: This is actually a really cool question. What's wrong with these depictions of the big bang as an explosion, but that they convey the idea that the universe is expanding away from a single point. It's not. All of space is simultaneously expanding – not away from anything, just expanding. Light was a real part of it.

In the original moments of the universe, everything was pure energy: quarks, photons and no atoms. Slowly, during a period called baryogenesis, we started getting matter and anti-matter forming and colliding and exploding off of each other. Then we had these nuclear reactions going on and all of these processes are producing more and more light… but it couldn't go anywhere.

An example I recently used with a bunch of schoolchildren was imagine a living room packed with 25 little girls, 25 little boys, and 25 hyperactive little yappy dogs. They're all trying to run around as fast as they can. None of these critters can get very far before they collide, knock into each other and have to change their paths. They can't run in a straight line.

When the CMB happened it was like all of a sudden a teacher said "grab your partner!" and all of the human children grab onto a human child and stand really close to one another. At that moment, all the little yappy dogs escape from the room entirely.

Those escaping yappy dogs were just like the cosmic microwave photons escaping in all directions. All of space was all of these different rooms, such that one room's yappy dogs, one area of space's bits of photon, are now getting to me. The photons that were created in our part of the universe are now getting to somebody else.

So all that light was already there, it just couldn't get anywhere until the CMB occurred.

Fraser: It's almost like if you were inside that ball, the distance from the front of your eye to the back of your eye would be an enormous distance, the likes of which the universe had never known before.

Everywhere else in the universe is completely cram-packed full of photons mashing into each other. If you were actually able to stick your little eyeballs into the universe at that point, it would be the largest space in the universe, which would instantly fill with photons. The point being it's kind of hard to describe or imagine what it would look like to look. It's like looking when you're in the bottom of tar – everywhere you look is just black (or the opposite, I don't know).

Pamela: Here, everywhere you look is light.

Fraser: Yeah.

Pamela: What's cool is the universe was expanding so fast that in the first gazillionth of a second, yeah – it's smaller than your eyeball, but within seconds it's bigger than a galaxy. The universe was expanding faster than anyone can really conceive except using computers. Today we can only see a few percent of the universe – and we can see an awfully huge distance. But the universe expanded so much during the epic of inflation during the first few seconds, that it carried everything amazingly far apart. Space itself was expanding such that two non-moving objects would see the space between them grow so much they'd see each other as moving faster than the speed of light (they're not moving, just hanging out on their grid of space, but the grid of space was expanding faster than the speed of light).

Fraser: I know we're going to get a million questions about this. We are going to do a separate show just on inflation and explain how the universe can expand faster than the speed of light.

So I think the amount of time you would have while everything was light, was just a fraction of a second. If you were there for that moment, it would all just be light.

Pamela: Everything would be light. But after that, for the next 300 thousand years, you could still be hanging out looking around and the light was so dense that it would still be bombarding your eye. It would be so energetic that your eyes would be forced to re-emit it after being completely destroyed.

Fraser: Right, right, right – I'm imagining I have these invulnerable superman eyes.

[laughter]

The point being that you've got light moving. Imagine every photon's got a trajectory it's on, and then normally if I was going to bump up and that other photon was going to bump down, left or right and the universe expanded… you've got all these photons trying to continue on that trajectory. Normally they would've bumped into something else, but now space has opened up so they can continue on those trajectories. If you're standing out there in the middle of it, you've got these photons that were on these trajectories finally getting a chance to go somewhere and your eyes happen to be what's in front of them.

Pamela: Yeah.

Fraser: Yeah.

Let's move on, because I don't want to ruin our inflation show.

This is great too – we get this question a lot as well. Robert Roland asks, "if we assume the universe began in a hot, dense situation, what mechanism prevented it from becoming or remaining a black hole, the most super-massive one possible?"

I'll add that I can imagine if you took all of the mass and light in the universe and somehow brought it to one location, it would turn into a supermassive black hole containing all of the mass of the universe. What is the difference between that and the big bang, which contained all the mass and energy of the universe?

Pamela: This is a really wonderful question. The first time someone asked me this, my brain actually stopped. Then it realised the answer.

In our modern universe, if you throw a whole bunch of mass together without giving it some way to support itself, it'll collapse. If you put enough of it in one place, it will collapse into a black hole. What's happening here is mass, within the framework of space around it, collapses compared to space, and it can drag in stuff around it.

In the beginning of the universe, everything was as dense as a black hole. So one chunk of space can't really pull on any other chunk of space because they're all the same density. There's no place that has a higher gravitational pull than some other place. Everything's about the same density, and the space that all of this stuff is embedded within is what's carrying it apart.

Fraser: So that's the extra ingredient.

Pamela: That's the extra ingredient: the space is pulling everything apart.

Fraser: If you made a supermassive black hole now, you wouldn't be cramming space into it.

Pamela: Yeah, it's just a single point in a vast universe.

Fraser: But in the big bang, the extra ingredient was love – no, the extra ingredient was space itself that was jammed into the big bang singularity as well.

Pamela: So what was able to overcome the gravity, was the expansion of space. So yes, you have this huge, dense area where the conditions would've been as dense for a period of time as the centre of a black hole, but then space itself carried all of that energy and matter apart and spread it out thin enough and it spread it out thin enough that instead of forming a supermassive black hole, it was able to form stars, galaxies and us.

Fraser: Cool.

I think that's it – that's the answer. I've got nothing else. The difference is that it had space, and that made all the difference in the universe.

Let's move on then. Joshua Leviton asks, "although gamma rays pass through all matter, would an organism be able to have eyes that could see wavelengths of gamma rays, or is this impossible because gamma rays pass through all matter and can mutate DNA?"

I know that gamma rays don't hit us down here on Earth, thanks to the Earth's atmosphere, so it almost seems like it's not something an organism would evolve. Let's pretend that we had organisms that wanted to keep safe distances away from a nuclear reactor – would they be able to evolve some kind of gamma ray detectors? And what's a gamma ray detector?

Pamela: Gamma rays don't really pass through everything. They can pass through stuff: they're really high-energy particles of photons, and I think this person may be combining the ideas of gamma rays and neutrinos.

Gamma rays do pass rather well through different things. X-rays will actually pass straight through a wall – in fact they'll pass through your hand. Gamma rays are even higher energy than x-rays, and they will pass through you unless they hit just the right part of a piece of your DNA and cause cancer (which is a bad thing).

We do have things on the planet Earth that create gamma rays. There are different nuclear reactions. You can have a bit of nuclear material that lets off a gamma ray when it decays. Inside of nuclear reactors you can have different things that give off gamma rays. The way we detect this is we have crystals that are scintillation materials. When a gamma ray hits part of this crystal, it will give off normal light we can detect with normal detectors.

You can imagine some sort of science fiction creature that developed with eyes that instead of having normal lenses to focus light, the lenses instead are made of some sort of scintillation material such that when a gamma ray hits it, the material radiates off light the detectors of the eyes are able to see.

The problem is we really don't know how to focus gamma rays very well. They don't like to be focused, you can't use a normal lens – they'll just fly through it. We have to use all sorts of crazy reflection techniques to try and figure out where gamma rays are coming from. So you're really looking at having a creature that has giant eyes that are somehow able to funnel the gamma rays in a meaningful way.

I'm not sure why such an organism would exist, but I see a great sci-fi plot emerging out of this with some sort of crazy creature out in space (I don't know what it would eat, or how it would survive, but it has really cool eyes).

Fraser: Right, I think we always make that comment – if you could just look up into space with gamma ray eyes, the brightest object would be this or that. Imagine if we could have some actual life form that could see it. It's important as well because the way they detect gamma rays is different from the way we detect regular light. You can't have a great big mirror, you've got to have something completely different – a crystal detector.

Pamela: It's just cool to think about. All the normal ways of designing eyes we have (a lens that focuses light, a retina that detects the light) you have to throw out the window. If a gamma ray hit your retina (and hit it just right) it would destroy your retina. That's generally a bad thing.

The scintillation material doesn't really focus it, it just transforms the gamma ray light into a different type of detectable light. You still have to come up with a way to focus it using reflections, after detecting it with scintillation crystals before it can get to a normal retina.

It's kind of cool.

Fraser: So it's unlikely.

Pamela: Unlikely.

Fraser: We'll call that life form unlikely, here in our gamma ray protected atmosphere.

We've run out of questions.

Pamela: Okay.

Fraser: Well, we haven't completely run out of questions – we have mountains of questions still to get through, so we may get a couple more questions shows bunched up here as we continue our tour through the solar system.

If you have any questions about the universe, space, astronomy, previous shows, please feel free to email us your question, or even better send us an audio question and we'll incorporate it into a future show.

This transcript is not an exact match to the audio file. It has been edited for clarity.