Astronomy Cast Episode #35:
Listener Question Show #4

Fraser: It's been a long time since we've tackled the listener questions and they are starting to pile up, so I thought we'd catch up and help everyone make sense of the Universe, but first I want to remind everybody that this show is a little bit interactive. If you have questions about the Universe or if we cover a topic and you don't think we've covered it well enough or you still don't understand what we're going on about, drop us an email and send in your question and we'll try and bring it back for a future question show.

The other thing, and this is our favourite thing, is if you can actually record your questions. Take your computer, if you have a microphone record your question and email that to us and we can play it on the show.

So, no recorded questions this week unfortunately, but we've got a bunch of great questions. Let's start.

Carl (hopefully I get this right) Carl Lepine asks, "how does gravity escape a black hole?" That's a really good question because if gravity is some kind of graviton particle, how can the particles themselves escape the gravity…

Pamela: I have to admit, I thought about this and went, "ooo, cool question!" and went down the hallway, found myself a theoretical physicist who didn't want to grade and said, "how does this work?" The person I was talking to is Dr. Chris Glosser, and the way he explained it is, there's this thing called the uncertainty principle that a lot of us learned about in chemistry. It says that we can either know exactly where something is located or how fast it's going but we can't know both things exactly. Because of this, weird, funky stuff can happen and we can know about how a group of things are moving but not necessarily how individual things are moving.

Stuck in the details and some really pretty Feynman diagrams is this idea that while information can't get across, the Schwarzschild radius, the escape radius of the black hole, forces can escape black holes. So, a black hole can have charge and you can actually feel the force of the charge of the black hole. Black holes have gravity. That gravity can get communicated across the Schwarzschild limit. It's simply information itself that can't make it across.

Fraser: Isn't there information in gravity, or information in energy? Like, for example, a computer is information and it runs on electricity.

Pamela: This is where quantum mechanics starts to get a little bit sketchy.

Here we're looking at, on the philosophical, Einstein relativity level, gravity is physically bending space. You have a field that is going across the Schwarzschild limit and that field is continuous across the limit. It's the slope of the field that we get communicated across the limit.

Fraser: That's where we've seen those pictures of the black hole as bowling ball on a sheet of rubber, right?

Pamela: Exactly, except here we have to actually think of it as, we have a three dimensional Universe that is somehow getting bent into a fourth dimension.

Fraser: And the bowling ball, or the black hole, the slope of the Universe, of the space as it approaches the black hole that can go right past the event horizon, right to the singularity.

Pamela: But things like gravity waves, which we've talked about in earlier episodes, those can't get across the event horizon. So, information itself can't get across the event horizon but forces can act across the event horizon.

Fraser: Okay, so with gravity waves we would see a gravity wave the moment a black hole is formed, but we wouldn't necessarily see a gravity wave if the black hole happens to consume something big.

Pamela: Exactly. At least, that's how I understand it, and I have to admit this is starting to get into the boundary layers where quantum mechanics and gravity attempt to interact with one another, and it's right on the edge of my ability to follow a discussion. My hat's off to Dr. Chris Glosser, he really has a firm understanding of this and was able to communicate it effectively.

Fraser: All right. So, let's move on then. Dwight Randall says, "Astrophysicists have talked about matter versus anti-matter. How does dark matter compare to anti-matter? Is there such a thing as anti-dark matter?"

I think with this, if I get this right, anti-matter is this opposite of matter and if matter and anti-matter are collided together (or even touch each other) they are mutually annihilated and turn into energy. Since we know there's dark matter up there, is there some anti-matter version of dark matter? That's a great question.

Pamela: This is one of these things where there's our first level understanding of physics that we pick up in magazines, that we pick up in high school and college, that says all matter will self-annihilate on anti-matter, they must be kept away from each other.

But then there's this second level, where there's things like anti-neutrinos that are passing through your body in huge numbers every second. The neutrinos coming off the Sun are anti-neutrinos, but they're not annihilating us as they pass through our bodies.

There are anti-matter bits that there's no mechanism for them to annihilate, so an anti-neutrino and a neutrino that come into contact are just going to go, "ahhh" and then pass past each other. Neutrinos are one small part of the dark matter recipe. We're looking at probably less than one percent of the dark matter recipe. They are a piece of matter that only interacts via the weak force, and they're out there in both matter and anti-matter forms. There's no reason to think that there aren't other matter and anti-matter things also out there making up the dark matter constituency and just not self-annihilating because they don't know how to react in an annihilating sort of way. I guess dark matter's stuff that knows how to get along well.

Fraser: When we count up the matter in the Universe, and weigh it, and it accounts for four percent of the Universe, we don't think that there is any free floating anti-matter out there, right?

Pamela: The problem is, how do you weigh something and say, "this is matter and this is anti-matter". They both have mass in the same sort of way, what makes something anti-matter is it has the opposite charge of it's normal matter constituency – you have electrons and positrons, protons and anti-protons and they have opposite charges. In the case of protons and anti-protons, they're made up of anti-quarks. In the case of electrons and anti-electrons (positrons) they're symmetric versions of one another.

But in terms of mass (and we think that mass comes from how things interact with the Higgs-field, and you start getting into scary particle physics here), in terms of mass, there's no such thing as something having a negative mass. Both matter and anti-matter will have mass in a similar way.

A planet could orbit an anti-star, the problem is that anytime a regular particle fell into the anti-star they'd self-annihilate and the Universe isn't a perfect vacuum. So as near as we can tell, looking out across the Universe, there aren't anti-stars. But if there was one that was able to somehow form in a perfect, perfect, perfect vacuum, where there were no particles near it ever, we'd never be able to know it was an anti-star. Probability-wise, this will never, ever happen.

Fraser: I can imagine the planet orbiting the anti-star being buffeted by the solar wind and it being a lot more dangerous than our solar wind

Pamela: Yeah! Exactly.

Fraser: Okay, so I guess that because there seems to be anti-particles for everything that we know of so far, it's almost like a natural conclusion that there could very well be an anti-dark matter particle.

Pamela: Yeah. There's a few mass-less particles that don't have anti-particles, like photons – there's not an anti-photon, and there's not an anti-gluon. As far as we know, the stuff out there that has mass… all of that stuff also has anti-particles.

Fraser: Since we don't know what dark matter is, why don't we just search for the anti-dark matter particles and say it's the opposite?

Pamela: There you're assuming there's a mechanism for these anti-matter particles in the dark matter part of the Universe that have a way to annihilate. They could be just like anti-neutrinos, where there's really no easy annihilation mechanism for them.

Fraser: All right. That is a puzzler.

[laughter]

Pamela: It's fun, but it hurts!

Fraser: The first question was about black holes, the second question was about dark matter, third one… let's put them together.

Pamela: We're just on a dark roll

Fraser: I know, it's totally…

[laughter]

Okay. So (and I'm going to mess up the name again), Bruno Wroblewski asks, "so just what is the relationship between dark matter and black holes?" So put it all together!

Pamela: So, black holes are basically big, massive objects that things that interact via gravity can fall into. So, in theory, since dark matter interacts gravitationally, dark matter should be able to fall into a black hole the same way any other type of matter can. If it's headed off in the correct direction where it's never going to get anywhere near a black hole, it's just going to keep going. But if dark matter does head in the direction of a black hole with a low enough velocity that it can fall in, it's going to fall in.

The neat question is… regular matter, as it falls into a black hole, if too much of it tries to fall in at once ends up forming an accretion disk and you get these gorgeous jets and this is how you end up with active galaxies. So can dark matter do that too? Here's where I don't know the answer.

A lot of theorists talk about dark matter probably being a collision-less type of stuff. This means that as the dark matter particles form their clouds they generally don't interact with one another.

Fraser: I remember when they discovered some evidence for dark matter, I think it was earlier this year, they had two galaxy clusters that collided or passed through each other, and they were able to detect that the clouds of gas collided and slowed down but the dark matter, even though it went right past each other, continued on without interacting at all. It's almost like this collision separated out the gas and dust out of both galaxy clusters, but the dark matter just kept going so it didn't even interact at all. It's almost like it wouldn't choke up around the black hole, right?

Pamela: The way to think about it is, I've used this analogy before, if you and I walk across the room and we walk across such that our shoulders biff into each other, we're going to collide. Now, with electrons and things, they don't have to physically touch in order for a collision to take place because they interact via the electromagnetic force.

Well, with dark matter, you can have these itty-bitty, little, tiny, tiny, tiny particles that don't interact in any way except perhaps via gravity, perhaps via the weak force and so they can pass practically directly through each other and no interaction will take place. This is why so many neutrinos can pass through your body and nothing bad ever happens.

Now, we generally say with dark matter, it's collision-less. If it was colliding, we'd see the dark matter get more scattered out, the distribution of it would be smoother, sort of like if you shake a bunch of marbles you can watch them collide off of each other and this will scatter the marbles in all directions. If the dark matter particles are colliding, they're going to scatter and you'll end up with a smoother distribution of dark matter.

But, it's possible to have dark matter particles that have such a small cross-section that the probability of interaction is excruciatingly low, so low that we say they don't collide. But it's a non-zero thing. They still have physical dimensions, they are a particle and there is the really tiny, tiny probability that they will collide head on, interact via the weak force, just like neutrinos every once in a while do interact with dry cleaning fluid in mines under the surface of the Earth.

Fraser: So we can get a situation where, like with matter you get accretion disks which is where these particles are bonking into each other and slowing each other down and all entering a nice, orderly (or disorderly) line up to get into the black hole. With these little particles of dark matter, they could be so small and so non-interacting with each other that they could just be zipping past the black hole and never slow down and so never get sucked in.

Pamela: Well, they'd still get sucked in they just wouldn't collide with each other as they got sucked in.

Fraser: Right, but I guess the point is that if matter didn't interact, it wouldn't get slowed down and go into this accretion disk in the way that it currently does, right?

Pamela: Right

Fraser: So only if the dark matter made a direct shot right into the black hole would it actually get sucked in. Otherwise it's just going to make these little ellipses around the black hole.

Pamela: Right. Exactly. So you can end up with the dark matter is more likely to be orbiting rather than falling all the way into the centre. The thing is, there's a density at which if you get enough dark matter in one location, you can end up with dark matter accretion disks and here I don't even know how to begin those calculations or if I could do the calculations, how to observe that. So, it starts opening some really neat… how could dark matter interact if it has a non-zero cross-section as it falls into a black hole?

Fraser: So I guess if anybody knows of any dark matter accretion disks around active nuclei of galaxies, let us know.

Pamela: Or if there's a theorist out there who's figured out this problem, we'd like to know how you figured it out.

Fraser: All right. Let's move on: now, we didn't get the name of the person who asked the question, "BeaverZ" was the email address and I thought it was a great question – it was essentially, can a moon have a moon or can a planet have two suns?

So, could you have, for example, the Earth with it's moon and then the Moon would have another moon? Or could you have a binary system which I guess you'd have I guess a trinary system where you've got like in *Star Wars* two suns in the sky… would a planet actually be able to survive in that kind of environment?

Pamela: Yes, and yes! This is where sci-fi and some of it's prettiest paintings are actually made into reality in our Universe. There is actually a binary star system, Gamma-Cephei where we know that there's a planet orbiting the larger of the two stars, and so you have: big star, little planet (well, it's actually a fairly big planet, it's a hot Jupiter) – hot Jupiter going around a big star, and out at a very large distance you have a second star. There's also a system, Tau-Bootes where you have planets again, and it's another binary star system.

We're starting to find these all over the galaxy, so catch seems to be that you have to have a wide binary. You have to have two stars that are far, far apart and one of the stars has planets that are very close in and orbiting only the one star. We don't know of any systems where you have a planet orbiting two stars that are close together.

Fraser: It sounds like that would be the problem, that if you had the planet try to go around the two stars, there would just be so many combinations that it would eventually get kicked out or consumed by one of the stars.

Pamela: It's also a problem of how do you form something like that, because you could end up with a low-mass planet or, any mass planet for that matter, orbiting the centre of mass of two near-by stars, it's just orbiting far out so that it doesn't see those two stars as two piles of gravity, it sees it as a single centre of mass of those two stars. But it would have to be awfully far out, and how do you form a planet there?

You could, in theory, get one out there through interactions that kick it out, but I think there you're starting to get into the situation where you have to steal a planet from somewhere else.

Fraser: And then the moon going around a moon… could our Moon have another moon?

Pamela: Oh, easily. Think about the Apollo satellites; those were moons going around the Moon. The definition of a satellite is just something small going around something else. A moon is a type of satellite. So, when we sent the Apollo missions out to the Moon, we were giving the Earth's moon its own moon for a little amount of time.

We've seen asteroids that have their own moons: there's Ida and Dactyl. Imagine if Jupiter captured Ida and Dactyl – then we could have these two asteroids with the small one orbiting the larger one both orbiting a giant gas planet. So this is completely feasible yet again.

Fraser: Now is this a situation… would it be stable, would it be able to last for a long period of time or would Jupiter's tidal forces eventually tear them apart?

Pamela: It's all a matter of the distances. If you have Ida and Dactyl far enough away from the centre of mass of, say, Jupiter, that the effects don't try to shred Ida (which is the larger one) and Ida's gravitational pull on Dactyl dominates Jupiter's gravitational pull on Dactyl, then yes it can be completely stable.

Now if you try and form a closed system like this in a low orbit, they're probably going to separate themselves.

Fraser: So I guess in our situation the Earth is able to have it's moon and it's going around the Sun. The Sun doesn't tear our little friendship apart, so if you got a similar situation but to scale, had a little moon going around Jupiter and it had its own little moon, as long as you placed everything at the right distances and speeds, then it would work.

Pamela: Yeah, and it should be like nesting dolls where it's fully scalable as long as you keep staying at reasonable distances.

Fraser: Wow, that'd be great.

All right. Moving on. Michael Ward asked a question, "what would the Orion Nebula look like up close with our own eyes?" I'm paraphrasing, but essentially, he says, looking at all the beautiful pictures we get with Hubble of all the nebulae and galaxies and gas clouds, is that a realistic view of what we would actually see with our eyes, and could we fly out in a space craft and get to a certain range and look at those objects and see what Hubble sees?

Pamela: There's a couple of different problems here: the first problem is that when we take these really pretty pictures, we're leaving our film open for several minutes, we're using large telescopes to funnel the light into our eyes, we're somehow condensing the photons into a smaller area to make them appear to be brighter. If you're just hanging out in a spacecraft, those things aren't going to be working for you. In fact, the closer you get to these giant nebula, the more their light gets spread out across your field of view and this works to water down the light. Think of it this way: if you took a 100 watt light bulb and split it into 100 one-watt light bulbs and scattered those across the front of your house, they wouldn't appear nearly as bright as that one 100-watt light bulb focussed on one location.

Fraser: And we're looking at objects tens of light years across.

Pamela: Right, so the closer you get the larger the area you're spreading that light out across and pretty soon, the photo receptors in your eye are just going to sort of go, "yeah, there's a slight fuzzy glow there, move on."

So, in order to see these nebula well, we need to have their light concentrated into a small area in our eyes so that the light from these extended objects can actually trigger the photo cells in our eyes. The closer you get, the harder it is to make that happen.

The other problem is that with a lot of the space-based missions and the Earth-bound telescopes that take these beautiful digital images, we're using filters that are sensitive to light in ways not like how our eyes work. Our eyes build pictures out of, basically, red, green and blue photo receptors. With digital cameras we can choose to instead perhaps, be sensitive to infra-red, ultraviolet and green. We can choose whatever sets of colours we want to end up building a picture and then to make those pictures viewable to our normal eyes, we translate often infra-red into red, ultraviolet into blue and so we create false-colour images that are able to condense information our eyes can't see into things that our brain can understand.

Fraser: So in many cases the colours we see in those photographs aren't the real colours anyway.

Pamela: No. So, there's these many different factors that are making what we see in the pretty astronomy calendars and textbooks not what we'd see from a spacecraft.

Fraser: But I wonder if I was an astronaut working on Hubble and I just took a quick peak through the mirror (although it doesn't really have an eyepiece, let's say it did) and looked at Orion, I wonder what I would see?

Pamela: With Orion there, you do have this beautiful blue reflection nebula. Some of the things we see are quite real in their colours, it's just a matter of collecting enough light all at once. If instead you looked at the Orion nebula with a four metre telescope here on the Earth, you'd still see this beautiful blue nebula. It's the extra details, the extra bits of colour that you'd never see with your eyes that get thrown in.

Fraser: How long will they do a recording for? How long will Hubble or one of the big telescopes view Orion for?

Pamela: Oh, it all depends on what they're doing. Some of the Hubble heritage images they've used tens and tens of orbits to collect enough light to make these beautifully detailed pictures.

Fraser: So hundreds of hours sometimes?

Pamela: At least tens of hours.

Fraser: So there's just no way your eye can record that many photons.

Pamela: No, so we're going to miss the nuances, we're going to miss the slight details in the clouds.

Fraser: So, just to re-cap, we've got false-colour and then as you're approaching, let's say you were flying in a spacecraft toward some of these beautiful nebulae, as you're approaching it's getting more and more diffuse around and so you're just not able to see anything.

Pamela: Exactly.

Fraser: That's too bad. There goes a whole reason for space exploration!

[laughter]

Pamela: Yeah, but you'll be able to see all the swirls and whirls on gas giants up close and personal. You'll be able to see the pulses of a pulsar reflect off of the surrounding Interstellar Medium.

Fraser: I guess that's what I was going to ask, what kinds of stuff would look good if you got close?

Pamela: In all of the little comets of the Helix Nebula, you'd be able to actually see. You'd be able to see the hot spots on hot Jupiters, you'd be able to see the differences in different parts of accretion disks, so many different fluid mechanic things where we can say we believe the clouds are doing this, we believe the different parts of the accretion disk are doing this… you'd be able to see those bandings, you'd be able to see those flashes.

Fraser: All right, we'll keep my space exploration program going then.

[laughter]

All right. Let's move on with the last and hardest one.

We covered, back a few episodes ago, we covered what is the Universe expanding into. One of the requirements for that was that the Universe be flat, or that the current thinking among astronomers is that the Universe is flat. So we got a couple of people asking us a question, and this is one from Douglas Sykora, and he says "why do astronomers accept that the Universe is flat?" We said it, but we didn't really go into the evidence that gives that conclusion. So Pamela? What's the evidence?

Pamela: The Cosmic Microwave Background Radiation –

Fraser: Hah, I knew it!

Pamela: --the source of WAY too much information…

Fraser: Always the Cosmic Microwave Background Radiation…

[laughter]

Pamela: Okay, so at the moment that the Cosmic Microwave Background formed, there were different temperature fluctuations in the stuff that made up the Universe. The size of these fluctuations depended on lots of different things. The maximum sizes those variations could be is directly related to the size of the Universe at the moment (and we can figure out these things using lots of complicated physics). The size that we'd see those fluctuations on the sky is directly related to the geometry of the Universe.

So, the way it works out is, if the Universe is flat, we'd expect the angular size of some of these variations to be roughly a degree in size. IF the Universe were spherical, it was a closed geometry, we'd expect the brightest spots to be only about one and a half degrees across, so you get bigger spots for spherical Universe. If it was open on the other hand, more saddle-shaped, then you'd expect the fluctuations to only be about half a degree across.

So very bored scientists who were doing excellent science, went through and measured the physical size of the fluctuations and the amount that they were fluctuated, the amount of the temperature variation and made a plot… and out of this they found that there is a peak in the fluctuation size at one degree across, which directly corresponds to a flat geometry.

So, it's from the number of fluctuations of given sizes in the Cosmic Microwave Background that were able to figure out the geometry of the Universe.

Fraser: And so if the Universe were not flat, if it were curved, what would that make these fluctuations look like?

Pamela: They'd just be bigger or smaller.

Fraser: So, it's like the size of the fluctuations exactly matched their predictions for what it should be if it's flat.

Pamela: Exactly.

Fraser: So, as always the answer is: look in the Cosmic Microwave Background Radiation.

[laughter]

Pamela: Exactly.

Fraser: Wow. I hope that's good enough answer for people, but I suspect they're going to want more.

Pamela: We'll put some links in the show notes.

Fraser: We'll put some links in the show notes and then if people want to keep digging they can keep going. Or, ask your question and we'll have another run at it.

All right Pamela, that's good. Six questions for our fourth question show. Keep more questions coming in and we'll get at them down the road.

Pamela: Sounds great: I'm looking forward to all the great questions that attempt to break my brain in the next question show.

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