Episode 14: How Do You Spell Quasar?
Physicists: Laura Hainline, Sean Moran

Transcribed by Denny Henke

Ben: Over the course of my studies in theoretical physics I’ve traveled across the continent and around the world sampling new ideas and tasting different answers to the questions of how and why. And still I find there remains a deep hunger which lives within me, a burning desire to share these great ideas with the people around me. And so, I have assembled a team of some of the greatest, most lucid, most creative minds, I have encountered in my travels and I call them my Titanium Physicists. You’re listening to the Titanium Physicists Podcast and I'm Ben Tippett. And now allez physique!

[1:49]

Radio astronomy was really a revolution. It's like this. Imagine you're in a forest and you can only look around. There are brightly colored birds in the trees and you can see them. You can even see some of them which are far away in far off trees. Radio astronomy, in this metaphor, is like suddenly being able to hear. You can do more than just see the birds now. Now you can hear them as well. In fact, sometimes you can use your hearing to locate birds that are behind leaves and stuff. You know, just so, radio waves, electromagnetic waves with really long wavelengths, can pass through dust and crap which blocks out visible light. But, what if you start hearing chirps in the forest that can't belong to a bird. What if you start looking towards the place where this weird chirping is originating and you don't see anything there? There's no bird. And if you listen really carefully to this chirp it doesn't even sound like a bird chirp. It's something else. This is, essentially, the problem faced by astronomers in the 1950s. They saw things in the night sky that looked to be about the size of a star but they weren't stars. Stars don't emit light in radio wave frequencies but these objects did. They were very bright in the radio. What's more, when we looked at the emission spectra of these objects we saw spectra that didn't match any known matter. These objects were weird and definitely not stars. Well, eventually the mystery was solved. It turns out that the spectra lines we were looking at were the emission lines of hydrogen. They'd been red-shifted and by quite a lot. Recall that the universe is expanding and as a photon travels through space at intergalactic distances it get's stretched out as the universe expands and it turns more reddish colored. This means that the strange objects were two things. One, they were very, very far away and two they were very, very bright. How far away? 2 to 13 billions of light years as the photon flies. Now keep in mind that our universe is only 14 billion years old so these objects, whatever they are, are really old. What's more, they're bright. How bright? The luminous energy that they put out when they flare up can be 100 times greater than all of the light emitted by the whole galaxy. At the time no one knew much about these space dinosaurs. We knew that they were small, smaller than a galaxy, about the size of a solar system. And we knew that they definitely weren't stars. So, they were called quasi stellar objects or quasars for short. Today we're going to be talking about what the heck a quasar is. And to help us I'm pleased to introduce my guest today, it's Howard Tayler, the author of the hit web comic, Schlock Mercenary.
Schlock Mercenary is a space opera, it's an en epic science fiction. It's what romance of the three kingdoms would be if it took place in space. It's about an amorphous pile of goo named Schlock who's friendly and amoral and has joined a crew of mercenaries travel the galaxy eating snake lawyers and occasionally work for a Koala who's made of computers. Howard has one multiple Web Comic Choice awards and has been nominated four times for a Hugo award.

He's currently in the running this year for a Hugo award for best graphic story for his most recent published collection of Schlock Mercenary strips entitled Schlock Mercenary: Emperor Pius Dei. He's also on a weekly podcast called Braiding Excuses where he talks about writing genre fiction. Hey there Howard, thanks for working so hard on entertaining me for over a decade and welcome to my show.

Howard: It's good to be here. Thank you. By the way, just a quick correction, the Hugo nominated story is actually Schlock Mercenary Force Multiplication, that's book 12 which is only available on the internet and Emperor Pius Dei is now available in print and was never nominated for a Hugo but it should have been but they didn't have an award category for it.

Ben: For you today I have assembled two of my greatest Titanium Physicists. Arise Dr. Sean Moran!

Sean: Heeeeeeeeeeyyy.

Ben: Dr. Sean did his PhD in astrophysics at Caltech and he's currently a postdoc at John Hopkins University in Baltimore, Maryland. He's an observational astronomer who looks at galaxy evolution. Now, arise Dr. Laura Hainline.

Laura: Beep beep.

Ben: Right! Dr. Laura did her PhD in astronomy at Caltech as well and she's currently working as a postdoc at the United States Naval Academy. She studies accretion disks around black holes.

Alright, let's get to talking about quasars.
Howard: Well, let me start with a question. In your description you said that these quasi stellar objects, these quasars were, what did you say, around 13 billion years old, with the estimated age of the universe being 14 billion years.

Laura: Some of them are 13 billion years, some of them not that old.

Howard: Okay, you know, actually he said 13 billion light years away which says the light we're getting from them is light that is coming to us from some of the earliest days of the known universe and so...

Sean: That's right.

Howard: Yes, they're really old but what we're seeing is them really young.

Sean: Absolutely. In fact, they're probably long gone now. We're getting ahead of ourselves when we think that they're not actually all that long lived so they probably sputtered out a long time ago and we've just been waiting for the light to get here.

[6:49]

Howard: So this signal, this light that we're getting from this, the radio waves that we're getting from them, is in fact, say, a transmission, saying, help, I'm burning out too fast and I don't know how to stop. There's nothing we can do.

Sean: That's right. Because even if we could get in our spaceship and travel there it would take us 13 billion years to get there if we could travel at the speed of light.

Ben: Even more because they've, the universe has gotten much bigger since then.

Laura: That's true.

Howard: I just want to take a moment to feel sorry for them. Now let's talk about how cool they are.

Sean: Well, they are cool because they're, you know, blasting out energy clear across the length of the universe, basically. Almost, the only things we can see that far away. So, the amount of energy that's being shoved off in our direction is truly, you know, staggering. Sometimes bigger than what you get from a whole galaxy, leading to the fact that we think that these are black holes.

Howard: Let me ask this question, in terms of the energy that we're getting. The moon reflects energy from the sun and on a night with a full moon, the moon is reflecting a whole lot more energy that my flashlight is. But, if I hold my flashlight up to my face I'm getting a lot more energy out of that flashlight than I'm getting from the moon.

Ben: Yeah.

Howard: Right. So, in those sorts of terms how much energy are we getting from those quasars? I know they are way bigger than an individual star. But are they delivering to us more energy at their range than a star within our own galaxy is.

Laura: No. In general, they can be much fainter than a star in our galaxy.

Sean: So, the trick is that in the radio they actually are among the brightest things in the sky if you, you know, had radio vision and you looked into the sky you would see these as among the brightest things in the sky.

Laura: But that's because stars are so faint in the radio.

Sean: Stars do not emit very much in the radio so that's how these things were discovered is because almost nothing else is this bright in the radio. Even, you know, they are intrinsically very luminous but also the energy that gets to us in the form of radio waves is much more energy than gets to us from almost anything else we see. But in other wavelengths, in the optical and other bands that are not any brighter than say, a faint star the night sky.

Laura: Or a very distant galaxy.

Howard: I think that's hugely cool. I guess that's part of how they were discovered you know you fire up the radio telescope and pull the information into the optical realm where you can look at it and all of the sudden there's a bunch of new stars that are really bright that aren't where you can see anything else.

Laura: Exactly.

Sean: Yup. They look like stars in the optical because they are sort of point like in your telescope but if you take a spectrum, if you split it up, into it's, you know, constituent colors, ah, it looks very different from a star. So, that's why it was such a mystery for so long as to what these were because there were all these sorts of emission lines. And in these quasars the emission lines come from a sort of glowing gas much like a neon sign that has neon that's glowing and emitting a particular color. The quasars have these signatures in this glowing gas that we see and it was not at all like anything we've seen before.

Howard: Okay, so, it wasn't like the difference between a red giant and the sun.

Sean: Yeah (crosstalk, unintelligible)

Howard: But the point is the emissions from a red giant would be a little different from the emissions of our sun but the emissions of quasars are like out in left field...

Sean: Yeah.

Howard: Across town, in a different county, entirely.

Laura: Because the red giant and the sun would have pretty much the same emission lines in the same places because they contain, basically, the same gasses. But then, so when you look at the quasar, those lines that you usually see in the red giant and in a star are not there and there's this new set of lines that doesn't match anything else.

Howard: Now, the new set of lines, you know, when we did the introduction, does red shift move the lines or does the existence of the lines, is that somehow independent of, do we call it a doppler effect.

Sean: Yeah, the lines shift too, so that's part of the answer.

Laura: So, we see them as shifted but but they're still...

Sean: When they were emitted from the quasar...

Laura: When they were emitted they were...

Sean: ... They were something different but as we see them, part of the mystery as to why we couldn't figure out what they were is that they didn't know at first that they were red shifted. They didn't know that they had traveled all the way across the universe because it was so preposterous at the time to imagine seeing light from anything so far away. So when we figured that out...

Howard: When it shifted back does it line up to anything remotely recognizable?

Sean: Yes.

Howard: Do we see hydrogen?

Sean: We see a bunch of common elements, some of the same ones in stars, but the ones that are lit up, the lines that are lit up are not quite the same pattern as you would see in a regular star. Or in a galaxy or anything else familiar. There's some pretty peculiar things about how they look. Part of the reason for that is that some of the things that we are seeing being emitted from quasars seem to be from very highly ionized things. So an an iron atom with like, you know, 10 or more electrons knocked off of it. So, there's some very hot material that has to have been, you know, super heated and stripped of all it's electrons and now we're seeing signatures of that happening so that's one of the lines of evidence that led people to think, well, the only thing that can do this to this matter has got to be a black hole. We've got to be seeing matter swirling down into the, you know, into the drain hole of a black hole. That must be what these things are.

[12:02]

Howard: How hot does iron need to get before it looses that many electrons?

Laura: So, it takes an x-ray photon to strip iron of that many electrons.

Sean: Some of these are non-thermal processes so it's not necessarily the gas is quite that hot, it's that there is enough energy there to be stripping electrons away like crazy.

Howard: Man, this is cool. And inhospitable.

Sean: Yes.

Laura: Yes.

Howard: Yeah, I guess that's a good question, well, how big is a quasar? Do we have an answer to that? Are they galaxy sized objects or galactic core sized object?

Laura: Galactic core sized objects. That's what we actually think they are, they are the cores of galaxies and it turns out that what we can do with our, some of our imaging techniques, in astronomy, is that we can block out the quasar, that central little source and then we can image the rest of the galaxy around it. What we found is that quasars really lie at the centers of galaxies.

Howard: And so all of (unintelligible cross talk) whatever else in that galaxy is reflecting radio light back at you.

Sean: It's more a factor that the radio and optical light that we see from this little point source, in many of the earlier cases was just so bright that the glare from that bright thing was obscuring the fact that there's actually a whole galaxy with lots of stars and everything that is sort of underneath that. And then if you can sort of block out that light you can see, oh yeah, there is a whole galaxy under there we just couldn't see it before. And that, in fact, as we learn more we realize there are a bunch of less bright but still sort of point like things at the centers of galaxies that we knew about. And they're actually the same thing. They weren't called quasars at first but they are still thought to be black holes at the centers of galaxies, they're just a little bit less bright to begin with so we could see both the point source at the center and the galaxy itself.

Howard: Let me ask you an obvious question. You say they're not as bright, are they not as bright because they're just not outputting as much energy or are they not as bright because the flashlight isn't pointed at us?

Laura: That's a very good question. So, it turns out it can actually be both. If you drew a picture of a galactic core.

Howard: I've actually drawn more than one picture of a galactic core... But go on. I probably got it wrong, but ah...

Laura: If you had a piece of paper in front of you what you should do is put a little dot on the piece of paper and that would be your black hole. And then you could draw a circle around that and that will be the accretion disk.

Sean: The accretion disk being the sort of, the spinning disk of matter that's going into the black hole.

Laura: Yes.

Howard: Yeah, that's all the pieces of you know, star stuff, dust clouds...

Laura: Yep.

Sean: Get rid of.

Laura: So, then you can draw another ring around that circle and that outer ring is going to be a ring of dust. And because dust absorbs light from the optical and the ultraviolet, and the x-ray which is where the accretion disk is emitting, the dust can block the light from...

Sean: From the black hole.

Laura: From the black hole. The thing is, so, astronomical objects they can have any sort of rotation.

Sean: We could be looking at it at any angle.

Laura: Yeah, we could be looking at it at any angle. So that the picture I just had you draw with the concentric I circles, that's if you were looking at it straight on.

Howard: Yep.

Laura: But they looked at it edge on.

Sean: You'd be looking just at the dust.

Laura: You'd be looking just at the dust.

Sean: And then your black hole.

Howard: I'd be looking at the Sombrero Galaxy.

Laura: That's the angle, yes.

Howard: Okay.

Laura: And if you're looking at it from that angle the dust would block out all the light from the black hole.

Sean: So some of them are dim, because we're looking at from the wrong angle, some of them are dim because the black hole actually isn't sucking in as much matter and so it's not building it up into a big source of energy.

Howard: It ate everything and now it's...

Sean: Yeah. Well, like the black hole at the center of our galaxy that we think is there, it's not eating a very big meal right now, so otherwise we would see it a little bit more clearly. It would be easier to figure out it was there because it would be one of these quasars. So, how bright these things are does depend on what angle we are looking at, but it also depends on how hungry the black hole is.

Howard: What's falling in. Um, now, you know, when I was in grade school, I was fascinated beyond words when I learned about black holes. The whole idea is that stuff goes in and nothing comes out. It doesn't emit anything, um, and I've been led to understand since then that, yeah, beyond the event horizon it's not emitting anything but all that crap that's falling in as it dies is what's throwing energy back out at us. Is that a fair approximation of what's going on.

Sean: Yup.

Laura: That's pretty good.

[16:46]

Ben: I've got the best analogy ever for this one. I need to give credit to Bill Unruh because it's his idea but it's quickly becoming the place to go for general relativity metaphors. So, the idea is, imagine you have a big shallow lake and somebody has pulled the plug from the middle. And so, there's this sinkhole and all the water is rushing into this hole. If everything is large enough there's going to be a height along the waterfall at which the water is moving down the waterfall faster than the speed of sound in the water.

Howard: Okay, so, we just made a really big waterfall.

Ben: Yeah, right. And it's long but at any point in time in the lake or in the waterfall two fish are going to be able to talk to one another. But, past this height at which water is accelerating ends up moving faster than the speed of sound a sound wave won't be able to travel back up the waterfall, past that point.

Howard: Right.

Ben: This is the metaphorical horizon. If a fish goes farther down the waterfall than that height it's not going to be able to talk to fish higher up.

Sean: Like, hey, there's a waterfall down here.

Ben: Right. So, I guess in this metaphor what's happening is, imagine that there's a whole bunch of ducks in trees and flotsam and they're kind of swirling around the mouth of this sinkhole, almost falling in, kind of jostling each other. Ah, they're going to make a whole bunch of waves as they're running into each other but as long as they're making waves in the water before they fall past that height we're still going to be able to receive information from them. So, in black holes what happens is the space time is kind of flowing into the black hole faster than the speed of light at this event horizon. So, as this gas in the accretion disk around a black hole swirls in and slowly falls in towards the middle as it bumps up against other gas, as long as the objects are outside this radius, we're still going to be able to receive light from them.

Howard: Okay. The metaphor police have told me that you can't have the talking fish but other than that, other than that, great metaphor.

Ben: Thanks.

Laughter.

Howard: So, and I guess all that rotational energy, just the fact that it's moving around faster and faster and not knocking into each other, all this matter in the accretion disk, that generates energy. It's getting hotter by doing that and that's the quasar light that we're seeing.

Ben: Exactly

Laura: Yeah.

Sean: Now, there's some complicated stuff that happens right down in the mouth of the black hole and some of what happens to convert the energy of that infalling matter into the light we see is still not really quite understood. Ah, so, it's really at the hairy edge of what we understand but in general that's, that's how we think it happens.

Howard: Okay, so let's come, let's come back for a moment and say there's noises coming out of this lake that don't make sense as just trees bumping into each other so, we're postulating, talking fish for now.

Sean: Yeah.

Laughter.

Laura: Why not.

Ben: One thing we mentioned earlier was that, so, in terms of the luminosity that these quasars put out, the black hole is the only candidate for how bright it is, right? So, in stars...

Howard: Okay.

Ben: The light comes from fusion at their hearts and in essence, ah, you know, helium and hydrogen atoms fuse at the center of these stars and generate photons that kind of flow out into space and that's what we see as the light from the stars.

Howard: Right.

Ben: You explain the mechanism by which this light is produced in the accretion disk very well but what happens is, there's an astronomical amount of energy that's just gravitational potential energy that's turning into light. Talking about turning something's gravitational potential energy into light is a little bit esoteric.

Howard: That, well, yeah, I uh, the black hole is turning gravity into light.

Ben: Right. And somehow that seems really strange but in actuality it's not all that crazy. I mean, so think about a hydro electric dam. In essence what we're doing is we're making a big column of water so we're just raising the little block of water several hundreds of meters in the air and as it fall that hundreds of meters we extract the kinetic energy it gains as it falls that distance and that pushes a turbine around which powers our lights and stuff.

Howard: Yeah, well the falling of the water is powered by gravity.

Ben: That's right.

Howard: So, we're turning gravity into a turning turbine and the turning turbine is making electricity with magnets and stuff. I probably skipped a step in there somewhere.

Ben: That's about right. In essence that's what's happening is that we have some matter that starts off really far away from this black hole and in the course of falling into this black hole it gains a lot of kinetic energy and it bumps into other gasses because it's not the only gas particle that wants to go into the black hole. In doing so it generates a lot of heat and that heat turns into light. And it just happens on this astronomical scale. It turns out that there is a maximum amount of energy that you can get out of, say, a brick that you throw into a black hole. It's something like 42% of the mass of the brick can be turned into useful energy So, if you set-up a bunch of turbines and then threw in a 1kg brick into a black hole as it hit every turbine or windmill on the way down you could extract 42% of the mc^2 of the brick's mass in energy as the brick fell into the black hole.

[21:51]
Howard: And the other 58 is lost to us because it ends up becoming part of the black hole.

Ben: That's right, that's the black hole's tax. It's taking it.

Laughter

Ben: Yeah, so in these quasars something like 10% of the rest mass of the falling gas turns into light and it's just an extraordinary amount of energy which is why these things manage to be so bright.

Howard: I'm sorry, let me state that to be sure I'm following the numbers. When you were talking about the brick, you were saying 42% of the energy of the brick theoretically, that's the maximum that we could get out of the brick dropping it into a black hole, that's the most energy that we could get back out of it. And what we're observing from these quasars appears to be like around 10%?

Sean: That's calculated mainly from how much matter we think they are swallowing up and then we compare that to the amount of energy we're actually measuring in terms of the light that's coming out of the black hole. It seems to be more like...

Howard: So, maybe the message they are sending us is "help, I'm eating too quickly and I'm not very efficient about it." I think I could improve by like 32%.

Sean: Well, what happens, actually is when you start shoving more matter down the of mouth of the black hole there gets to be so much energy that it actually pushes back on the matter that's going down the black hole. There's sort of a natural limit to how fast you can shove matter down the black hole because at a certain point the force of the gravity pulling it in sort of balances the pressure of the radiation that's trying to get out of that little region. So, that's sort of a natural limit on how much, in the real universe, you can put into a black hole. But, if you're throwing in individual bricks it's a little different. But for these big clouds of gas that are sort of being funneled in, the limit is around 7 to 10%.

Ben: It's like if you have a bon fire and like a little kid wants to put more wood in it. At some point in time he'll make the bon fire so hot that he can't get close enough to put more wood in it.

Sean: Yeah.

Laura: Yup.

Howard: So, we've gone from talking fish to burning children. Awesome.

Laughter.

Howard: How do you go about studying these things? I mean, there's the size of the center of our galaxy and so far away that when we first saw them we were surprised that we could even see them. How much of the information that we have, how much of the science is based on things that we have to observe up close? You know,how much of it's based on math that we're able to do here, that we then extrapolate? How much can we see?

Ben: Can I interject here? So, let's focus this as to how we know the size of the object because it's not exactly hocus pocus. There are some pretty clever, fairly easy to understand reasons for us to be able to say this actually a very small, very, very massive object.

Laura: Well, so, one of the earliest ways we knew that this was going to be something very small was that we observed that these quasars would vary their brightness over timescales as small as weeks and days. And we could then calculate from that timescale and the speed of light how far it was from one side of the object to the other.

Sean: We're really just saying that, you know, if we know that something got brighter over the course of a week, well, you know the light had time to travel from one edge of the object to the other over the course of that week. So, that, the whole thing is getting brighter together. If the information was traveling at the speed of light, we would, basically, from that know that it's got to be, you know, less than a light week across, for example, because if it were more than a light week across then maybe whatever physics was causing it to brighten on one side of the object hasn't reached the other side yet and then when we look at it from a large distance away when we see it brightening for as much...

Howard: Okay, that makes sense. So, yeah, if it were a light month across then there's no way for the whole object to brighten within a week.

Laura: Exactly.

Sean: Exactly. Yeah.

Howard: If it's a light day across and it brightens in a week then it's possible that whatever process is brightening it just took that long to occur? You can set an upper limit but you can't set a lower limit?

Sean: Right. Most of what we know about these black holes is really playing that game and setting upper limits because it's really hard to drill down and say aha, here's this Schwartzchild radius with this black hole right in the middle. It's so impossibly tiny to see from so far away. Most of the work has ended up being pushing ever stricter limits, ever tighter limits on how big these could be, how massive they are, ah, that sort of thing.

Laura: Okay, the other way that Ben mentioned was, this is one way we've observed that these are very small and that is that we've been able to detect x-ray emission lines from iron atoms and the shapes of these lines, of the iron atoms, are not like you would normally expect to see if it were just a shape dictated by the doppler shift. We've determined that the only way to get this shape is if there is some gravitational redshift of the light from this iron line coming out. So, in order to have a gravitational red shift you have to have a very massive source and a very small size, to be able to see that.

[26:57]

Howard: So the of the width of the spectral line is caused not by, you know, emissions along multiple frequencies but it's based on the actual physical stretching of the light by virtue of the mass of the central object.

Laura: Yup.

Sean: As it tries to climb it's way out and away from the black hole it gets red shifted and that's something that you never see otherwise in astronomy. So, it's a pretty unique signature that you're looking down very close to a black hole.

Howard: That's cool. Let me pitch a couple of questions, from the standpoint of a writer. If I wanted to tell a spec fiction story about, for instance, a close encounter with one of these objects, and, for astronomical values up close. If we had something at our galactic core that was emitting at these energies what would we observe here on earth? What would we be looking at? Would we be cooking?

Laura: We...

Ben: No, I don't think we'd be cooking but it would be pretty bright.

Laura: Yeah, I remember if you took a quasar and put it in the solar neighborhood it would be as bright as we see the sun from the earth. The galactic center is a lot further away than the solar neighborhood.

Sean: It would still probably be the brightest... in the sky.

Laura: It would be pretty bright.

Howard: So, now I'm a little bit confused. If, when you say the solar neighborhood does that mean...

Laura: I mean like, uh, a few times, 10 parsecs.

Howard: So, solar neighborhood does not mean solar system?

Sean: Yeah, the nearest dozen or two stars are within a hundred light years, fifty light years.

Howard: So, from, from multiple light years away, maybe not three digit numbers, um, it would be as bright as the sun. That's terrifying. Wow.

Laura: And it would be emitting a lot of x-rays which are not good for us. So, we might not be here.

Howard: Well, we'd be able to find the cancer very quickly though.

Laura: Yeah. But if you put it at the galactic center I'd have to do the math.

Sean: It would be brighter than...

Howard: Well, we're what 25 or 30,000 light years away from the galactic core?

Sean: Yeah, 30, or 25

Laura: 25, 25 yeah.

Howard: Yeah, I thought it was 25. I cough that number up all the time in the comic. Because hey, you know, you've got a galactic civilization you've got to know how far away things are. So, from 25,000 light years away it would still be bright but might not be x-ray lethal, hold a film under your hands and get a picture of your bones bright.

Sean: Yeah.

Laura: Yeah.

Sean: One interesting nugget is that these things, we see many of them from way in the early history of the universe. And it turns out they actually were much more common really early in the universe. Around the same time that the stars and the galaxies that it's in were forming. Like the sun is 5 billion years old and many of the other stars in the galaxy are even older. So, it turns out that perhaps there wasn't any life yet to nuke in these galaxies when these things were active. The solar systems and stars were forming furiously at about the same time that these black holes were furiously sucking up this matter in the center. We think it's all tied together, sort of a process by which galaxies grew in their early stages.

Howard: Okay, so that thing I said at the very beginning where they're incredibly old and we're looking up and they're very, very young. It's not beyond the pale that the Milky Way that we currently live in used to be one of these.

Laura: Yes.

Howard: And thankfully it's not now but it could have been and we're past that stage in galactic evolution.

Sean: Yup. Exactly. So, they're not all at the far edge of the universe, at the earliest bits of the universe, there are some that happened more recently or are in galaxies that are not quite so far away from us. And they tend to actually be not as intense as the ones we see really far away and a part of that is just because the dimmer ones that are at the edge of the universe, we don't see. Just a sort of observational bias but the dim ones that are nearby, maybe have turned on again after some period of inactivity. It's unclear how often galaxies go through a phase like this.

Howard: In terms of galactic evolution, my understanding is that one of the stages of galactic evolution is collision. Well, for instance you have the lesser Magellenic Cloud were to make a close pass with our galactic core, even though it's fantastically unlikely that stars would actually be hitting each other, there would still be fantastic amounts of dust in-falling and heating the core up and we'd get a pretty light show 25,000 light years afterwards.

Sean: You know your galaxy evolution sir.

Laura: Yes.

Howard: I write epic space opera for a living and so, you know, slamming galaxies into each other is something I'm actually working on.

Sean: Well, yes, that happens quite a lot. Galaxies slam into each other and the stars don't hit each other but the gas does tend to funnel towards the center and big clouds of gas slam into each other, there's friction in the gas that lets it drop towards the centers. So, that's one way you could turn on this sort of quasar. In the early universe where there was a lot more gas around and a lot less locked up in stars we think that's probably why we see so many more of them way far away, way in the early universe. But these sorts of collisions, these sorts of injections of gas into galaxy centers would happen from time to time, even still in galaxies.

[32:10]

Howard: If you have a cloud of dust the size of a galaxy spinning into a black hole versus a cloud of dust that has all coalesced into stars spinning around a black hole, in the second scenario almost nothing is generating friction because the stars aren't hitting each other and in the first scenario the gas is constantly hitting itself and so there's a lot more heat. So, the early, pre-stellar fusion, I'm making words up but I'm sure you guys already have words for, the pre-stellar fusion, proto-galaxy ends up being a hotter place because the small stuff is all slammed into each other.

Sean: Yeah, um, well, one thing that happens is when you have these big gas clouds like this it fragments under gravity into smaller clumps and they fragment into smaller clumps and then they you end up, before most of it can fall into the black hole you end up actually turning most of it into stars just...

Howard: Alright, but that stage you just described, that's where the math gets really complicated.

Sean: Right, exactly. That's the sort of stuff people spend whole careers trying to understand.

Ben: Okay, that was fantastic. So, thank you Laura, thank you Sean. You've pleased me. You're efforts have born fruit and that fruit is sweet. Here is some fruit straight from the refrigerator. Sean, you get a banana. And Laura, you get grapes. Fantastic.

Howard: Can I have a talking fish? I, well, I don't usually give my guests gifts but yeah, here's a talking, it's a trout I think. Have fun.

Unknown funny voice: Don't eat me, don't eat me.

Howard: Ahhh, this is delicious.

Ben: So, thank you Howard Tayler for coming on my show. Um, yeah, did you want to tell anybody about your fantastic website or anything.

Howard: Sure, if you want to me drawing pictures of galaxies and stuff head on out to schlockmercenary.com. The book in which I start talking about slamming galaxies into each other deliberately is Schlock Mercenary Resident Mad Scientist and it is all available for free on the internet with the magic of recycled electrons.

Ben: Well, Howard, your work has personally seen me through thesis' and thank you very much for, it's absolutely fantastic and it's way better than writing a thesis.

So, if you'd like to write to us you can email us at barn@titaniumphysics.com or you can follow us on Twitter at @titaniumphysics. You can visit our website at www.titaniumphysics.com or you can look for us on Facebook. If you have a question you would like my Titanium Physicists to address email your questions to tiphyter@titatiumphysics.com and if you are a physicist and would like to become one of my Titanium Physicists email physics@titaniumphysics.com we're always recruiting. Let's talk about how you can listen to the Titanium Physicists Podcast. Just me and you, the listener.

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[37:27]

Howard: Now I've been led to understand that when we discovered the whole spectrography thing where you could look at the emission lines that helium was something that we found via that method before we actually found it in nature. Are there things that we're looking at, are there lines that we haven't identified yet?

Laura: Perhaps.

Sean: I think they're all at least theoretically known. They may not have been measured in a lab but they line up to what we expect from certain elements.

Laura: Well, so what happens is that on earth we're limited to the kinds of conditions that we can create to cause elements to act a certain way. So we can only see certain lines because we can only, to emit ...

Howard: So what you're saying is right now the government won't let you wrap a hydrogen bomb in, oh, for instance, ah silicon...

Laura: No, no, it's that we can't, ah, physically we don't know how to do this.

Sean: But they wouldn't let us do that either.

Laura: Yeah, they wouldn't let us do that either. Fair enough.

Howard: Yeah. Okay. The humorist in me just thinks that you haven't wrapped enough esoteric things around hydrogen bombs and set them off to look at the pretty colors...

Laughter

Sean: We could try but...

[38: 50]

Laura: On the other hand if someone swept a whole bunch of gas into the center of our galaxy we're not entirely sure that..

Howard: Yeah, don't do that, don't do that. You scientists, you're always trying to find ways to kill us all.

Laura: Well, hey, if you're looking for a big bad guy, all you have to do is figure out a way to send some gas to the center of the galaxy.

Howard: I've already had a big dust up as it were at the galactic core in the comic itself. I decided not to do that again for awhile. The good news is, you know, if they did have a big dust-up at the galactic core it would be 25,000 years before we knew about it.

Sean: That's right.

Howard: That's plenty of time to build lead roofing and uh move all of our food production under ground and stuff. We'll be fine.

Sean: Well except we wouldn't know about it. We wouldn't know it was coming.

Howard: Well, we need, yeah, you're right. We would need a detection mechanism, we need an early warning system for galactic core disasters. Get on that!