GalaxyQuenching

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Jorge: [00:00:00] Hey, Daniel, how old are you?

Daniel: Well, I'm turning 47 pretty soon. Mm. Does that feel old to you? Well, whenever I'm feeling old, I just decide to count my age differently.

Jorge: Oh yeah. Like a different

Daniel: base number? No, like how old would I be if I lived in a different place, for example, because Mars is years longer.

I'd be in my early twenties if I was a Martian.

Jorge: Oh, but you would die in like a few hours would, or a few minutes if you lived a Mars right now,

Daniel: depending if Elon Musk has money left over from his Twitter purchase to fund our oxygen on Mars.

Jorge: But I guess even if you're a Martian, you would still live the same amount of time.

So you'd be just as old. It'd just be a different year

Daniel: unit. That's right. But it's all about how the number feels, man.

Jorge: Yeah. But also you have to take it through account your life expectancy that also gets changed on Mars,

Daniel: right? Yep. On [00:01:00] Mars, we all die young anyway.

Jorge: Or maybe not me. The air, there is so much better that people would live longer, long enough to tweet forever.

Hi, I'm Jorge may cartoons and the co-author of frequently asked questions about the universe.

Daniel: Hi, I'm Daniel. I'm a particle physicist and a professor at UC Irvine. And I plan to teach until my old, old age. Do you

Jorge: think you'll still have a, something to teach when you're that old? I

Daniel: often teach freshman physics, which hasn't changed since Newton.

So I'm planning to teach it until I grade away.

Jorge: what if you start forgetting things, even Newtonian

Daniel: physics. I'm sorry. What'd you ask? I forgot the first part of your question.

Jorge: but anyways, welcome to our podcast, Daniel and Jorge explained the universe, a production

Daniel: of iHeartRadio in which we explore this [00:02:00] incredibly old and incredibly young.

Which has lived for billions of years and may survive for trillions and trillions more. We explore all of the fast moving and slow paced processes that grow and shape and define our universe and make it the one that we love. Our goal is not to be intimidated by the age of the universe or the billions and trillions of years at.

Hard to come, but to try to understand the processes that shape it and to explain all of them to

Jorge: you. That's right, because we live in an amazing universe. It's been around for 14 billion years or maybe more, which sounds like a long time, but who knows? We could be maybe in the universe's infancy right now.

The universe might live on for a long time, maybe even

Daniel: forever. Imagine if you had lived in the universe in the first few hundred thousand years, you might think, oh, this is what the universe is like. Not realizing that it was about the first flash of the universe and that it would live for billions of years with glowing stars.

And now we live in the Starfield era of the universe, but it might just be the [00:03:00] first flash of a universe that lasts for trillions of years and is mostly filled with black holes. So this era of the universe could be very short lived and very weird,

Jorge: weird, but also pretty cool. I think, you know, right.

Technically we are living in the cool years of the universe. not the hot, crazy, insane years. And also not the, you know, super freezing years.

Daniel: Well, because the universe is expanding, it's cooling. And so technically it gets cooler every year and not just because they keep releasing more Marvel movies about more multi.

Jorge: Yeah, but at some point you, it is, I think it is possible to be too cool. You know, like if the entropy of the universe is at a maximum and the temperature is like zero out there, Kelvin. That's not cool, Dr.

Daniel: Strange and the heat death of the universe coming soon.

Jorge: I hear the last one is pretty dark, right?

Everything's getting darker.

Daniel: everything in the Marvel universe is getting darker, but in our universe, things continue to glow and brighten and to fill the universe with photons that allow us to see the incredible [00:04:00] views across billions and billions of miles and allow our tiny human brains to grapple with questions about how everything came to look the way that it does.

How long it will continue to shine. Yeah.

Jorge: Because unless you're Elon Musk, I guess the universe will be bright and shiny and beautiful and amazing. And an open mystery, uh, pretty much until your old age. Right.

Daniel: Is Elon Musk gonna figure it out? Is that what you're saying?

Jorge: I think he's gonna figure out. How to beat old age

Daniel: probably oh, I see.

He's gonna download himself into a Tesla and launch himself into space and live there forever. That's

Jorge: right. With that, uh, you know, special module for Twittering

Daniel: maybe he should combine all of his companies, you know, TWI put Twitter onto a Tesla in a boring tube and launch that whole thing into space.

Jorge: that's right? Yeah. It'd be a TWI X would be the new company. The boring twist lax,

Daniel: but we are not funded by Elon Musk. Although, you know, you know where to send your donations, Elon, if you're a listener, but we are [00:05:00] motivated by the desire to understand everything that's around us and figure out exactly how long this flash in the pan will last.

Yeah.

Jorge: Because as much as we know about how the universe works right now, there are still open questions about how the universe. Keep on working and how it's gonna work up until the end of the

Daniel: universe. Remember that when you look up at the sky, it seems sort of static and frozen. You don't notice from day to day stars, appearing or disappearing or changing their location.

But that's just because we live in a tiny little slice and the universe operates on much longer time scales. If you could see a movie of the universe sped up to see all 14 billion years in just a. It would seem like a crazy chaotic dynamic place. Even our solar system has had planets shift around in orbit.

Our galaxy is spinning and swirling and colliding, all sorts of stuff is happening. And as we look out under the universe on those cosmic scales, we ask questions about how everything came to be and how long it will continue to swirl and glow.

Jorge: Yeah. Yeah. So you're planning to be a professor until [00:06:00] you grow old or even die.

Apparently. They're

Daniel: gonna have to drag me out of this office. I'm gonna be here until the Milky way stops, spinning I,

Jorge: I have a similar plan. My plan is to be a cartoonist until I'm

Daniel: rich. I see. So I, another a hundred billion years.

Jorge: yeah, so basically the same thing as a growing old till I die. Yeah. But anyways, it is an interesting and growing.

Universe, which makes you sort of wonder how it's all gonna end. If not the universe, at least maybe

Daniel: our galaxy that's right on the podcast. We have talked about the future of the earth and our solar system, how the earth will get subsumed eventually into the outer layers of the sun. We've even talked about the lifetime of.

Stars how long they will burn and how long our universe will keep making stars. But the universe is not made just of planets or solar systems or stars. One way to look at the universe is that the basic unit are galaxies. These big swirling swarms of billions of stars that float through the universe.

How do galaxies form and how long do they live? [00:07:00] Do they just keep spinning until they become rich cartoon?

Jorge: So today we have an amazing end galactic question today we'll be tackling,

how do galaxies die or how do they fade away? I guess maybe, maybe that's a nicer way to say it. How do they become

Daniel: emeritus? Galaxies?

Jorge: How do they move on? How do they join the farm?

Daniel: how do we make room for new galaxies? Because they're just taking up space. These old folks.

Jorge: Oh, right. Well, well, there's plenty of space and space, right?

That's

Daniel: true. There is plenty of room for galaxies, but you know, they are using the raw materials. They're occupying a whole lot of carbon and iron, all sorts of other stuff that could go to seed new stars and new galaxies and new forms of life and intelligence. Mm.

Jorge: Well, the first thing I thought when I saw this title was like, Galaxies can die.

I didn't know that. Do they have like a beating heart?

Daniel: it depends a little bit how you define death, right? Galaxies don't live, of course, in the same sense that [00:08:00] organic entities do the way you and I do, but they do have a really interesting life cycle. And at some point they stop making stars. And eventually those stars will burn out.

And so the fate of galaxies is in fact to fade away into darkness, which some could describe as the death of a galaxy.

Jorge: Mm. I see you're defining the death of a galaxy as when it, I guess when it goes dark. Is that what you're saying? Like when it stops shining or you can't see it, or do you define it as like no activity or.

When it breaks apart or when it turns into a black hole there are many possible ways to kill galaxy. I guess there

Daniel: are lots of milestones in galaxy retirement, but scientists call this galaxy quench. When it stops making stars, those stars burn for a while, and then eventually they will all fade out and you will indeed get just black holes with lumps of stuff swirling around it.

Jorge: Mm I see. So you're really talking more about asking how do galaxies retire? like when they start producing light, kind of, yeah.

Daniel: It's not a funeral home. We're pushing these galaxies into it's a. Senior [00:09:00] living facility with all sorts of other active galaxies to hang

Jorge: out with. Mm, interesting. There, there are cost bank, retirement homes.

do we have early bird specials too?

Daniel: Well, once you no longer making stars, you're not really part of the game anymore.

Jorge: uh, yeah. Yeah. I guess you're you're off the rat race kind of to see who's the shiniest galaxy. You're

Daniel: definitely onto a new era in your life, because if you don't have stars, then you can't make new elements.

You're stuck with the composition that you have. Remember that new elements are only born in the heart of stars and supernovas, and then the collisions of neutron stars. But once you've stopped making stars, you no longer initiating that process. That ends up with new elements. And so eventually you're gonna get stuck with whatever you have.

You'd be sort of frozen with your mixture of stuff. Mm.

Jorge: All right. Well, we'll get into the details of a Galaxy's retirement, both from its job and mainly from its life. But as usual, we were wondering how many people had had these sort of dark [00:10:00] thoughts about galaxies and what happens to them in the future.

So as usual, Daniel went out there and asked people the question, how do galaxies.

Daniel: So, thanks everybody who participates in these fun questions. If you'd like to hear your speculations here on the podcast for everybody else to enjoy, please, don't be shy. Write to us two questions@danielandjorge.com.

Jorge: Think about it for a second.

How do you think Galax sees retired? Here's what people had to say. I think I

Daniel: have a decent guest for this. There are super massive black holes at the center of every galaxy and at some point black holes do die or evaporate rather. It is possible. So maybe when that happens, when the black hole kind of doesn't exist anymore, then the galaxies just disintegrates, as far as I know, galaxies die, when their stars start dying and stop making more stars and, and it just becomes a cold cloud of sadness.[00:11:00]

and you can't see it. So I guess that's a

Jorge: dead galaxy. I don't know how galaxies die. I would guess

Daniel: that either

Jorge: the, if it's a black hole in the middle of

Daniel: the galaxy, that it, as opposed to

Jorge: swallows large parts of the, of the galaxy or that

Daniel: stars. Either sort of die by

Jorge: not admitting as much light as they previously would've been.

And so

Daniel: the galaxy becomes sort of darker and darker.

Jorge: So

Daniel: I think galaxies are so large and have so much angular momentum that all the stars within the galaxy will reach the end stages

Jorge: of their life. And we will no longer have the starting conditions necessary to get new stars created before. The entire galaxy will be eaten up

Daniel: by the super massive black hole galaxies die in three ways.

First, when they crash in and merge with a larger galaxy. Second, when the stars fall [00:12:00] into the black hole at the center of the galaxy and third, when the galaxy creates no new stars and the stars in the galaxy die. from old age, the galaxies die. If eventually they lose the ability to make new stars. So this can come from a different reasons, but one of them that I know it might be that the black hole from the center of the galaxy starts this process by.

Emitting, probably a powerful cluster. Hmm. The super massive black holes in the center, suck them up or something.

Jorge: Right. Uh, a dark answers for a dark question. I guess a lot of people went for the black hole scenario.

Daniel: Yeah. That's really interesting. People are aware that eventually everything will fall into the black hole and they imagine that that's, what's gonna [00:13:00] kill the galaxy,

Jorge: but little, do they know , there's something worse around the corner or what.

Daniel: Yeah, there's sort of two competing timelines there. Like will the stars burn out? Will it stop making stars before it falls into the black hole? Or will the black hole like eat up a bunch of otherwise lively elements of the galaxy, which could have made new stars if only they hadn't fallen into that gravitational?

Well,

Jorge: All right. Well, before we start to consider a Galaxy's death, let's, um, you know, let's do a little retrospective here and let's consider the whole, uh, life of the galaxy. So let's start at the beginning. Daniel, how do galaxies even get born?

Daniel: Yeah, I like that. We begin with a nostalgic sort of like montage musical

Jorge: montage.

all the good

Daniel: moments. Remember those?

Jorge: With, with that oldtimey like film feel or something.

Daniel: You soft focus, you know, fuzzy pictures of the galaxy playing in the kiddie pool.

Jorge: Like the projector sounds going,

Daniel: the galaxy being mean to the cat, you know, that kind of stuff.

Jorge: but [00:14:00] looking so cute, no pictures of the galaxy crying or throwing a

Daniel: fit.

I think of galaxies as one of the most fundamental units. Of the universe, because even though the stars are within them, it's the galaxies that are formed by like the initial fluctuations. So, you know, you begin at the very, very early stages of the universe. Everything is smooth and filled with matter.

There are no wiggles. There's no extra lumpy bits. Then you get quantum mechanics that fluctuates and gives you like a little bit more stuff here, maybe fewer particles over here, but that's really tiny. That's super microscopic that kind of quantum fluctuation is happening all the time, even today. But in the very early universe, those fluctuations were blown up to a huge scale.

By early universe inflation. The way space itself was stretched by like a factor of 10 to 30 blew up these little tiny lumps, these little bits where something was heavier and something was lighter into actual macroscopic sizes. And then gravity took over and it said, all right, this spot is a little bit [00:15:00] denser than that spot.

So all the particles are gonna get attracted over there. So you begin with these very shallow gravitational Wells that slowly roll more particles into them, and then they get stronger and stronger and strong. We're talking about, it's mostly dark matter. It builds these gravitational Wells that then normal matter falls into and where you have these Wells, you have big blobs of matter.

And that's what forms galaxies.

Jorge: Yeah. I think we sort of nice talk about it as the seeds of the galaxies, right? Like the seeds, like where the galaxies came from were, was all sort of laid out in those first moments of the big bang. So kind of in a way, like galaxies were maybe the first things that were defined in the.

First kind of organization, right?

Daniel: Yeah. You can think about it like that. We think that probably stars formed and then they formed into galaxies, but they all formed outta these big clouds of gas that were themselves formed by these dark matter halos, which were themselves formed by those initial seeds that we talked about.

Something I think is really cool, is that the pattern of dark [00:16:00] matter, which controls the whole structure of the universe is like these Fila. These like lines of, through a cosmic web and where those filaments overlap with each other are the dark matter halos you could think of it sort of like these filaments are funneling matter into these lakes, which are where they intersect.

And so gas is falling from these filaments into these halos. And then swirling together to form stars, which form galaxies.

Jorge: Mm, interesting. I guess what I mean is like, if you had been around at that time, that early in the universe, you could have been predicted maybe like, oh, there's gonna be a galaxy and there's gonna be a galaxy.

You know what I mean? Like the definition of a galaxy was sort of, uh, right there at the beginning of

Daniel: the universe. Yeah, you definitely would know that this is where complex structure is gonna form. Now I think it's super fascinating what you end up getting. I mean, you start with just clouds of hydrogen and then like you get stars and you get galaxies.

It's really fascinating, sort of the size and the scale and the shape of what forms out of that. It's one of the, I think the deepest questions in modern [00:17:00] physics. Why these objects emerge at these scales, you know, why do we get stars? They're about this size? Why do we get galaxies about this size? Why didn't we get just one humongous galaxy in the whole universe?

Or why do galaxies form it all? Why don't we just have stars spread out everywhere? So I think it would've been pretty hard to predict computationally. I think it's really interesting to sort of. See what emerges from structure in the universe. And that's just what we're doing now. We're still seeing structure emerge.

Now we have clusters of galaxies and super clusters of galaxies. And that process is still happening because we're still fairly young in the universe. Yeah,

Jorge: we are. Are we still in the, like the teenage years, you think the awkward teenage years full of, uh, pimples?

Daniel: Well, gravity is really slow, so it takes a long time to form structure.

So it's formed galaxies and galaxy clusters, but those galaxy clusters themselves are like very loosely grouped into super clusters gravity. Hasn't had time really to gather that together into something greater. In the meantime, dark energy is doing the opposite job. It's pushing everything apart, preventing gravity from making super structures.[00:18:00]

So we might be living in the moment when the universe is the most. So, I don't know if those are really the teenage years or that's like it's mid thirties, you know, it's really sort of on top of its stuff before it starts to get old.

Jorge: Mm. Before it has its midlife crisis as we all do. Exactly. All right.

Well, I guess that's the birth of a galaxy. And so a surprising idea is that galaxy change and they might even die one day. So let's dive right into that. But first let's take a quick break.

All right. We're talking about the death of galaxies. Daniel. Does that mean our Galaxy's gonna die?

Daniel: Scientists think that the Milky way itself is beginning to quench. We're entering a period where we're making fewer and fewer stars and that's gonna happen faster and faster. So sort of the Milky ways peak might be behind

Jorge: us.

Oh boy. Well for a second, I thought you were gonna give [00:19:00] us a super plot twist and say like, oh, our Galaxy's already dead. it's been dead the whole time.

Daniel: we're just ghosts. That's right. This whole galaxy is nothing but an M night ch land film.

Jorge: yeah. Spoiler alert.

Daniel: I talk to dead

Jorge: galaxies I see dead galaxies with my telescopes.

you kind of do maybe, right? Like if you look at, into the far universe, you might be seeing galaxies that have died already. Right? We do see a

Daniel: lot of galaxies that are dead. And one of the surprising things, and with something we struggle to understand is what's killing all these galaxies. Why are there so many galaxies out there that are already quenched and have stopped making new stars?

Jorge: Wow. This just went from a thriller to a mystery. We just switched genres here. It's a

Daniel: combination because somebody's still out there. Killing galaxies. It's not over yet. We still have a chance to catch the killer and maybe save future galaxies

Jorge: and maybe do nothing about it. because, because [00:20:00] it's just physics,

Daniel: it's just physics.

Are you saying we can't learn things about the universe and intervene in its fate that we have no control, no power to change the future of humanity. It doesn't sound like an engineer. You

Jorge: tell me, I, I guess, you know, the physicist has to tell us if it's possible.

Daniel: Well, the first thing to do is to understand what it is.

That's killing these galaxies, and then we can figure out if it's possible to intervene, then we have, have to start training some galaxy engineers.

Jorge: That might be the, the sequel, I guess. All right. Well, I think one interesting bit of news is that, you know, galaxies seem to change and, and I guess they clench and they maybe eventually die.

And so is that something that we've always believed in that galaxies can change? Or did we think that we would just, you know, swirl around forever? We've

Daniel: always thought that eventually galaxies would use up their raw materials in terms of making stars. You know, you have a certain amount of hydrogen in the universe, for example, That's primarily what's burned to make stars.

Eventually you will run out of them. We have a podcast episode about how many generations of stars will there be, cuz you know, stars don't live forever. And eventually they [00:21:00] explode and spew their materials back out in the universe, which gets gathered back together. But we don't think that can happen forever.

So we've always known that eventually waves of star formation will end, but we were surprised when we looked at the galaxies and discovered how many are already dead. How many have stopped making stars? Well, before we expected them

Jorge: to interesting. Yeah, I guess, you know, there's a limited supply of fuel in the universe.

Right. And at some point we run out, like we have a gas tank kind of, and you know, hydrogen gets you up, gets turned into heavier element and then to break it apart, you. It's extra energy. Yeah.

Daniel: There's two things that drive. This one is you need to have the fuel. And the other is that the fuel has to have the right conditions.

Like it's not just enough to have hydrogen. You have to have hydrogen in the right situation in order to get a start to form. And the key thing to making stars form is that you need. Huge blobs of cold hydrogen, if you have hydrogen, but it's really hot. It's not gonna form a star because remember that gravity is super duper weak in order to tug things [00:22:00] together, to make a star, the particles have to be very slow moving.

If your gas is heated up too much, then gravity's not gonna be able to pull it together to make a star.

Jorge: Mm. All right. Well, that's the birth of a galaxy that I guess that's how they start, right? They start for fluctuations and the universe and the dark matter seeds, which pull in stuff and. Galaxy form.

That's just kind of the beginning of the story, right? Eventually galaxies also merge

Daniel: mm-hmm and our thinking there has changed. Also originally we looked out at the universe and we saw really big galaxies, mostly because that's all we could see because they were brighter and we thought, oh wow. Maybe these really big galaxies sort of form all at once.

Like. Monolithic collapse of a huge cloud of gas into a swirling disc. But then as we developed the technology to look further and further into the universe, and earlier and earlier, back in time, we discovered a lot more galaxies that were much smaller. And we realized that the story of galaxy formation is more complicated instead of having really big galaxies form at once.

It turns out it's much more likely to form a bunch of small [00:23:00] galaxies than have those merged together. The galaxies are doing a lot of merging. Most of the galaxies we see out there are actually the products of lots of little baby galaxies that came together to make a bigger galaxy.

Jorge: I see. It's like we looked that into the universe and saw more baby baby galaxies than we expected.

Is that kind of the idea, which I guess would then logically mean the bigger galaxies don't didn't form. They, they they're the result of two baby galaxies merging. Exactly

Daniel: or multiple baby galaxies margin. It also helps explain the shape of these galaxies. Like when an individual galaxy forms, it tends to form as a disc could give a big cloud of gas and it's spinning a certain way.

And that spin prevents it from collapsing in one direction, but gravity can collapse it in the other direction, which is why you get a disc. So disc galaxies tend to have formed from a single cloud of gas and dust with some spin, but then when two of these things merge. They come in with different shapes and different sizes and different discs.

And that's how you get like elliptical Galax. Things that are [00:24:00] more rounded, cuz you're combining like the spin of two disc galaxies together. So the idea is that the bigger elliptical galaxies are formed from a bunch of smaller disc galaxies that came together. For example, the Milky way Andromeda are gonna collide, but they're not spinning in the same direction.

So you're not gonna end up with one big disc galaxy. You can end up with something more elliptical that has like two spin ax. Mm,

Jorge: interesting. So a lot more of the galaxies foreign from merging than we thought before, I guess, why do we have that wrong impression? Well,

Daniel: we had the wrong impression just because we didn't see a lot of these baby galaxies early on, you know, we didn't have the technology before Hubble and those kinds of telescopes, we just couldn't see them.

But when Hubble looked really deep into the universe and discovered how many galaxies are out there, that's when we got the clue is from seeing these baby galaxies in the early. You know, the number of galaxies out there is sort of amazing. If you hold up your pinky at arm. Then the part of your sky blocked

by your fingernail on your [00:25:00] pinky contains about a million galaxies in the observable universe, you know, layered further and further and back in space and time.

And so now, like scan your pinky around the whole sky. Each of those is a million galaxies. So this is an incredible number out there. And now we have a huge population to study. So we get a better. Of how these things have evolved.

Jorge: Wow. That's wild. What if I let my pinky fingernail grow

Daniel: then you are containing more and more galaxies.

You're becoming master of even more of space in time.

Jorge: a pinky master, I guess. All right. So that's, uh, I guess that's the basic of, of the life of a galaxy, right? They're born is little baby Galax. They grow up to be a teenager. They start hooking up doing inappropriate things, and then they merge into bigger galaxies.

And then they keep burning for a while, I guess like what's the average age of a galaxy

Daniel: galaxies are really old. Like the Milky way is almost as old as the universe. Galaxy's formed very early on. A lot of them in the first billion years of the universe, many of them are more than 10 billion years old,

Jorge: [00:26:00] but at some point, as you say, they die, they stop shining.

They stop making stars, they quench. So, uh, I guess Daniel, what's the process for a galaxy.

Daniel: So for a galaxy to die for, to stop being able to make stars, something has to heat up its gas. Something has to prevent its gas from staying cold, because in order to form stars, you need that cold gas. And some of the star formation comes from the original gas that the galaxy started with whatever was in that dark matter.

Halo. Remember that galaxies are not really alone in the universe. They're sort of like at the intersections of these dark matter Fila. So there's also sometimes new gas falling into these galaxies along those filaments, like tributaries to a lake. And so galaxies can also continue to form stars as they suck in more gas from these filaments.

So the way a galaxy dies is somehow losing access to that new gas or blowing out the cold gas or heating up. The cold gas that's inside it because remember you need cold gas to make star.

Jorge: Mm I see. All [00:27:00] right. So you're defining the death of a galaxy is when it stops forming new stars is that I guess the definition, but even if it stops forming stars, it's still shining though.

Right? Astronomers,

Daniel: don't talk about galaxy dying. They use the technical term quenching, which means it stopped forming new stars, but you're right. Even if it's stopped forming any stars at all, those stars themselves can burn for billions and billions for sometimes even trillions of years. Remember that stars, their lifetime depends on their size.

So really big stars. Don't burn very long and really small stars will burn for a very, very long time. So even a galaxy that's totally quenched won't make any new stars, but those stars will continue to burn for a very long time. Oh, I see.

Jorge: I see. What's going on. I think really what you mean to ask is how do galaxies peak or like how do galaxies stop?

Um, getting brighter, maybe mm-hmm

Daniel: yeah, exactly. How did they stop having any babies?

Jorge: I see, I, I think I see what's going on here, Daniel. I think you associate, uh, not working with dying.

Daniel: that's why [00:28:00] I'm never gonna

Jorge: retire actually. Yeah. That's why you're never gonna retire. like if you retire, you die. Like if a professor stops.

Making papers that's that's like that for them

Daniel: who even argue anymore in that situation.

Jorge: but yeah, just to be clear, that's kinda what we're saying, right? Like, uh, galaxies don't maybe. Well, I guess they will, at some point grow dark, but here

today, what we're talking about is like, how do galaxies peak or how, when do they stop, um, being active.

Daniel: Exactly. And as we look out into the universe, we can tell whether galaxies are still making stars or not. We do that. We see some pretty surprising things about what's going on with all the galaxies in the universe.

Jorge: Mm wait, that's kind of weird because I guess, uh, we're defining death as stopping production of stars.

You would need to like, know how many new stars are being made and right. But how do you tell that on a short human life? So it's

Daniel: not that we look at the galaxies and we count the stars and we say, oh, look, it's still making [00:29:00] more because these galaxies, a lot of them are really far away. So all we can see them is like a pixel or two on the Hubble.

But what we can do is look at the color of the light that comes from these galaxies. And that tells us about whether or not there are new young stars in the galaxy. And the reason is that new young stars means hot stars. When stars are formed, you get big ones and you get small ones, but the big ones, the ones that burn hot, that burn blue, they don't last for very long.

So if you're looking at a galaxy and you're seeing blue light from it, that means recently formed stars. If you're looking at a galaxy and you only see red light, that means cooler stars, only older stars. No recently formed stars. So by looking at the color of the light from the galaxy, you can tell if there are recently formed stars in it, because there recently formed ones burn hotter and

Jorge: burn blue.

Interesting. You're saying that galaxy kind of peak, they start producing new stars when they return from [00:30:00] blue to

Daniel: red. Exactly. Blue means you've recently produced some stars because only young stars are ever blue because blue stars don't last very long and eventually all your blue stars burn out and all you're left with are red stars.

So if you're an all red galaxy, it means you haven't made anything recently. Mm. I

Jorge: feel like that's like people these days, you know, everyone starts out as, uh, Democrat and liberal, but then they get more conservative and red and all age,

Daniel: you know, maybe we should avoid the political analogy and think about like musicians, you know, are you a musician that keeps putting out new albums or are you just like the Beatles?

You just making money on your old catalog? .

Jorge: Well, the Beatles came out with the white album. So I, I don't know how you fit that into the

Daniel: color spectrum dinner. Well, the fascinating thing is when you look at this color spectrum, you see some that are still making new stars, but you see a whole huge number that are already quenched many more than we expect.

And you see very, very few in between very few in this region, they called the green valley. Between the blue and the red, the ones that are [00:31:00] like quenching. So there's a bunch that are not quenched. There's a huge number that have been quenched and very few in the process of quenching.

Jorge: Mm, interesting. Yeah.

As you said, it's a big mystery. And so let's dive into that mystery of what is killing or I guess retiring all the stars in the universe, but first let's take another quick break.

All right. We're talking about, um, I guess when galaxies change their political views, right?

Daniel: when galaxies stop recording albums. when

Jorge: they stop, uh, polishing papers, which according to professors. Is the same as death, like gimme research or gimme death. what if galaxies get a hobby then they, they won't see retirement as death anymore.

Daniel: I do see a lot of America's professors still around the department. And I wonder, like, why do you still come in every day? And I think, you know, maybe their partners [00:32:00] at home don't really want them hanging out, doing their hobbies at home, you know?

Jorge: Mm. They probably thought the same thing you, you are thinking right now.

And you're like, they're gonna have to drag me out. drag me out or call the grim ripper, I guess. but apparently galaxies do retire. At some point they peak they stop making new stars. And I guess it, it shows on a galaxy, you know, like it's pretty, it sounds like it's pretty obvious. Like if a galaxy is.

Pretty blue, then it's young. If it's pretty red,

Daniel: it's old. Exactly. And there are very few galaxies in between, which suggest that this process of galaxy happens rapidly. Right? You're not in the green valley for very long on your trip from blue to red.

Jorge: Mm well, it's sort of like when you run outta gas in your car, it's not a gradual process.

Like once you run outta gas, Your car

Daniel: stops. Yeah, but the galaxies are huge. Right? You might imagine that one part of it might quench another part of it might still be active, but this seems to happen on a sort of a galaxy wide scale

Jorge: all at once. Well, let's, uh, recap a little bit here. You said the Gakis, uh, peak.

They start producing new stars when they run out of [00:33:00] gas. And you said that it's not because you run out of hydrogen gas, but because you run out of cold hydrogen gas in

Daniel: order to form stars, you need clouds of cold gas that gravity can work on to pull together to make those stars. And so it might be that there's plenty of hydrogen left in those galaxies.

We suspect that there might be, it might just be that it's too hot. So either you lose the gas or the gas gets too. Those are the ideas for how to quench a

Jorge: galaxy. Wait, what happens if it gets too hot? Like why is it hard to make a star from hot

Daniel: gas? Well, hot gas. The particles are just flying around too much.

You know, gravity is not very strong. And so if you have a gas that's really hot where the particles are flying around with high speed, gravity just doesn't have the power to gather them together into a star counterintuitive because gravity makes them hot. Right. But once it's already trapped them in a gravitational.

Think of it like escape, velocity, the earth is boiling off molecule right now at the edge of our atmosphere because they're too hot for the Earth's gravity to contain them. And so it's certainly possible to have a whole [00:34:00] gas where there's not enough gravity to contain it, where it just disperses. It just keeps flying around instead of clumping together.

To make a dense well at the heart of it. Mm.

Jorge: But I guess, you know, the temperature is just one part of it. What if it, you have, uh, hot gas, but really dense or like a lot enough of it or a lot of it wouldn't that also sort of create the intensity you need for, uh, a

Daniel: start to form. Yeah. If you have a seed, if you have a dense seed, but how does that form, right.

So you need gravity to do that work. The only way to get density is to have gravity pull things together. So primarily it's from having cold clouds of gas, there are other rarer ways for it to happen. You can have supernova shock waves, for example, that compressed things and then make over densities. But primarily it's just from having clouds of cold gas.

Jorge: Interesting. It's like a chill process. Star formation. You know, like an needs, a certain amount of calm and Zen for things to kind of, um, build up to a start, right?

Daniel: Yeah. You can't rush it, man. It's like the slow food movement. You want a hot start? It takes [00:35:00] time. Yeah.

Jorge: Yeah. No fast food galaxies in this universe.

It's all organic. you can't microwave

Daniel: a star

Jorge: that's right. You gotta it's all, uh, natural and organic. All right. Well, um, you said there's a bit of a mystery, right? Like in the sense that there are

more stars sort of quenching or dying or retiring than maybe we thought was possible or think is, is likely.

Yeah, we

Daniel: sort of can't explain all the quenching that's happening or at least, you know, 20 years ago, when we discovered that this was happening, we were very surprised. We thought. That very gradually galaxies would start to lose the ability to form stars. And we'd seen this slow drop off with a lot of galaxies in the green valley and a few that are totally quenched, but it happens faster than we thought.

And so there's been a lot of research in the last 10, 15, 20 years into why galaxies, quench. And now we have a few ideas. All of course, stimulated by this observation, we dug deep into the physics of it and thought, how would you quench galaxies? What are the processes we might have overlooked that could be [00:36:00] doing.

Jorge: Mm, I see. So, uh, what do you mean, I guess it happens faster than you thought or earlier than you thought. Do you know what I mean? Like, are you saying that, you know, the process of retirement is faster than you thought, or that it's happening earlier than you thought, or that it happens, you know, more than you

Daniel: thought.

All of that, right? It definitely happens earlier than we thought, because there are more galaxies that are quenched that are in that red category than we expected. And it also happens faster than we thought, because there are very few in the green valley. There's like two peaks. If you look at a distribution of the color of galaxies, you don't have a broad spectrum from red to blue.

You have a peak in the blue and a peak in the red, almost nothing in between with suggest that galaxies don't live in the green valley very long when they start to quench, they quench quickly. And then it's over. It's a

Jorge: fast process, you know, there's, you can't vote for like an independent third party.

It's like, you're either blue or you're

Daniel: red. I mean, I guess that's good news. If you like a quick death, you know, it's not a long tortuous. Struggle against the eventual demise

Jorge: man, I feel like a lot of the [00:37:00] confusion here today is that this view that to a professor retirement, is that , they're like, wait a minute.

Why are, why are so many galaxies retiring? Why would anyone retire? That's crazy. Yeah, well

Daniel: maybe they like it. You know, maybe they're tired of making new stars and they just wanna enjoy the stars that they have and hang out for a long time, trillions of years until they eventually all fade. Maybe it's a happy retirement.

Jorge: Yeah, there you go. You don't have to call it death it could be their, their new life. their second life. So that was the mystery, I guess. And you said that physicists have looked into this and so they have theories, I guess, about what's making all of these galaxies retire so quickly. If

Daniel: they have theories, none of them are really perfect or comprehensive, but they have a few cool ideas.

One is related actually to the black hole at the heart of the galaxies. And it's not that the black hole is gobbling up stars. Not that stars are falling into it, but black holes actually emit a lot of radiation. The black hole itself is not hot gas in the dust. That's swirling around the black hole before it falls in.

[00:38:00] That gets really hot and AITs a lot of radiation. And so that blows out a lot of the gas and. Once we talked about like how super massive black holes form, and there's a maximum rate at which they can grow because the bigger they get, the more they push away, the gas that's feeding them. And so this could also be spewing out radiation into the galaxy, which heats up a lot of the gas in the galaxy, or also helps blow it out of the galaxy.

And so that can stifle star

Jorge: form. I see you're saying like, you know, because star formation depends on very chill, calm conditions, anything that kind of excites the galaxy is not good for star formation. So one idea is that maybe it's the black hole in the middle of galaxies. That's I guess, agitating everything.

Yeah. And we

Daniel: see that these black holes grow at the same rate of galaxies is like a ratio of the black hole mass to the galaxy mass. Which seems roughly constant. And so that might help explain it because as these galaxies get big and get old, the black hole gets big and powerful and not just heats up the gas, but also helps [00:39:00] prevent more gas from falling into the galaxy from these filaments, from the intergalactic medium or the circum galactic medium.

Jorge: Mm. All right. But, uh, so that's one idea, but it's not perfect. It's

Daniel: not perfect because you know, the black hole is at the center and they don't really understand how it could like heat up the entire galaxy. You should still see star formation sort of at the edges in that case. So it can't explain everything.

Okay. So

Jorge: then what's another possible star retire. RO

Daniel: another possibility is that stars themselves are killing the galaxy. Remember that stars also generate radiation. Our sun doesn't just send out light. It sends out protons and electrons and all sorts of stuff, the solar wind. And so if you have a lot of these stellar winds, these particles, they can be blowing the gas out as well or heating it up.

It's sort of the same processes happens at the galactic center from the black hole, but instead it's happening everywhere. All at. So in some senses, it's a better candidate for what might be stopping star formation, cuz it's spread out across the whole galaxy. Mm

Jorge: I see. It's sort of like [00:40:00] stars form, but then they kind of spoil star formation for the area around them.

Right. Cause they like, it warms the star and, but then it starts to heat up this, the gas around it so nobody can make new stars. Mm-hmm

Daniel: it's really nimbyism, you know, it's all these old professors, they've got these nice houses they bought in the sixties and they don't want anybody building apartments in their backyard.

Jorge: Yeah. Yeah. Or like, you know, like, uh, you know, the, the old professor is taking up office FaceTime.

Daniel: exactly gotta make room for those young

Jorge: bloods. All right. And, but that, this one is also maybe not a perfect idea or

Daniel: cause yeah, because remember that the Galaxy's surrounded by gas and that gas should be falling.

The dark matter halo should be pulling that gas in and supplying us with fresh cold gas. That's been out there between galaxies. It hasn't been heated up from the stellar winds. So another area of research is understanding why that might stop happening. And one suggestion there is that the dark matter halo, the thing that forms our galaxy and shapes [00:41:00] it and provides the gravitational well to suck in this new gas that might get a little too big.

If that gets really big, then its gravitational power is really strong. And then what happens when the gas falls in, from outside the galaxy into the galaxy is that it gets heated up. This is called shock heating. If there's like a gradient in the density, outside the galaxy, then when this gas falls in it basically collides with the other gas and then it gets too hot.

And so you get hot gas falling in instead of cold gas, and then you can't use that to make

Jorge: new stars. Ah, interesting. But, but what do you mean? The dark matter halo gets too big, like, or dark matter is growing

Daniel: in galaxies. The dark matter halo is definitely growing because, you know, we have these filaments and it's sucking in not just gas, but also dark matter gravity in the universe.

Remember its goal is to gather everything together. So the reason you have these halo. And then these filaments is that the filaments are feeding the halos and not just bar matter, not just normal matter like gas and dust, but also dark matter is flowing [00:42:00] along these filaments into our halo. So our halos getting bigger and

Jorge: bigger.

Oh, I see. So as the galaxies get older, they pull in more of the stuff around them. They get bigger and heavier, which makes it more gravitationally

powerful, which sucks in. The gas may be too fast. And so when it sucks, it in it's too hot and it can't form anymore stars and

Daniel: all this just comes together to give you a picture of star formation in galaxies as sort of fragile and special.

Like you need these special conditions. Things have to be just right. And it's not that hard to perturb it and to make it so that galaxies while they're still big swirling blobs of stuff, they no longer have the conditions to make these stars and, you know, without stars. Wow. The universe just wouldn't be the same.

Makes you wonder if like, if the universe had been a little bit different, would we have not gotten stars at all? Just like big swirls of hot gas that never formed stars.

Jorge: Yeah. It would be a much darker universe, right? Without stars. You couldn't see anything.

Daniel: Exactly. We certainly wouldn't be here. You could have a literally dead universe [00:43:00] without the capacity to form life.

If it had been a little hotter, if all the gas in the universe had been too hot to form stars in the very beginning, well, you

Jorge: would still have, I guess, quasars, right? Like black holes maybe shining because of the gas swirling around them. You would still have some bright spots in the

Daniel: universe, right? Oh yeah, absolutely quasars.

You're right. And there were some of the brightest things in the universe. I wonder if life could form in the vicinity of a quasar. Yeah.

Jorge: That'd be pretty cool. I mean to, to that, to that, uh, civilization, it would be indistinguishable, right. That would be their son. That would

Daniel: be their son. Yeah. And in podcasts around that za, they would wonder, you know, are quasar is still growing.

They would wonder why quasars are no longer forming because you know, also Kosar is formed in the early universe and we're not really making quasars at the same rate as we used to.

Jorge: Mm that's. The next episode, I guess how do quasars retire? Who's killing

Daniel: off the qua zone. I'm just trying to tap into.

Paranormal true crime podcasts, which seem to be so popular. Ah, I

Jorge: see, I see, I see you're going for, um, [00:44:00] murder

Daniel: is Bigfoot killing galaxies. Next time I'm Daniel and

Jorge: Jorge. That's right. Although we still want the science category.

Daniel: Amazingly Bigfoot podcasts are in the science category. Don't get me started

Jorge: on that.

Oh, really? Wow. Well not maybe not the natural sciences category. Oh

Daniel: yes. In the natural

Jorge: sciences. Well, I guess who killed Bigfoot would be another, uh, topic. Why is Bigfoot retiring? that foot or her foot, uh, stop

Daniel: growing. Maybe he stepped on a galaxy and got quench.

Jorge: Well, um, so those are three reasons why a galaxy might stop making new stars.

And is there, are there any other reasons there are lots

Daniel: of other theories out there. Some of them involve like how galaxies tug on each other. Like we've noticed that sometimes galaxies that are more by themselves, that aren't part of a cluster tend to get quenched less often. One hypothesis is that galaxies are like harassing each other.

That gravity from other nearby galaxies might be preventing gas from falling into those galaxies to help spur new star [00:45:00] formation. So if you're in the middle of a cluster, rather than by yourselves, it might be that your friends in the cluster are interfering with a gas in fall and you need to make those new stars.

Jorge: Mm, wouldn't other galaxies though, help you in a way, slow down or cool off your own gas, make it better

Daniel: to make stars. Yeah, they do slow it down, but they might slow it down to the point where it doesn't fall into your galaxy anymore. So you still need that gas. It's a really fine balance that you need the gas to fall in, but not too fast.

Mm.

Jorge: You need it to be, um, like in the Goldilock zone,

Daniel: kind of. Yeah. You need a very slow delivery of frozen.

Jorge: All right. Well, I guess that's the mystery, although I wouldn't, you just think that, you know, a Galaxy's born, it has a certain amount of cold gas and at some point it runs out. And so the whole thing just kind of ends all at the same time.

Like, wouldn't that also be an explanation why. It seems to be so binary, so red or blue, like it just runs all outta gas at the same time, because all of it was formed at the same time.

Daniel: Yeah. It's a [00:46:00] good question. Why it's a surprise that Galaxys quench all at once. You're imagining that they start with some supply of gas.

And then the star forming that uses that gas is like used up all at once, all over the galaxy. But remember that it's not really about having the raw materials, the gas to make stars. You could keep making stars for zillions of years with the gas supply that we have stars, burn and die. You could just keep making new stars for a long time.

The issue isn't the supply. It's the conditions to make new stars. Remember you need cold conditions. So it's a surprise. If something is spoiling those conditions and doing it quickly and in a. Coordinated banner across the galaxy all at once. That's not what you expect to have from just the sort of random distribution of conditions that you expect in galaxies.

Jorge: Mm. I see it doesn't match a random distribution. It's kind of the mystery. All right. Well, um, I hope [00:47:00] you find a culprit, Daniel. I, you know, maybe before it kills our galaxy or no, wait, our Galaxy's already dead.

Daniel: Well, I thought you were pro galaxy retirement anyway, so I thought you'd wanna find the culprit and then encourage it.

Like, Hey man, would you let all these galaxies off the hook? They've done enough. I have pro

Jorge: retirement in any situation. okay.

Daniel: All right. You teenagers out there, Jorge suggesting that you retire tomorrow.

Jorge: Yeah. If you can, you know,

Go for it. You know, I feel like I retired in my early twenties, so I definitely

Daniel: recommend you retired and then started three or four new careers.

Jorge: yeah, I retired about three times. That's how pro retirement I am Daniel. Exactly.

Daniel: So I guess we shouldn't think of these galaxies as quenched. We should think of them as beginning their next adventure.

Yeah, there

Jorge: you go. And we hope you also find your next adventure pretty soon in the near. Hopefully in this galaxy before

Daniel: it retires. And remember that we are still learning about the process of galaxy formation and galaxy quenching and galaxy retirement. And hopefully we will live long enough to learn [00:48:00] much, much more.

Yeah.

Jorge: And I guess the main lesson is that the universe is still a work in progress. It's changing, it's growing, it's changing its color and showing its age,

Daniel: it's getting

Jorge: redder and redder. Well, we hope you enjoyed that. Thanks for joining us. See you next time.

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