Was the Big Bang just a black hole?

February 15 2016, by Fraser Cain

Black Hole

Fraser Cain "Asks a Spaceman" Dr. Paul Matt Sutter – why do we call the Big Bang a singularity, when we also call black holes singularities?

The universe is filled with coincidences. Like the size of the Moon and the Sun in the sky, even though they're so far apart. Or the shape of the Pac Man Nebula or the Wizard Nebula. Or like the plot of Force Awakens and every other Star Wars movie, the coincidences are everywhere.

But here's a pretty strange coincidence, and it has to do with the nature of the universe itself. Follow along with me here.

Let's consider black holes, a topic we've covered many times on this channel. If you've watched enough of our videos, you know a black hole is a region of space where matter and energy have been mashed so densely that the gravitational escape velocity exceeds the speed of light.

We don't know how big black holes are, but it's possible that they've crushed down into an infinitely dense region, known as a singularity.

Singularity, singularity… where have we heard that word before? Apart from Ray Kurzweil and his crew of technological singularitarians.

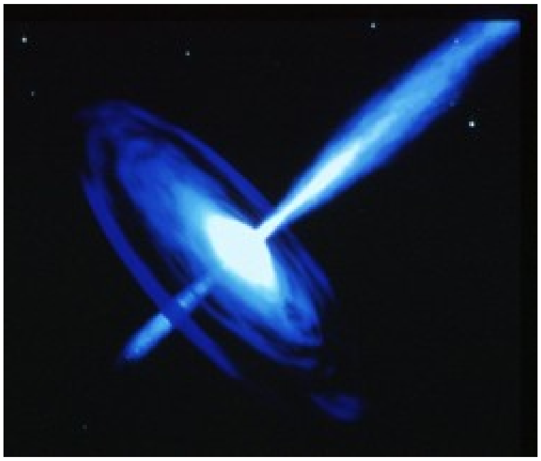
That word comes up when we discuss the formation of the universe; the Big Bang. Back at the beginning, 13.8 billion years ago, everything in the entire universe was crushed down into a region of infinite density. And then, in a fraction of a second, everything expanded outward.

Astronomers call this region of infinite density the Big Bang singularity.

This can't just be a coincidence, right? It's the same word.

Was the Big Bang singularity just a really big black hole singularity? A black hole with all the mass of the universe inside it?

I'm going to admit, this question is a little beyond my pay grade. To fully explain the science, I thought I'd bring in a ringer. Dr. Paul Matt Sutter is an astrophysicist with Ohio State University and the Astronomical Observatory of Trieste.



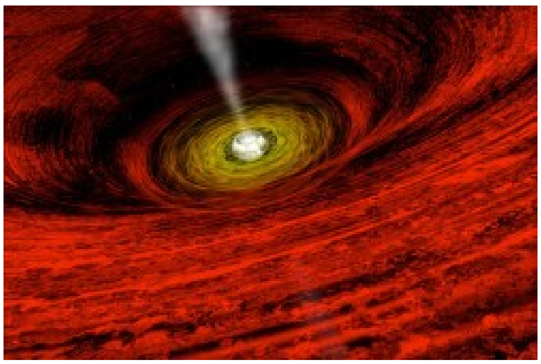
Galactic Black Hole with Optical Jet

Paul specializes in cosmic voids, he also knows plenty about both the Big Bang and black holes. I've reached Paul on the set of his Ask a Spaceman podcast, and thrown this zinger right at him.

Hey Paul, what's the difference between the singularity that formed the Big Bang and a black hole singularity?

1. Did the whole universe start off from a really massive black hole?

Paul: Thanks, Fraser. So, when we're looking at singularities, it's important to keep in mind what a singularity is. A singularity is a place of infinite density, and that's not really a thing. It just means that the mathematics that we're using to describe the thing have broken down. Like we get infinities in our answers when we try to calculate what's going on. In as far as we know, these kinds of things, these breakdowns in the mathematics, happen in two places. One is at the center of a black hole, where stuff is compressed down so much that we can't follow the math anymore, and the other time is in the very early universe, when the entire universe is crunched down into such a tiny volume at such high densities that we can't follow the math any more. So that's the only thing that they have in common – that there's a singularity, which means that we can't do the math any more.



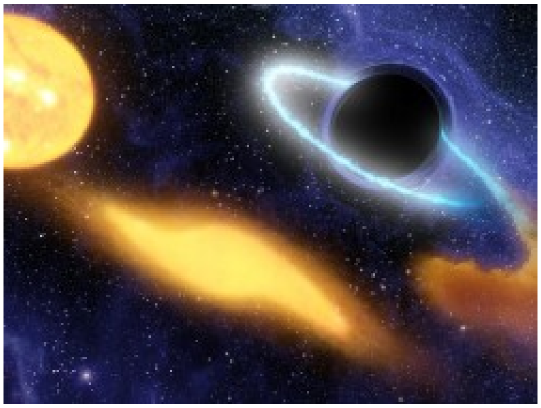
A black hole. Credit: NASA

Paul: And so even though they're the same, they're very, very different. A black hole singularity is a point in spacetime – like you live in the universe and you can point – there's a singularity like right over there, or over there or over there. It's a piece of the universe that's embedded in the larger universe, whereas the Big Bang singularity is the whole entire universe. It's a different thing where the entire universe is compacted down at such incredibly high densities that our mathematics can't keep track of it any more.

2. Why didn't the early universe just collapse back into a black hole?

Paul: You're thinking about these incredibly high densities in the early universe, and it's natural to wonder why it didn't just behave like a black hole behaves and crunch down into an infinitely dense point – why even bother expanding? And it's important to remember here just how different black holes are from the early universe. In both cases, we're using general relativity – these are the laws of gravity – they govern the laws of these systems. But we're using the same set of equations in different scenarios. We're using them to describe different things. A black hole is a particular solution to Einstein's equations of general relativity, and that solution comes about from asking the question "If I take a bunch of stuff over there and compact it down to incredibly high densities, what happens?" The answer is that you get a singularity surrounded by an event horizon. That's one particular set of solutions to the mathematics of that scenario.

Paul: But in the early universe, we have a different solution – we have a different thing going on. It's a different universe. The black hole solution is static – it's fixed, it's unchanging with time. That's an assumption in the mathematics. But in the early universe, things are changing. It's a different set of questions we're trying to answer when we apply general relativity to the early universe is "If I fill the whole universe evenly with a whole bunch of stuff, what does the whole universe do?" That's a different question than the question we're asking about black holes, and so we get a different answer. So even though we have that incredibly high density, the mathematical solution describing it, because we're describing the time evolution of the universe, we get different answers than we get for the black hole bits. And when it comes to the early universe – when you fill it up evenly with a bunch of stuff and ask what the heck happens to the universe, there's only two answers. Either the stuff in the universe causes the stuff to collapse and contract, or the stuff in the universe causes the universe to expand. And it depends on what the universe is made of, and it turns out, handily enough, that the universe is made of the kind of stuff that makes it expand. It's that time evolution component here that's important – that sets the difference between what's happening in the early universe and what's happening in a black hole.

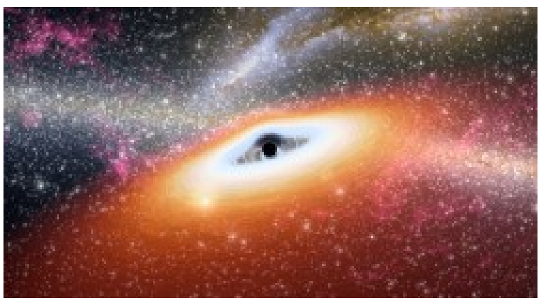


Black Hole Grabs Starry Snack

3. Could Black holes have formed in the Early universe because it has such high densities?

Paul: Oh yeah, very clever, Fraser. I see where you're going with that. With incredibly high densities, you're wondering maybe a little piece of the universe pinched off and made a black hole. Maybe in those early microseconds. And why couldn't that black hole have expanded to consume the rest of the universe? And the key here isn't about density, it's about differences in density. What separates a black hole from me is that it's way more dense than me, or at least I hope so. That's what makes it a black hole. It's much more dense than it's surroundings. But in order to make that black hole form, you had to have a little bit of extra stuff like in a pocket, like an extra gas cloud or a star, a little bit higher density than normal. Then gravity can work, and start pulling in more stuff, and more stuff, and more, building and building until you get the gravitational collapse that leads to a black hole.

Paul: But in the early universe, everything was uniform. There were no differences in gravity. Yeah, it was incredibly high density, but if you could be transported back there and actually survive, you wouldn't feel any gravitational pull anywhere because every direction is the same density. You're surrounded by the same amount of stuff in every direction – there's no gravity. It all cancels each other out. So there's no opportunity for a black hole to form because any one spot in the universe is no more dense than any other, so all the gravity cancels out and you get nothing. No black hole – they don't come onto the scene until much, much later in the evolution of the universe, and by that time, the universe is so big, the black holes can't affect the overall evolution.



This artist’s conception illustrates one of the most primitive supermassive black holes known (central black dot) at the core of a young, star-rich galaxy. Credit: NASA/JPL-Caltech

4. Right now the universe is expanding – will it someday collapse?

Paul: Yeah, a lot of astrophysicists and cosmologists worry about this decades ago – we thought that yeah, maybe the universe is expanding now, but maybe there's a little bit too much stuff in it – maybe that expansion will slow down, stop and then reverse, and then we'd end up in this massive big crunch scenario, the opposite of the Big Bang.

Paul: But it turns out, dark energy is here, and dark energy makes the expansion of the universe accelerate, so not only is the universe getting bigger and bigger every day, it's getting faster and faster every single day. And that, well, that kinda sucks.

That sounds pretty open and shut, but there's more to this journey. If you took the mass and energy of the entire universe and turned it into a black hole, it would have almost the exact same density as the universe itself, and an event horizon larger than the observable universe.

So does that mean that we are, in fact, living inside a black hole? Could we tell the difference?

Source: Universe Today

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