A Dark and Lonely Future

Fred Adams can't tell you the score of tomorrow's ballgame, but he can predict where the universe is headed. And it's not an appealing future. Luckily, we've got some time.

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by SCOTT DODD

FQXi Awardee: Fred Adams, University of Michigan July 20, 2007

Fred Adams went into astrophysics because he wanted to ask Big Questions: How was the universe born? Where do stars come from? Are there other planets out there?

Although Adams now spends most of his time studying star formation, even that's not enough to satisfy his inquisitive mind. "Once you've understood the birth of everything," he says, "the next big question is: What happens next?"

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Back in 1995, while teaching at the University of Michigan, Adams had a chance to answer that intriguing question. The university had a tradition of developing "theme semesters," centered on a common concept, such as "Death, Extinction, and the Future of Humanity." Usually, theme semesters passed over the physics department in favor of humanities-style analysis. But this time, Adams saw an opening: He could design a class on "The Future History of the Universe."

Adams would leave predictions about what might happen to humanity in a decade or a hundred years from now to others. But using his expertise in cosmology, he could predict what would happen to humanity's home – the earth, the solar system, and the universe – billions and trillions of years into the future. Now that's an interesting story.

Start With What Happened Before…

Einstein's equations and other building blocks of modern physics actually provide one heck of a crystal ball, Adams says. They predict that the universe – born in the Big Bang – will continue to expand, quite possibly forever. Planets, stars, galaxies, and everything else that exists, will be driven farther and farther apart, until the universe is a very empty, lonely place to be. (A less likely alternative hypothesis, the "Big Crunch," envisions the universe eventually reaching a point where everything falls back in on itself.)

Many cosmologists had studied the universe's expected expansion, Adams says. But while previous work examined how big the universe would eventually become, hardly anything had been done on what would happen to the objects in the universe as it continued to grow.

Adams' expertise in stellar objects made him ideally suited to consider the latter issue. Designing his theme class helped to organize and develop his thoughts, eventually leading to a review article and a 1999 book, The Five Ages of the Universe: Inside the Physics of Eternity, published with his post-doc and now FQXi Member, Greg Laughlin.

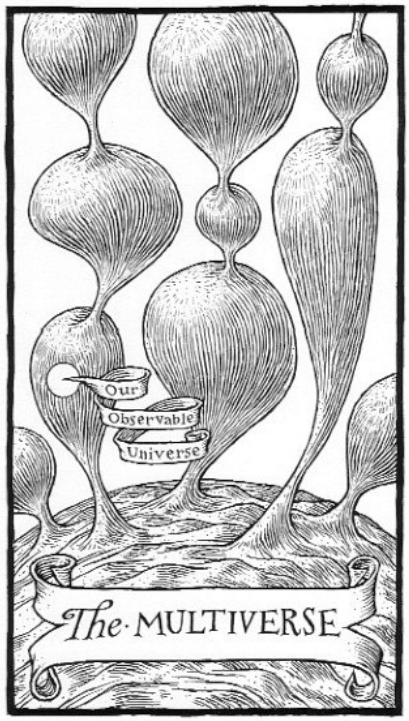
According to Adams and Laughlin, we live in the second of the five great ages, dubbed "The Stelliferous Era." Think of the current era as the 'age of stars,' when the universe is filled with light and energy, born in the nuclear fission of many billions of suns.

The stelliferous age, thankfully for us, is just getting started: We're 10 to 14 billion years into an era that will likely last 100 trillion years. In other words, we're only one-tenth of 1 percent of the way into the star-bearing life of the cosmos – the equivalent of a one-month-old baby. "At that point, your whole life is ahead of you," Adams says.

…Then Fast Forward – A Lot

But at a time very far in the future, stars will exhaust their nuclear fuel and burn out or explode into supernovae. Eventually, galaxies will run out of hydrogen gas, no more suns will form, and the longest-lived stars – red dwarfs – will fade away. Darkness will slowly consume the universe.

Depressing stuff? Not in Adams' eyes. "The timescales we're talking about are enormous," he says. "The universe is going to live for an incredibly long time."



OUR UNIVERSE The Multiverse

Adams also finds it exciting that at such an early point in the history of the universe, inhabitants can see so far into its future. "The fact that we can say anything on those kinds of timescales is empowering," he says.

One of Adams' colleagues in the physics department at Michigan, Gus Evrard, specializes in creating computational models of the structure of the universe. He and Adams have designed virtual universes together, so he knows how Adams' mind works.

"Fred is a remarkable character," says Evrard, who thinks of himself as an engineer as much as a physicist. "There are times when he's a very practical guy, like I am. Then a minute later, he can be talking about some very far-out ideas. And that combination, I think, makes him unique."

PREDICTING WHAT HAPPENS NEXT **Fred Adams**

When Adams began considering the universe's future, a lot of questions remained unanswered. The acceleration of the cosmos hadn't been measured yet. The discovery of brown dwarves, and the confirmation that planets circled other stars, only dates back to1995. Physicists understood a lot less about dark matter and galaxy formation than they do now.

"We know the universe much better today, which means we can project it into the future in much more detail," Adams says. That's why, this year, he's embarking on a three-year re-examination of the future universe with an $85,519 grant from The Foundational Questions Institute.

Reshooting The Ending

What more does Adams hope to learn? For one thing, there's the question of whether the fundamental properties of physics might change over the enormous timescales he's contemplating. Could gravity get weaker after trillions of years, or could the electromagnetic constant change? And if they do, what could changes in these fundamental forces mean for the future of stars and galaxies and everything else that exists?

Adams is also looking into the possibility that multiple universes could exist, each with different laws of physics. Imagine that you could turn the volume knobs up or down on the four fundamental forces of nature, to make them weaker or stronger. Are the settings of our universe the only ones that work, or could others also lead to a universe filled with matter and energy, planets and galaxies?

"Which settings will have stars, and which won't?" Adams wonders. "How lucky are we to have stars, in other words?"

Evrard says that Adams' work helps expose the limits of human thought, such as how far we can see into our future. "Fred is in a very small class of physicists who have successfully worked in this area," he says.

It seems, though, that at least some other people find questions about the end of time as interesting as Adams does. His 1995 course on the future history of the universe was so popular, it's still offered at Michigan today. Adams hopes that work done with his FQXi grant can help add to the knowledge taught in that course.

"It's a bit out of the mainstream," he acknowledges. "NASA's not really worried about the future of the universe because it doesn't affect NASA missions. But what more fundamental question can there be than what happens next?"

The Five Ages of the Universe

The Primordial Era: It started with a Big Bang – literally – and ended some 10,000 years later when the radiation-filled cosmos had cooled enough to allow the first hydrogen atoms to form.

The Stelliferous Era: You're living in it. "Stelliferous" means "full of stars." In this era, stars are being born, living and dying all the time – some orbited by planets, at least one of which, ours, harbors life – and stars' nuclear fusion bathes the universe with energy. The first stars were born when the universe was only a few million years old. These stars have long since exploded into supernovae, providing the building blocks of new stars and solar systems. Galaxies and galactic clusters pulled themselves together after a billion years or so. And so it continues, for a very long time.

The Degenerate Era:: After 100 trillion years, stars will exhaust their nuclear fuel, galaxies will run out of hydrogen gas, and the universe will be cold and dark, filled with white dwarfs and neutron stars that give no light, and black holes that suck everything they encounter out of existence. A few collisions of leftover stellar matter might occasionally provide a spark of new energy, but those rare stars will lead a lonely existence, like a single candle shining at night in the middle of a vast forest.

The Black Hole Era: Eventually, the final stellar remnants burn out, protons decay away, and the cosmos is left with nothing but black holes – until even they run out of energy, evaporate and disappear.

The Dark Era: What can you say about a time when utter loneliness is all that remains of a once-bright cosmos? A stray surviving electron and positron might occasionally bump into one another and form a single atom. That's what passes for excitement when everything else is gone.

Source: "The Five Ages of the Universe: Inside the Physics of Eternity" by Fred Adams and Greg Laughlin