

Quoting from Alan Lightman's, "A Modern Day Yankee In A Connecticut Court and other essays on Science".

Conversations with Papa Joe

The Third Evening

"The next day I had three lectures to give, which didn't go so well, and late meetings with students. It was seven o'clock by the time I got home. I began wondering if I'd ever see my great-grandfather again. To my delight, he appeared that evening in the usual place, chipper and perched in the wingback, scarcely after I'd got the pipe going. Apparently, he was getting the knack for his strange kind of travel.

"In my time I used mostly Prince Albert in the pipe," he said, taking a broad whiff of the smoke. "Named after the Queen's husband. Now there was a woman with good common sense. And she wasn't afraid to speak her mind either."

We chatted awhile about Queen Victoria, whom my great-grandfather was well up on. From there, Papa Joe moved on to the Great War, and how he nearly went broke when the prices of labor skyrocketed and he felt morally bound to stick to the costs in his contracts. I loved hearing his stories. After a few minutes, however, Papa Joe grew impatient and got up from his chair to look out the window.

"You haven't really kept your promise to tell me about stars," he said. I started to speak, but he continued. "I used to take your father out in the backyard at night to look at the stars. That's when we all lived in the stone house on Sixteenth Avenue South. Your grandfather was always too busy with business."

"Dad did the same with me when I was a boy," I said.

"What are stars, anyway?" asked Papa Joe.

"Well, to begin with, stars are pure gas, gigantic balls of gas, much larger than planets. Their gravity holds them in, the same way the earth's gravity keeps our air from flying off into space."

"All gas, you say. Confounded flimsy material for heavenly bodies, if you ask me. So if I dove into the sun, which is a star as I remember, I'd never hit solid ground, all the way to the center?"

"Right. Of course, you'd get burned into powder long before that, bones and all. Stars give off a great deal of heat as well as light."

"I have no plans to visit one of those balls of fire, beautiful as they are," said Papa Joe, "But tell me, young man, how can you be so sure that the sun isn't solid in the middle, with the gassy part only a covering, like the air around the earth? Have your solar scientists gotten up their courage and launched themselves into the sun?"

"Hardly," I said with a grin. "Scientists these days prefer to take their adventures through frightening equations. According to which, the Sun requires a temperature of millions of degrees to keep itself inflated the way it does against the inward pull of its gravity. At that temperature, you can be sure any solid matter would be instantly vaporized. The sun's got to be gas all the way through."

"So now it's equations, after smudges of light through a telescope," said the old gentleman, jingling some coins in his pockets. "Please answer me this. Why don't stars burn themselves up, in such a high heat?"

"They do," I answered, "but not for a very long time. Stars outlive ordinary fires because they don't run on chemical combustion. You burn wood or gasoline or flammable gas, and you're getting energy only from the outer parts of atoms. If the sun ran on that kind of energy, called chemical energy, it would be out of

fuel in a few thousand years. What you need in a star is a different kind of energy, call atomic energy. That's the energy you get from the inner parts of atoms. It's set free when two atoms fuse together to make a larger atom, which happens only under much higher heat than in chemical fires. In the sun, for example, atoms of hydrogen gas are continuously joining to make atoms of helium gas. Pound for pound of fuel, atomic energy is millions of times more powerful than chemical energy. It should keep the sun shining for billions of years."

Papa Joe nodded, "I love the way nature has various energies or each different purpose, like you great-grandmother with outfits for every occasion. Sometimes she wanted to shimmer and sometimes to blaze." He chuckled. "But back to the sun. Can your scientists predict what will happen after it's burned up its atomic fuel?"

"Yes. Near the finish, it should change brightness and color, swell up to hundreds of times its size now, and engulf the earth. Then, when it's entirely exhausted its fuel, it should collapse to a very dense sphere about the size of the earth, growing dimmer and dimmer and colder and colder. The outer planets of the solar system, the ones not boiled away earlier, will continue to orbit a dead central mass."

"It doesn't seem right," Papa Joe said, "the sun ending its career shrunken up but kept on, like an old general with a desk job." He sat for a while staring at the fire. "I just don't see how you can figure so far in advance," he said finally. "Last night it was billions of years in the past and tonight it's billions of years in the future."

"Some of the predictions come from equations," I replied.

"You talk about your equations as if they were the Ten Commandment. Where do they come from, anyway?" he asked.

"To be honest," I answered, "I wouldn't put complete trust in the equations either, if that's all I had to go on. But there's other evidence, observational evidence. Astronomers have looked at a great many stars of all different ages and stages of development, and from this, they believe they can piece together the life story of a single star."

Papa Joe thought for a moment. "That must be the same way those agricultural fellows figure out the way a redwood tree grows," he said. "From what I've heard, a redwood lives a lot longer than a man. But I guess if you studied a lot of them and saw some just planted and some throwing their first leaves and some getting old, you could get a pretty good idea how a single tree lives out its life."

The old gentleman got up from his chair and put three more logs on the fire. He remained standing comfortably by the fireplace, resting on arm across the mantel. "From what you've said," Papa Joe said, "I'd imagine that space should get darker and darker, as each star goes out one by one."

"It's not quite like that, Papa Joe," I replied. "New stars are continually being born, throughout the galaxy. The basic ingredient, gas, is everywhere, strewn between the stars. To make a star, the gas has to bunch up, which happens here and there because of all the activity in space. Once such a clump forms, it collapses under its own weight, causing it to heat up. Eventually the temperature is high enough that atomic fusion can get under way, and the thing becomes a star. We've actually seen newborn stars and the gas that produced them."

"Death followed by birth," said Papa Joe. "It seems like a law of nature. But with stars, I guess there are a lot of cold bodies left floating through space."

"The end isn't that gruesome for all stars," I replied. "The ones much heavier than our sun depart with a much grander flourish. They explode at the end, and, while donating their insides to space, they

briefly outshine a whole galaxy. We call those stellar explosions supernovae."

"That's the way to go," said my great-grandfather. "I don't imagine that calm fellow Aristotle, who like his universe undisturbed, would be happy with supernovae."

"He wouldn't be happy with a great many unheavenly bodies astronomers have recently found, a lot of them in our own galaxy. For example, there are pulsars and black holes, created by the collapse of stars that can't hold themselves up under their own weight. A pulsar is an extremely dense sphere with the mass of a star and a diameter of ten miles. It spins once around every second or less and spews out a stream of energy into space like a rotating searchlight. A black hole is a mass with such high gravity that not even light can escape from its surface. Large black holes, it's believed, chew up and swallow whole stars."

The old gentleman whistled. "It's a wonder our own solar system has got on so peaceful, with all of the spinning and spewing and chewing."

"Our stretch of the galaxy happens to be very quiet," I said. "The interesting goings-on are much farther out. Even with telescopes, some of these pulsars and black holes are the devil to find. Unlike stars, many of them shine mostly with X-rays, which the human eye can't see and which never get through the earth's atmosphere in the first place. Luckily, we've figured out how to launch small man-made moons, called satellites, which orbit the earth above the atmosphere. Astronomers have gotten into the act and begun loading their new instruments onto satellites. The way it works is, the instruments catch the X-rays coming in from a particular direction in outer space, convert them into electrical signals, change these into a kind of Morse code, and broadcast it all by radio to humans waiting below. On the ground, scientists take the information and try to reconstruct a picture of the object that gave off the X-rays."

"That certainly doesn't sound like what I remember of

astronomy," said the old gentleman. "I knew a professional astronomer once. A big man named Thayer, who lived on Fifth Avenue. When it was time to do some observing, he'd pack up several days of sandwiches and good books for the cloudy nights, travel to the top of a mountain somewhere, and sit at the eyepiece of a telescope, making notes and drawings and simply enjoying the view firsthand. I wonder whether these X-ray fellows have fun in their work."

"Some of them do, at least the ones I know," I replied. "They hang up their graphs and their charts and their numbers sent down by satellite, and they stare at them, and pretty soon they start talking about these pulsars and black holes like they were cousins in Nebraska. Each one has got a name--there's Scorpius X-1 and there's 3U 0900-40 and there's Cygnus X-1, and so on. For each of them, the astronomers will tell you how many trillions of miles away it is, how heavy it's likely to be, how large it's likely to be, how fast it's spinning, what it would look like if the eye could see it, and dozens of other details. These things are real. Astronomers will never get anywhere near them. Astronomers will never even see them. But they're real. The instruments say they're real, so they're real."

"What's real and what's not is a swamp I'll steer clear of," said the old gentleman. "But I do like the faith of modern scientists in their gadgets. These black holes I'd like to hear more about, if you don't mind. You mentioned that light can't get away from a black hole, because of its gravity."

"Yes. That's why they're called 'black.' A black hole doesn't have a material surface like a star, but has a boundary, and within that boundary any light emitted, even headed out of the hole, will be turned around and pulled to the center by gravity. The size of the boundary varies in proportion to the mass inside. For a black hole the mass of our sun, its boundary would be a sphere a few miles across."

"Wait just a minute" said Papa Joe. "I took you to say

that we've picked up X-rays from black holes. How do X-rays get out from one of those things when light can't?"

"I'm sorry, I should have explained that," I said. The old gentleman was quicker than any of my students. "The X-rays from a black hole don't come from the black hole itself, but from hot gas rushing toward it. What we're looking at, or rather what our instruments are looking at, is a sort of cocoon of shining gas surrounding the black hole. Black holes with no gas around them are completely invisible. They're harder to find."

"But of course, for you and your friends, invisibility is no handicap against seeing things," said Papa Joe, with a wave of his hand.

"That's truer than you think," I said, smiling. "Even if every black hole were bare and invisible, a great many scientists would still believe in them. The equations predict they exist."

"You keep dangling those damn equations," my great-grandfather said, and began growing dim.

"Come back one more night," I pleaded to his vanishing form. "For the equations. Just one more night."

"One more night," came a faint reply. After Papa Joe had gone, my study felt very empty.

To Be Continued