Astronomy Cast Episode 191
Chandrasekhar

Fraser: Astronomy Cast Episode 191 for Monday May 24, 2010, Chandrasekhar. Welcome to Astronomy Cast, our weekly facts-based journey through the cosmos, where we help you understand not only what we know, but how we know what we know. My name is Fraser Cain, I'm the publisher of Universe Today, and with me is Dr. Pamela Gay, a professor at Southern Illinois University Edwardsville. Hi Pamela, how're you doing?
Pamela: I'm doing well, how are you doing Fraser?
Fraser: I'm doing very well also. And we don't normally do this, but I wanted to send a special message to Ally who wrote us in... and congratulations on getting a B on your test. So, we're gunning for you. Right, let us move on to today's show. So, the first half of the 20th century was a productive time for astronomy, with theorists working out much of the science that we take for granted today. One of these astronomy stars... pardon the pun... was Subrahmanyan Chandrasekhar, who determined the maximum mass of a white dwarf star and won a Nobel Prize. So Pamela, another duo... partnership... the person and the robot. So, today we're going to talk about the person who was the inspiration for the robot which is actually up there doing work today, so we'll have a lot to talk about the Chandra mission, but let's talk about the person.
Pamela: Sounds good... they're both full of a lot of high energy so it works out.
Fraser: And we were talking about this before... trying to sort of work out how to pronounce his name... now Subramayan, that is...
Pamela: His patronymic....
Fraser: Right, so that's almost like a last name so it's...
Pamela: It's a different way of handling names than we're used to in the Western language. It's not your friend-to-friend name first and then your family name or your patronymic second or third, but rather they start with the patronymic and then do the friendly person-to-person. So calling Chandrasekhar "Chandra" is much like calling Elizabeth "Beth." It's a nickname for the person's name.
Fraser: But from here on out, we're just going to call him Chandrasekhar.
Pamela: Or Chandra.
Fraser: Right... 'cause we're close... we're like that...
Pamela: I'm actually academically sort of descended vaguely in a class by class way to Chandrasekhar...
Fraser: Well I wonder... and unfortunately I don't know all my history here... there is a number that mathematicians use to determine how many positions they are...
Pamela: The Erdos number...
Fraser: That's right!
Pamela: I do have an Erdos number... but it has nothing to do with Chandrasekhar. And what's even cooler is the Bacon-Erdos number, which I challenge all...
Fraser: What's your number?
Pamela: So it turns out that I actually have a Bacon-Erdos number of 6 which kind of makes me proud... it comes from papers that I worked on with Dr. David Lemberg at

McDonald Observatory to get to Erdos and then working with Kevin Grazier on the Universe to get to Bacon... and I'm kind of stupidly proud of my Bacon-Erdos number.

Fraser: Oh, I see, so you're connected to both Erdos and Kevin Bacon by various degrees of separation, ok... someone should work out something like that for astronomy... what's your Einstein number? How far away removed are you from Einstein?

Pamela: I'm probably pretty close because of some of the people that I've published papers with... I need to figure that out at some point....

Fraser: Anyway... we're completely off topic... so then it's time for the history lesson. Who was Chandrasekhar?

Pamela: He was one of the most concentrated scientists... and I didn't mean for that to be a pun, but he was one of the most focused scientists of the last century. He approached research with an intensity and a passion that has rarely been seen, I think it's safe to say. His best discovery in terms of "Wow, that changed everything," may have been the understanding that when large enough stars die, they collapse to the point that the material is so packed together that it can't get any closer without actually changing states. So when the sun dies... it's a normal, everyday, not-too-big, not-too-dangerous of a star... when it dies it's just going to collapse down until the electrons start pushing on each other and the electron degeneracy pressure supports the star as a white dwarf. But if a much larger star... something that might have started its life off as a 6-8 maybe 10 solar mass object, when it dies it leaves behind a core that's more than 1.4 times the mass of the sun. Something that's greater than this 1.4 times the mass of the sun, when it collapses down the electrons go no, can't, can't handle it anymore... and the electrons and protons actually will end up combining, releasing energy, releasing neutrinos, and the star collapses down into a neutron star. If something is much, much bigger than that, even the neutrons can't push one another apart and instead you end up with a black hole.

Fraser: Right. And we get the Chandrasekhar limit, is this number which is the maximum mass of a white dwarf star. So if a star somehow happens to gain more mass that pushes it beyond this Chandrasekhar limit... like 1.44 time the mass of the sun... then it's too much and it just collapses catastrophically and you get a supernova.

Pamela: Now the thing is, he came up with that while on a boat from undergraduate school in India and he graduated college at 19. He came up with his theory while on the boat, at the age of 19 to attend graduate school in Cambridge.

Fraser: Well, now we're getting ahead of ourselves, so let's talk about his history then... So, Chandrasekhar... that's an Indian name.

Pamela: He grew up in Punjab, in British India, which is now Pakistan. He started out speaking Tamil growing up. He comes from a Hindu family, and he actually comes from a scientifically famous family. His uncle was C.V. Raman who came up with the Raman effect which we'll talk about in a different show. Nonetheless, really cool thing needed to understand the splitting of spectra... and he was a Nobel Laureate. So here we have Chandrasekhar growing up in a family of a prominent physicist. As a child he was home-schooled, his father was an accomplished musician, he worked for the railroads. It was an interesting childhood yet then led to him to attend the Hindi High School and then Presidency college, and like I said, he graduated from college at 19 with his Bachelor's degree.

Fraser: And then had to go to another country to get an even better education, right?

Pamela: Well, just as it is today, there's only a few really, really top colleges in the world. At the time, the top college was probably Cambridge... arguably Oxford... maybe Harvard... There's only a limited number of really top schools you can have in the world. Cambridge was one of them... it remains one of them. And he was able to get to go there for graduate school and then he stayed on with a fellowship after that before going to the University of Chicago. Along the way he got married to another woman from India who was another scientist as well, someone who had actually attended Cambridge with him... was at Trinity College... and one of the neat things in his biography is she actually not only became a stay-at-home wife in a lot of ways, but was in some ways his personal assistant for science... she could read over his papers and offer critiques. So she was there to support him... by just making sure that he ate. If you're too busy of a scientist, someone usually feeds you. I'm lucky enough that my husband, when I'm working on grants, will feed me.
Fraser: Perfect!
Pamela: But she was there to help him in all aspects of his life.
Fraser: Right. And so you say that he ended up at the University of Chicago?
Pamela: Yes, and he was there throughout the entire rest of his career with the exception of during World War II when he worked on ballistics at the Aberdeen proving ground, instead. But throughout his life he was a very dedicated theorist, although he did have an office at the Yerkes Observatory, and while he was at Yerkes Observatory he was still teaching his classes at the University of Chicago, which was a bit difficult and led to him occasionally making insane drives through snowstorms. There's one famous anecdote of... anyone who could, attended Chandra's courses... he was not the kind of researcher who couldn't teach, though those exist... we wish they didn't... but it happens. You're a trained scientist, you're not a trained teacher. And Chandra was one of the exceptions... a lot like Fermi. He could just teach things amazingly well. And one day, during a particularly bad snowstorm, he was told... just don't bother. Why are you driving the entire 200-mile round trip between Yerkes and the university to teach this class on stellar atmospheres? Well, the only two students who showed up in class that day were Tsung-Dao Lee and Cheng Ning Yang, who if their names were pronounced correctly would know who I just said... they won a 1957 Nobel Prize in physics. So he made that 200-mile round trip through snow, and it turned out that the people who he took the time to teach, who he put the effort into, both went on to get Nobel Prizes before he did and that's just kinda cool.
Fraser: So, he was a professor, he had an office at the observatory, but his research... where did his research really start, and what were some of the major advances that he made?
Pamela: Well he started fully involved in stellar structure. This is where he worked on this theory of white dwarfs, where he then went on to study stellar dynamics, and he just migrated through the different physics involved in stars, moving on to the theory of radiative transfer... Eventually he worked on black holes, and in his final years he was working on the new field of gravitational waves. So he always kept himself in highly mathematical fields... if you ever get the chance to read any of his books, they're very precisely written... no word that isn't needed is included... but the mathematics doesn't skip steps. He just goes through and does it right and does it well.

Fraser: And would these be books that your sort of regular person would be able to read, or is there a lot of math in there?
Pamela: It's solid math. If you were an engineering or science major in college, you might be able to survive this. The thing about stellar atmospheres is it's beautiful math. This is someone who really doesn't like doing math... and a lot of relativity has reduced me to either throwing things or crying, but stellar atmospheres is the type of thing that it's a lot of algebra... you chew through it... there is some integration... you do need to know calculus... but you chew through it meticulously, and you can actually, on paper, build a star. And that's amazing! But, it's overwhelming to look at. When I was an undergraduate, I got to take stellar atmospheres from Eugene Capriotti, who had done his PhD work under Chandrasekhar, and I remember the first day of class sitting there... and this was my second year of college... so I'm sitting there at 19 as he spews equations across the chalkboard, and I'm still writing down the top of the third chalkboard as he's erasing the first chalkboard... and by the end of that class with Eugene Capriotti I had the realization that I knew all the math I needed for the course, and dropping the course was not going to make it easier later, but it was the type of thing that I just had to sit down and consume. It's not something you can scan-read, it's not something that you catch onto quickly... you have to chew it up and understand it. But if you have that basic perseverance with algebra and you have that basic perseverance with figuring out the calculus as needed, any of you out there could figure out how to build a star on a notepad or in your computer.
Fraser: Whether you would want to... is another question, but.... So we've talked about stellar structure and white dwarfs... but he did a lot of work in stellar dynamics. What is that and how is that different?
Pamela: Well, stellar dynamics is basically the theory of how is it that stars move... that's where the word "dynamics" comes in... and so you're looking at the statistical understanding of how is it that globular clusters keep their form whereas open clusters drift apart? How is it that different systems evolve over time? For instance our modern understanding of stellar dynamics allows us to finally understand that globular clusters actually beat like hearts, and for the middle part of Chandra's career he's actually looking at the stellar dynamics of our Milky Way galaxy. It's not sexy work, but it's fundamental work that really helps us understand how it is that things hold their shape and change over time.
Fraser: Right, and up until some of the recent missions, like the WMAP, this was one of the ways that astronomers would try to get at the age of the universe.
Pamela: Right. It didn't work, but...
Fraser: No, no... that's right... but at least you could determine how old they were and how they were changing... So what did he work on next?
Pamela: So the next thing he was looking at was radiative transfer. This is one of the fields of astronomy that is... often when you're in it, you think you're taking quantum mechanics. It's the theory of how is it that light is absorbed and re-emitted by nebulae. It's the theory of how do we end up with the spectral lines that we see and that we don't see in stars. All of these different theories—that all falls into radiative transfer.
Fraser: And so... sorry... like I remember when we were talking about stars... is this part of the radiative zone of a star where light is generated in the core and then has to radiate

from atom to atom slowly moving its way out through the radiative zone until it can hit the convective zone...

Pamela: And the exact same physics that describes the radiative zone inside of a star is the same physics that applies to light passing through a cool nebula. It's just different parameters to solve the same type of problem. Now, there are different boundary conditions and sometimes you have to worry about one set of physics while in other cases you have to worry about another set of physics being the dominant player. But it's the same concepts that play in both cases. And trying to figure out absorption, trying to figure out spectral lines, trying to figure out just how is it that light finally makes it to the surface of the star and makes it from one side of the nebula to another. These are interesting quantum mechanics problems that are difficult and he spent a lot of years of his life looking particularly at different equilibrium states and how it is that things radiate.

Fraser: Right, and when you say equilibrium... like for example, how a star can remain at a certain size where the light pressure pushing out matches the gravity pulling inward?

Pamela: And not just that, but you have heat pouring into a nebula, it's absorbing some of the wavelengths and reradiating them in all directions, there's different cascade effects going on, and so at different temperatures you can have nebulae supported in different ways. They're just externally heated, where stars are internally heated.

Fraser: Right. And this is an incredibly long career... I mean we're looking at what he did in the 50s, the 60s... I know in the 80s he worked on black holes.

Pamela: He kept doing science up until he died in '95. This is someone who was born in 1910, was doing Nobel Prize quality work in 1930, and kept on doing cutting edge research until '85.

Fraser: And he did get a Nobel Prize in '83.

Pamela: Yes... he finally got one. And it's funny, it was in some ways actually a disappointment to him because the Nobel Prize he got... admittedly I just did the exact same thing... looked at his earliest work and praised that. He felt that it somewhat denigrated the work he did later. It's sort of like saying "You peaked at 19, dude!"

Fraser: Right. Yeah, that would be pretty frustrating.

Pamela: Admittedly, it was his discovery that wasn't accepted for a long time... and part of the reason that he went to the University of Chicago was to escape the peer pressure to change his theory that he was experiencing at Cambridge. He put up with so much stuff to push forward and to get people to accept that white dwarfs are real, neutron stars are real... well, we knew about white dwarfs... but neutron stars are real, black holes exist. And when that finally was accepted, that changed everything. You get Nobel Prizes when you change everything.

Fraser: And so which of those... was it for the degenerate matter...

Pamela: It was for his work on stellar structures, specifically the Chandrasekhar Limit.

Fraser: Right.

Pamela: It was a shared Nobel Prize as well, so while it was his work that led to the Chandrasekhar Limit, it was all of the work he had done on stellar structure that ended up getting him the shared Nobel Prize.

Fraser: And you said that he passed away in '95...

Pamela: In '95. While I was an undergrad, it was really interesting to have him pass away with one of his students there, now as one of our most senior faculty, to talk about

him over the years. You got to hear the stories that you only find buried in the backs of biographies. From 1952 to 1971, Chandrasekhar was the editor of the Astrophysical Journal. And this was very much in the defining days of “What’s the difference between Astronomy and Astrophysics?” Chandrasekhar was perhaps one of the first people to work very hard to combine physics and astronomy... there were others... there were Eddington and a whole group of people that he was part of the cadre of that developed this new field. Chandra would set certain periods of his day that were only Astrophysical Journal, and if you tried to interrupt him with science, there was nothing you could do... he would send you away. There were other parts of his day that were strictly dedicated to science and if you tried to ask him about class or the Astrophysical Journal... you’re going to get sent away... and his ability to compartmentalize his life and have absolute focus is part of what made him so good at everything he did. It makes me wonder in our modern day world of email where if I don’t respond to something in 45 minutes I’m getting a phone call... hey did you get my message? Could this type of a scientist do the work he did? It was his ability to say right now, at this point in my life, I’m only going to do stellar structure. Right now I’m only going to do gravitational waves. His ability to segregate his time allowed him to do amazing things in a focused way that I don’t know how you can do in the age of email, and I really respect the ability to focus that he had.
Fraser: You just don’t answer your email.
Pamela: But then the phone rings...
Fraser: Don’t answer the phone...
Pamela: But then the other phone rings...
Fraser: Don’t have another phone...
Pamela: But then they Skype me...
Fraser: Alright, you got me there. Yeah, I remember when we were at the American Astronomical Society there was a big party and you were kinda walking me around and pointing out people like oh, Nobel Prize... oh, Nobel Prize... pointing out these people... and it’s this connection... we have this connection with people who now have done all this amazing work, and yet I think you can go and you can talk to them and you can find out their ideas and you can ask them questions and hear their responses. And that gift that they give of their interest in learning and knowledge and of the universe and then their professors... and that comes out everyday with the people that they’re interacting with. I think that’s what’s really special about the field of academia that you really just don’t get with other “celebrities,” and I’m using “air quotes” when I talk about celebrities. You don’t necessarily have that same connection with a famous actor or musician when you’re working in their field. So I think that’s just a really special thing and it’s amazing that you can attend a class with a Nobel Prize winning physicist, have them teach you about stellar structures, and then go to your other classes. Imagine what impact that would make in your life, so...
Pamela: Well, and some of the Nobel Prizes that we have today have gone to some of the most giving people. John Mather is someone who I’ve seen very graciously talk to all sorts of people, answering their questions, taking on new technologies to give talks in Second Life, talking with undergrads at AAS meetings... another one is Barry Blumberg who admittedly got his Nobel Prize in medicine, but we’ll accept him anyways, and he loves astronomy and he’s now working with a lot of the moon projects coming out of Nasa Lunar Science Institute and is tangentially related to our Moon Zoo project that is

coming out of the Zooniverse. A whole bunch of my students met him and they had no clue who he was. He was just this friendly older man... well-dressed... but looked like a professor, just another professor, and he walked down the row and talked to each of them about their posters... and it was like yeah, we met an old guy. One of my students I had to like kick because he was talking to a pretty female graduate student, and there was this old guy trying to ask him questions... and who do you give priority to? And after the meeting... it just failed to occur to me that I needed to point out to my students that they had a Nobel Prize winner talking to them because in the moment I knew better, but I should've told them after and forgot to.
Fraser: Right.
Pamela: And one of my colleagues was like "oh my god I just met Barry Blumberg!" And one of them Twittered "oh my god that's so cool!" To which I got to respond, "Yes, and he talked to you as well." He's just a down to earth guy and no one realized... it was awesome.
Fraser: Alright.... well, we kinda went a little off of topic in the end there so....
Pamela: We apologize for the random mutterings... this is what happens when we talk about people...
Fraser: Yeah, I know... I know... you get all these anecdotes. So again, next week, we're going to talk about the mission. It's a wonderful mission, one of the most productive missions that has happened in recent times. So, I'm looking forward to that. We'll talk to you next week Pamela.
Pamela: Sounds good, Fraser. I'll talk to you later.