Astronomy Cast Episode 186

History of Astronomy, Part 4 - The Beginning of Modern Astronomy

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Fraser: Astronomy Cast Episode 186 for Monday April 19, 2010, History of Astronomy, Part 4 - The Beginning of Modern Astronomy. 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, Fraser. How are you doing?

Fraser: Very well. Freezing cold, though. It's unseasonably cold here in Canada.

Pamela: That's not good...

Fraser: I know... surprise, surprise... but, yeah, so this week we continue our history tour. So, with our proper place in the universe worked out, and some powerful telescopes to probe the cosmos, astronomers started making some real progress. The next few hundred years was a time of constant refinement, with astronomers discovering new planets, new moons, asteroids, and developing new theories in astronomy and physics. Alright, so I think when last we left our heroes, we'd gotten to Newton, who, apart from being interested in optics, materials, and physics, and developed Calculus... he also did a lot of contributions to astronomy... specifically his theories on gravity. So he was able to help explain why planets and moons took the paths that they did around the sun and the planets. So, that contribution was pretty important. So where do we go from there?

Pamela: Well, the next place is... who did something cool with gravity? Now that we have this great theory, we can start playing... and it was Edmund Halley who was the first person to find a really neat application to the theory of gravity.

Fraser: I think I can guess what it was.

Pamela: You probably can.... the entire audience probably already has...

Fraser: Edmund Halley... what did he do? Yeah...

Pamela: So, he went through the records and started looking at comet apparitions. Up until the late 1500s, everyone had thought that comets were just atmospheric disturbances, but Tycho Brahe, as we've discussed before, figured out using parallax that comets had to be further away than the moon. Halley took it one step further and he started looking for regular appearances and found this one visual object that appeared on a fairly regular basis that seemed to vary between about 75 and 76 years and he ran all the calculations... figured out the effects of Jupiter, figured out the effects of Saturn... and made a prediction of when this comet, this recurring object, should appear one more time. Now he did this in 1705, and unfortunately he didn't quite live long enough to see it. In 1758 Johann Palitzsch observed Halley's comet based on those observations. It was thoroughly proven... gravity works! And you can do cool stuff with it if you bother to take into effect the gravitational yanks and tugs of the outer planets.

Fraser: So they could accurately predict every time a harbinger of doom would come through the night sky.

Pamela: And it's much less scary when you know when the bright shinys are coming...

Fraser: To harbinge the doom... um... ok, so that's great... and then I guess from that point other comets were discovered and tracked and predicted. I mean now, we know thousands of them, right?
Pamela: Right, and, unfortunately though, what we find is that most of these comets don't actually come back. What was pretty amazing about Halley's comet is it's really the only one of its particular orbital species that comes back on a regular basis and is visible naked-eye every time.
Fraser: Right... puts on a good show every time.
Pamela: Right. Most comets don't do that. Most comets that we see actually have a tendency to be rather suicidal when it comes to getting too close to the sun. So there's lots of objects that come in and we see them once and they shoot back out... or they plunge to their death in the sun. Still, comets are cool.
Fraser: So, 1758 was when Halley's comet was observed... what next?
Pamela: So now we start getting into the age of finding faint stuff in the sky. The things that are at the edge of your vision and you're not necessarily going to notice unless you're a very careful map-making observer.
Fraser: We have telescopes...
Pamela: We have telescopes... telescopes are cool! And with telescopes you can start to make accurate measurements of separations between objects... you can start to map the sky more effectively. And there were permanent observatories being built, and you really need to attach your instruments to the ground if you want to be able to make accurate measurements of where things are. Hand-made instruments--those lead to hand-made errors. So what we have now is we have Herschel building telescopes in England. He discovered the planet Uranus in 1781. We have Piazzi who's making his observations in Italy, and in 1801 while building maps he discovered the asteroid Cerus that was for a brief period of time considered to be...
Fraser: A planet...
Pamela: Yeah...
Fraser: The planet Ceres, yeah...
Pamela: And then we discovered other things occupied its orbit... kind of like what happened to Pluto but on a much shorter time period.
Fraser: Right, and Messier was working in France around this time, right?
Pamela: Right, and he was not discovering new solar system objects as much... he was looking for comets. He was compiling catalogs of them, but in the process of trying to discover comets... he kept finding these annoying non-moving, non-cometary faint fuzzy blobs in the sky. Now it turns out that these things that kept annoying him because they weren't comets, they turned out to be star-forming regions, nebulae, supernovae remnants, galaxies... and they didn't even have the concept of galaxy back in 1781. So, Halley made his comet, we had Herschel with Uranus, Messier with his faint, fuzzy object catalog, which, as a small child, I thought was the "messier" catalog of objects in the sky... which made perfect sense.
Fraser: Somewhere there's a cleaner one, yeah...
Pamela: Right...
Fraser: Now, we went into great detail on Herschel... so if you want to sort of hear more about that story, we have a whole episode just on Herschel. And a whole episode on

Uranus... but... ok, alright... moving on... I guess after Uranus, then Neptune had to be picked up?
Pamela: Neptune came in 1846. This one was a little bit harder... actually it was a lot harder. They were trying to figure out how to mathematically justify Uranus' not-quite-right oribit, so there're a bunch of mathematicians... specifically Joseph Le Verrier and John Couch Adams who were trying to predict exactly where this mysterious Uranus-orbit-deforming planet should be located. And it was Levier who eventually got it right, and he gave his predicted location to Johann Galle and he went out and from his German observatory found Neptune. That brought us to our modern set of planets... the complete set was discovered by 1846. This was also the period where we were starting to get more physics concepts involved in science, as well. So we're completing our catalog of the solar system, and starting to dive into the details.
Fraser: Details such as...
Pamela: Well, there's the Doppler effect, which we kind of need to figure out where galaxies are... that was sorted out in 1842. Samuel Heinrich Schwabe figured out the sunspot cycle. He spent about 17 years observing the sun, counting the sunspots, and noticed that the numbers changed over time, so he started digging through historic records and was able to go all the way back to the 1500s. In going over all of these records, he figured out that there's roughly an 11-year cycle to where sunspots appear on the sun and the number of them that appear on the sun. So, suddenly our sun is not just a non-perfect sphere, it's a non-perfect sphere that shows its own seasonal cycles.
Fraser: Right. And next...
Pamela: And next... well this is where we start getting into astrophysics becoming its own science. In the 1860s we started as a field figuring out spectroscopy... splitting light through prisms and grisms and slits and looking for individual dark and overly bright spots in the distribution of light coming off of stars, trying to match those bright and dark lines with the fingerprints of chemicals that were in general set on fire in different laboratories. So what we had was Henry Draper in 1872 took the first photographic spectrum of the star Vega. This followed on the footsteps of Sir William Huggins working in England doing spectral analysis of stars. So between these two men we were able to start saying stars have a specific chemical compositions. We know what stars are made of... and that's a pretty amazing thing to start looking at.
Fraser: So were scientists or astronomers pretty convinced at this point that the sun was just a star? I mean had this been going on for quite a while now?
Pamela: Well, we suspected for a long time that our sun was like the other bright spots in the sky. It was with stellar spectroscopy that we started to be able to say our sun has the same chemical properties as these other bright things in the sky.
Fraser: Right, so you could even now look at other stars and go... our sun is kinda like that one. Right?
Pamela: Yeah... And that was the cool new part of this. And what's interesting about this point is... our technology still wasn't that great. Our telescopes were good, but the human eye was still involved, to a large part. So, we had folks looking at the moon and seeing canals and imagining aliens there. So this was still a time of discovering things. We had in 1877 Asaph Hall discovered Phobos and Deimos orbiting Mars and we were desperately trying to figure out... are there aliens on Mars by looking at the changes of the coloring on its surface. There were observations of the sun coming from Mount

Wilson. We realized that our sun was alive, but we still didn't have the physics. We're getting there, but questions as simple as what makes the sun go... we couldn't answer.
Fraser: And I think it's interesting is that we're now a little over a hundred years ago... and we didn't know that the Milky Way is just one galaxy, and the other nebulae that we see could be other galaxies... don't know why the sun does what it does. Don't really know where the solar system came from and where it's going to go... don't even really understand what small pieces of matter... what things are made up of....
Pamela: The thing that really put it into perspective for me was... I've had the chance to talk to some very senior, in terms of age, astronomers over the years. One of my favorite things to do is ask what's the most amazing scientific discovery you've seen in your lifetime? And all of them have answered "galaxies." Just the fact that there are people alive who remember when we didn't know what galaxies were.... that's the thing that floors me on a regular basis. For people my age, the in our lifetime is probably going to be dark energy...
Fraser: Dark energy... or quasars as supermassive black holes...
Pamela: See, that one doesn't even really strike me as that amazing because the concept of black holes have been around for a long time and as far back as I can remember people labeled quasars as "the monster inside of the center of the black hole," usually with an amusing hand-drawn diagram. But then they said, it's probably a black hole.
Fraser: Right, but wasn't 1998 -- it came out of nowhere. Oh, by the way, almost everything in the universe is this dark energy.... it's accelerating the expansion... yeah, yeah... so that's pretty monumental. I've mentioned this story a few times, I think, that my dad had an old book.... a planisphere, and it was from the turn of the century... 1920s... and it had in it galaxies, but they were nebula. So, this is where the Andromeda nebula is...
Pamela: And you can still talk to some of the oldest astronomers at meetings and they'll say the Andromeda nebula because it's just so ingrained in their heads that yeah... it's a nebula...
Fraser: Old habits die hard...
Pamela: Right, and so what to me is most amazing is in the early 1900s we still didn't know how stars were powered... which really starts to put limits on the age of the universe because they were trying to figure out... well if it's coal and it's this big, how long will it take to burn up? Oh, that's not long enough. And so in trying to reconcile the geological history of how old we suspected the earth was, and how old we could make the sun last by powering it chemically, there was a real struggle going on because the sun just didn't seem big enough to have lasted long enough to explain the geological history. It was Eddington working in the 1920s that was actually able to look at the results coming from Hertzprung and Russell who were looking at the characteristics of stars and their spectra and the differences between giant and dwarf stars and the chemical properties and looking at all of these pieces and at the theories of gravity. Eddington said that stars are supported with radiation pressure. The light being generated inside of stars is what's holding them up and causing them not to collapse. And it's nuclear processes in the center of the star that are causing stars to live for millions and billions and in the case of little red dwarf stars trillions of years. So we've only known that for less than 100 years.

Fraser: That's another one of those ideas that... just imagine how that impacted people when they looked at the math and thought about the implications of it... Now, you jumped around a bit... I mean we just crossed into the 20th century and there was a pretty important guy right at the beginning of the 20th century...

Pamela: Albert Einstein working at the same time... while we had Eddington and Hertzprung and Russell and some of the other observers trying to understand stars, we had Albert Einstein starting his work in Germany trying to take a deeper look at gravity. It was in 1905 that he introduced his theory of special relativity and it was through special relativity that we started to get a clear cut understanding that the speed of light is the same no matter where you are. This has all sorts of different consequences. It's brought us to $E = mc^2$. Nuclear power was able to be developed because of Einstein's work. So Eddington definitely couldn't have done what he did without Einstein along the way. But it was all of these men contributing in so many different ways during this real new renaissance of astronomy during the early 1900s that allowed us to understand stars last a long time, gravity may be a geometric issue rather than anything else that we previously looked at it with in terms of pure mathematics... He abolished ether as something that fills all of space and time and carries waves... it was no longer needed. It was amazing work. And from there he went on to do the general theory of relativity. It was actually Eddington who mounted an expedition to go on and make the observations necessary to prove that Einstein's theories were right by observing a solar eclipse and looking to see how the sun's gravity bent--gravitationally bent--the light coming from distant stars coming from behind the sun.

Fraser: Now I know this is not directly related, but this also at the same time that you had the rise of quantum mechanics. You had Rutherford and Bohr probing the nature of the atom... and so all of that physics, all coming together at the same time as well.

Pamela: Maxwell's equations, blackbody theory...

Fraser: Yeah, so all of those really helped each other... you can see how interdependent all of these... physics and astronomy are all at the same time to answer some of these questions.

Pamela: This was the point where it went from astronomy to astrophysics. And it was actually Chandrasekhar while he was at the University of Chicago who took on editing the then new Astrophysics Journal where people sat down and worked mathematically to find things that we couldn't come up with any other way. One of the most interesting controversies of this period was Chandrasekhar was able to predict that white dwarfs should exist through the gravitational collapse of stars that are no longer undergoing nuclear reactions in the center and are roughly sun-sized stars. They, without the radiation pressure, collapse... become a special... what's called an electron-degenerate gas... are chemically made of the same stuff as the sun, but the way that stuff is supported is completely different. But then he took his theories a couple steps further and figured out neutron stars and black holes. Eddington felt that this was just nonsense and the two men spent most of their lives debating this and black holes weren't actually accepted until Eddington died and stopped deriding Chandrasekhar's work. But Eddington... the idea that you could mathematically suggest such a thing without empirical evidence as a starting point was just preposterous. Astrophysics opens the door to say well, if you have these conditions, then you should have these novel types of objects that may not exist locally, but if we look far enough we should find them out there among the stars.

Fraser: And so you gave us a little bit of a sneak preview there about the discovery of galaxies so you jumped around the history a bit there so why don't we kinda go back again and talk a bit about Cepheid variables because that's important leading up to Hubble.
Pamela: Right... during this period, all of these concepts are tangled together and everything is emerging all at once. Harper has this amazing plate stack collection of literally glass plates that were used to image the sky the way that film cameras are used to image everyday objects. One set of the glass plates was observations one after another after another of globular clusters... packs of old stars gravitationally bound together that all the stars in each of these systems formed at once out of the same stuff at the same time... also plates of the Large and Small Magellanic Clouds... partner galaxies that can be seen in the southern hemisphere. Henrietta Swan Leavitt, while working at Harvard as basically a calculator, this was in the days before computers and they hired women to be their computers for them. Henrietta Levett was going through plates documenting the brightness of variable stars, stars that change in brightness in some cases from hour to hour in very noticeable ways. What she found is that for one type of pulsating variable stars Cepheid variable stars that change in brightness over the course of many days, their brightness was directly related to how long it took them to pulsate in a given system. If you took the stars and you looked at all the ones in the nearby system and all the ones in a further away system, you can actually use this relationship between brightness and period to figure out exactly how far away these systems were. This is now called the Leavitt relationship and it was called the period-luminosity relationship for decades. This was our first real way of figuring out the distances to objects that we couldn't figure out by using parallax. It opened the door to figure out... where are galaxies? This was one of the things that Hubble worked on as well as many others. He looked at some of the nearest galaxies, and Shapley did the same and there's a bunch of different people who did this, and realized that there's pulsating stars in galaxies, too. I can figure out where those galaxies are. Then they also started looking at the distance to things and the relationship between velocity and distance. Hubble in 1923 was able to show that galaxies exist outside of our Milky Way. Then he went on to show that the further a galaxy is away, the faster it's receding from us. And this meant that our universe is expanding and that completely changed everything. Einstein with his theories had set the universe still using the cosmological constant... the math allowed it to be expanding or contracting but philosophically, even the scientists said... no, static universe... everything steady state. And Hubble went... no, it's expanding. And that allowed the Big Bang theory to be figured out, eventually.
Fraser: Right... and I think we'll save that for the next show. So I think we've got one more episode of our history tour, where we'll get right up to the modern astronomy and cover some of the... the Big Bang, some of those other big ideas, right up to some of the latest stuff. So, we'll do that for next week. Alright, we'll talk to you later, Pamela.
Pamela: Ok, talk to you later. Bye-bye.