THE PLANETS - Curated Transcript of BBC In Our Time podcast
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In Our Time is hosted by Melvyn Bragg. Melvyn's guests on this podcast are:

Paul Murdin, Senior Fellow at the Institute of Astronomy in Cambridge;

Hugh Jones, planet hunter and Reader in Astrophysics at Liverpool John Moores University;

and

Carolin Crawford, Royal Society Research Fellow at the Institute of Astronomy in Cambridge.

Curated transcript:

[Melvyn Bragg] Hello. Tucked away in the outer western spiral arm of the Milky Way is a middle aged star with nine or possibly ten orbiting planets of hugely varying sizes. Roughly 92 million miles and third in line from that central star is our own planet, Earth, enthralled to our sun just one of the several thousand million stars that make up the galaxy. Ever since Galileo and Copernicus gave us a scientific model of our own solar system, we've assumed that somewhere amongst the myriad stars there must be other orbiting planets. But it took until 1995 to find one. "51 Pegasus A" [editor's note: This should be "51 Pegasi b"] was discovered in the Pegasus constellation and was far bigger and far closer to its sun than any of our existing theories could have predicted. Since then, 121 new planets have been found, and now it's thought there may be more planets in the skies than there are stars. What causes a planet to form? How do you track one down? And how likely is there to be another one out there with properties like the Earth? With me to discuss an area of research that's at the forefront of modern astronomy is Paul Murdin, Senior Fellow at the Institute of Astronomy in Cambridge, Carolin Crawford, Royal Society Research Fellow at the Institute of Astronomy in Cambridge and Hugh Jones, planet hunter and Reader in Astrophysics at Liverpool John Moores University.

[Melvyn Bragg] Paul Murdin, let's start with our own solar system. Can you give us a brief outline of its topography? How many planets? How many moons? How many asteroids?

[2:07]
[Paul Murdin] Well, let's start with the main body in the solar system, which is the sun. It's not a planet, it's a star. Like all the other stars in the sky, it's by far the most massive object in the solar system, and you could say it's at the center with everything going round it. I think the broadest definition of a planet would be that everything else in the solar system is a planet of one sort or another. A number of celestial bodies in orbit, in a flat plane, in a disk, all orbiting pretty much in the same direction, or marching in a progression around the sun, like the traffic flowing round around about, counting outwards from the sun. The major planets, the ones which have individual names, the ones that are known as the planets, are Mercury, Venus, the Earth and Mars, which are four planets that are pretty much like our own planet: Solid surfaces, most of them with atmospheres sort of places that you can imagine an astronaut walking on further outwards from there, there's a group of four much bigger planets: Jupiter, Saturn, Uranus, and Neptune - much larger, much bulkier, known as the gaseous planets or the gas giants. I think it's fair to say [that there are] eight major planets. Beyond Neptune, there's a range of smaller bodies. They're certainly worlds, and I think under a broad definition you could also say they were planets as well. But their origins are probably a little different from the major planets so they're sometimes classed as a different sort of beast. And they are Pluto, discovered in the 1930s, the planet Sedna, discovered only in the first months of this year and other bodies like Quaoar and some with just catalog numbers. There's a big gap in the solar system between Mars and Jupiter and that's full of tens of thousands of smaller bodies called minor planets or asteroids. Just to give a depiction of the scale of the whole thing: If you imagine the sun as an orange at the center of the solar system then the Earth is a pinhead about 10 meters away and Jupiter is a pea perhaps 150 meters away and Pluto a grain of sugar, perhaps half a kilometer, three quarters of a kilometer, from [the sun], and the edges of the solar system extend on out many times beyond Pluto.

[Melvyn Bragg] What is the thing that distinguishes the sun from everything else?...

[Paul Murdin] Because the sun is so large, so much mass in it, [such a] big force of gravity, so much weight, so much heat in its center, so much pressure, [there are]nuclear reactions [that] take place in the middle of the sun as they do in the middle of every star. And these nuclear reactions supply the energy, and therefore the light, for example, that we see from a star. The planets are considerably smaller than that, they don't have the same kind of temperatures in their interior, they don't have the same kind of pressures and they don't have the nuclear reactions. They only shine by reflecting the light from their star.

[Melvyn Bragg] Hugh Jones, how are ... our planets formed?

[5:40]
[Hugh Jones] Well, if we look at other systems out there in the universe we can see clouds of material from which we can see new stars being born out of. We haven't actually seen planets elsewhere being born definitively out of these these clouds of material. But what we can see is those stars being born out of those clouds of material. And the hypothesis we have is that our sun was formed out of these similar clouds of material. And then following that formation of our sun one would be left with a disk of material which would be rotating around the sun. And ...[in] that disk of material ... smaller cores would be present... And onto these cores, we would find material would be gathered, and eventually the disk of material would be probably cleared away by the wind from the sun - our own sun has a solar wind, and that would clear away these cores. And what one would be left with would be [planets]. [In particular the] the "inner planets" [and the "outer planets"]. Paul was talking about [the inner planets] Mercury, Mars, Venus, Earth and we would call those the "terrestrial planets" - terrestrial being Earthlike. ... The outer planets [are the gas giants] Jupiter, Saturn, Neptune [and] Uranus. And ... those [outer] planets... have ... rocky cores, ... like the terrestrial type planets, but in addition ... they ... also have a lot of extra material around them which would have condensed onto them [such as] hydrogen [and] helium. And [the outer planets are] ... much larger bodies. They would have had a much longer formation process before any material they were forming from would have been cleared away by the star switching on and clearing the material.

[Melvyn Bragg] So let's go over that again. This cloud of swirling, let's call it, "dust", ... comes in about how many billion years ago, and it's swirling around all the time...?

[Hugh Jones] We believe our sun was formed around 5 billion years ago.

[Melvyn Bragg] The sun itself or the whole swirl?

[Hugh Jones] Well, the sun, we believe the sun would have formed first.

[Melvyn Bragg] Yeah. And then this stuff's going around and knocking into each other, and the heavier stuff is going to the center. So gradually objects are being formed out of this cloud, and then the solar wind is clearing the distances between, so we see what we think of as spaces, but may not be completely clear spaces out there, then that's the way it went.

[Hugh Jones] That's our picture.

[Melvyn Bragg] That's our picture. And so the planets were formed by collision - the dust [particles] colliding with each other and accreting. They were formed by some heaviness inside themselves, sort of drawing the gravity to make them... into these shapes.

[Hugh Jones] To build them yes, into larger and larger objects...Although accretion, if you like, the sort-of snowball of material gathering together in the early dust cloud is one of the processes, it's clear that collisions would probably have played an important role as well.

[Melvyn Bragg] Right. Carolin Crawford, how was the Earth formed and what happened to give us our moon?

[8:49]
[Carolin Crawford] Well, the early Earth was very different from the planet we now know because the planets form hot. Throughout their life, they'll gradually lose this heat, but it means the early Earth was completely molten...

[Melvyn Bragg] How many years ago are we talking about?

[Carolin Crawford] We're talking again probably about four and a half billion years ago that the Earth was completely molten, and this allowed all the elements in it to stratify. So you have the heavy metals sinking down to form the very iron rich core we have and the lighter elements rising up through the crust. And during all ... this first 500 million years of the Earth's formation, it's been continually bombarded by the debris that's still left over from the formation of the planets - slamming into it. And there's one particular impact which is important for the Earth and that's where we think a protoplanet, maybe something the size of Mars, another planet in the making, whacked into Earth. This enormous impact sent off masses of debris out into orbit round the Earth and that eventually coalesced to form our Moon and the protoplanet and the Earth merged together to form the Earth that we have now. Now we need an explanation like this for the Moon, for several reasons. One is that when you look at the makeup of the Moon, it's made of much lighter elements than the Earth, which is strange unless you say it's actually made up from the outer layers of the Earth that were shot into space when this impact happened. Also the Earth itself has a much heavier core than you'd expect for a planet of its size. Maybe that's from this merging of the two protoplanets to make our Earth. And finally the Earth-Moon system is fairly unusual. It could almost be regarded as a double planet. And it's unusual in our solar system to have such a large moon round a single rocky planet. And it's much easier to explain that by saying there was one unusual event within Earth's history that caused that.

[Melvyn Bragg] So this is called the great impact. But it's still a theory, isn't it? It means that we have two ages, an astronomical age of four and a half billion years and a geological age of 4 billion years. Because when the two predoplanet and the Earth came together, it reformed the geology.

[Carolin Crawford] Yes, certainly ... we can date the Earth and the Moon to be about sort of over 4 billion years ago from radioactive dating of the elements in the crust and also from meteorites that have come in from the Moon or other planets.

[Melvyn Bragg] Hugh Jones, at the beginning of the program I mentioned 51 Pegasus A as the extrasolar planet that was found in 1995. What methods did you have to discover that? And why did it take so very long to find more planets than the Greeks had, as it were, two and a half thousand years ago?

[11:38]
[Hugh Jones] Well, I think ... although planets have been found in the solar system since the Greeks, the key difference with the 51 Pegasus planet is that it's outside of the solar system. So whether we're talking about bodies beyond Pluto, additional

planets - I mean, Pluto itself was only discovered in the 1930s - ... 51 Pegasus is really something completely different because it's not a planet going around our own star, the sun, it's going around the star 51 Pegasus. What was special about 51 Pegasus was that we managed to, if you like, hone our techniques for looking for planets to such a level that we're able to see the very small signature of a planet going around it.

[Melvyn Bragg] Can you give us some brief notion of what honing the techniques meant and why did it take so long?

[Hugh Jones] Okay, well, what we've done to find the vast majority of planets going around other suns is to look for the so called "Doppler wobble". And what we're looking at is the motion of the star towards us and away from us. So in very much the same way that Paul was explaining earlier that Jupiter ... is the primary planet in... the solar system after the sun, we can imagine that Jupiter and the sun are orbiting around one another. And so the sun, if you like, is wobbling backwards and forwards slightly due to the mass of of Jupiter and all the other planets as well, but primarily Jupiter. And what we did with 51 Pegasus is to look at the star and to look for that small wobble. And that wobble is at the level of 50 miles an hour or something like that motion of 50 miles an hour over a time period of a few days. And in order to do that, we use a very high resolution spectrometer which has allowed us to see the individual spectral lines in the star 51 Pegasus and we look at those relative to a reference source and we see those lines changing with we see the position of those lines changing with time, which tells us that the star is going first, if you like, away from us and then towards us and then away from us in a regular periodic motion. And that's exactly what we would expect to see if one smaller body is going around a larger body - we're seeing the center of mass of the large star changing.

[Melvyn Bragg] Carolin, what is this going to mean? Are we going to find masses of more planets now? Is there a sort of planet burst happening?

[14:27]
[Carolin Crawford] Yes, now we're refining the techniques and the telescopes and instrumentation are getting better. There's quite an explosion really, since this discovery, of planet hunting. The very interesting thing is these solar systems we're finding are actually quite different from what we originally expected. In the case of 51 Peg, what was discovered was something of the order of the size of Jupiter orbiting the star every four days, just over every four days, which is incredible, because that means that it's nearer ... to its host star than Mercury is from our sun. It's about a 6th of the distance between Mercury and the star. And this really challenges our views about solar system formation. From looking at our own solar system and what we understand about its formation, this predicts that any kind of gas giant, any Jupiter-type planet should have formed far out in the nebula where conditions are cooler. And to actually see some planet orbiting so close to the star that's one of these gas giants is quite a challenge to explain. Either we've got our theories of the formation of the solar system wrong somehow. Maybe not all solar systems form that way, or alternatively, maybe we're right and this Jupiter sized planet formed far out in the nebula and has since somehow spiraled in towards the star, which again confronts our notion that once you've formed a planet, it stays put. And again, that's confronting any ideas we have about the stability of solar systems. It also makes you wonder that if something that's formed far out of the nebula has spiraled in close to the star, what then happened to

any rocky planets that might have also formed within that solar system? Maybe they've been swallowed up by the star itself. And maybe rocky planets like we have in our own solar system are much rarer than we thought.

[Melvyn Bragg] Paul, would you like to develop that?

[16:15]
[Paul Murdin] Could I step back from this a little bit and make a general overall comment about what's just been said? I think this is absolutely revolutionary, and I think it's revolutionary for the following.... I think it's triumph for science. And I think for this reason. For a long time, we ... human beings thought that their place in the universe was special, that the Earth was a special place, that it was like, completely unlike anything else, and that we were special creatures with a divine specification on our head, a divine label on us. That was a philosophy of our position in the universe, both philosophically and in geometry, that was completely transformed by the scientific way of looking at things - right from the atomists right through to the development of scientific perspective on the way of the world. We've developed a completely different idea in which, first of all, our world, the Earth, was a planet like many others, and the inference being that possibly life existed elsewhere on other planets. But then there was speculation about the realization that our sun was like ... all the other stars, and maybe other stars had planets too. And as we heard from Hugh, that actually turned out to be the case. But for at least a couple of thousand years, all of the speculation about what other solar systems were like, or indeed whether there were any other solar systems, was all based on a completely philosophical view of the world - like we were typical of things in the universe. And right in 1995, the position changed so much that we actually had actual evidence that this was really the case. It was a vindication of a kind of scientific perspective on where we are and what we are.

[Hugh Jones] And ... I'd like to just sort of pick up Paul's sort of the revolutionary aspect of this. I mean, Copernicus moved the Earth from being the center of the universe and, if you like, since has changed the definition of planet. Once the Earth was no longer at the center and the sun was at the center of our solar system then ... we developed the notions of different types of planets - terrestrial and gas giant planets. And here we're now moving into the notion of not just planets around our own sun but planets around every sun. And we've now got a situation where the planets that we found - this 120 or however many exactly we have today - we're finding them in all different types of environments. And, in fact, we're not we're still not sensitive to to any ... environment like our own.

[Melvyn Bragg] So the division of planets which is in our solar system is roughly terrestrial and gaseous. There may be many, many more categorizations?

[Hugh Jones] So far, ... the extra solar planets that we've found a few of them would fit into the gas giant category though, as Carolin was alluding to, most of them are actually very different. But we yet to really look at our own to constrain the solar systems. The revolution is that we've found all kinds of other planetary systems which are nothing like our own solar system.

[Melvyn Bragg] Given that the Earth is so small and dark, difficult to spot, how long do you think before you detect a terrestrial planet like our own?

[Hugh Jones] That's a very tough one to answer. I mean, in some senses, we have already detected Earth-mass planets around pulsars, around the remnants of failed stars - which is exactly the last place that you'd ever expect to find a planet. So just to go explain what that means, after a star has used up all its nuclear fuel and exploded and ... expelled all the outer layers (I'm talking about a very massive star) it would leave behind a very, very small, dense remnant. And what we find is that we can see some of these small, dense remnants to very large distances because they're spinning very fast. They got very strong magnetic fields. They give out pulses, and we call them pulsars. And we can see that going around pulsars. We have, in fact, got Earth-mass planets. Those are our first Earth-mass planets. But to call those terrestrial planets - we're not. Now, to find terrestrial planets going around real sun-like stars I think we're going to have to wait at least ten years.

[Paul Murdin] We need a new technology for that.

[Melvyn Bragg] You think you're going to get that? You think the idea of being unique here is but with the conditions that obtain on the Earth do seem to be very special and specialized, Paul?

[21:24]
[Paul Murdin] Yes, well, Carolin painted a picture of the evolution of planets that involved really quite chancy and flukey events. I mean, she described ...the major one is the collision of this Mars one [with the Earth 4.5 billion years ago]... I mean, that's a real fluke. It happened apparently, if you believe the theory. You wouldn't expect it to be the routine thing to happen. So at the same time as there are systematic similarities in the formation of all of the planets, there are also completely chance events. And some of these chance events have really big - let me pun and use the word "impact" on the evolution and the development of the planet.

[Melvyn Bragg] So we could be a fluke one-off?

[Paul Murdin] Well, the universe is a very big place and there are a lot of stars in it and there are even more planets, as you said at the beginning. So I'd hesitate to use the word unique for our situation. But I would say that there are features of our situation which are very rare. I mean, our solar System, for example, is apparently a case of arrested development in that it developed a Jupiter like all these other planetary systems that have recently been discovered. But our Jupiter drew in from the outer reaches of the solar system to where it is now and then stopped and didn't go on to become a very close Jupiter to our star in the way that these other planets of planetary systems have developed. So something happened to arrest the development of the solar system. That means that our Earth is in a very stable orbit and remains always just about at the right place in the solar system and to be the right temperature for water to exist and for us to be able to exist. We've had this collision which created a big moon for us and that ... gravitational pull of that big moon also holds the Earth in a particularly stable configuration. And all that means is that there has been a long time in which ... the environment on the Earth,...compared with all the other things that might be going on, has been a rather stable place. And therefore life has had billions of years to evolve. And although life starts pretty briskly and creates bacteria-like things, it takes a long time for those bacteria to get together in big colonies and make people.

And that process of evolution can be readily interrupted by all kinds of changes of circumstances. That didn't happen for us. It didn't happen for our world. Our Earth has remained stable for billions of years and as a result, we are here talking.

[Hugh Jones] I think it's important to say in this that the extrasolar planets that have been found are very much the ones that we could find. I mean, we're not yet sensitive to [be able to detect other solar systems that are just like] our own solar system going around any other sun. So while the Earth's environment is very special and does need a lot of very special circumstances, we've found planets going around something like ten to 20% of stars in the solar neighborhood and around those other 80 or 90% of stars, we haven't yet discovered planets. But we're thinking that the most likely thing is, in fact now that we will find Jupiter-like planets around those stars. So we can't yet pin down the existence of solar system like architectures. We think the scale and the way that the solar system is made up is important, then we haven't yet constrained that.

[Paul Murdin] We've got to be sensitive to the fact that we've got a paradigm in our minds about how life evolved and what happened that is based upon our own interpretation of what apparently produced us. And just as in the past, people regarded the Earth as a special case, and we have to be sensitive to the fact that there are other possibilities.

[Melvyn Bragg] I was going to ask that, actually. So what other possibilities of life could you speculate? Your jaw drops..?!

[Paul Murdin] Could I come back on that? There seem to be some things which generally people seem to agree, and other things they don't. There isn't another element in the periodic table of chemical elements apart from carbon, that generates chemicals which are of such complexity that you can imagine them producing complicated biological organisms. So probably life everywhere is carbon based. Probably you need a liquid environment for all the chemicals to get together and do their biochemical thing. And so water soluble, carbon-based life is what we should be looking for. I think the important thing is to free our minds of the sorts of environments in which we would expect to find life, but to stick with something which is fairly secure, which is we should be looking for carbon and water.

[Melvyn Bragg] ...It's been said this is a revolutionary, a particularly exciting time. Could you highlight, as far as you're concerned, Hugh, as a planet hunter, what is most exciting for you?

[Hugh Jones] Well, we're now entering an era where we're finding all of these whole range of different planets in a whole range of different environments, which allows us to look at the whole planetary formation scenario. And I think that very much links together with the formation of stars as well. So that's one linkage. And then I think the other way, as we've been talking, is in terms of the chemistry and biology of the situation. I mean, [there have been] lots of very exciting discoveries in the last few years about life being found in deep volcanic vents in all kinds of strange environments. Even yesterday I saw on the news something about potential life .... microbes in Venus's atmosphere, the whole range of different possibilities for life. And we're finding that from the astronomy of where these planets are found, that we're finding this vast range of different environments where life might be found, and we're finding the architectures for all of that.

[Melvyn Bragg] Carolin, what are you most looking forward to discovering?

[Carolin Crawford] Well, the extra solar planets are very exciting, but I think one thing that is really coming of age is the search for possibility of life within our own solar system. Hugh has mentioned about in the clouds of Venus. We're obviously all aware of the recent discoveries with the NASA rovers on Mars, but there's an upcoming expedition which is going to investigate one of the moons of Saturn, which is where ... there's a very thick atmosphere and possibly a lot of organic compounds beneath the surface. So I think that's a particularly exciting development that's going to be changing a lot over the next year.

[Melvyn Bragg] Well, thank you all very much. Thanks to Hugh Jones, Paul Murdin and Carolin Crawford.
