Transcript

OpenLearn Podcast
Exoplanets

Dr Jo Barstow and Ben Wood:

Ben
Hello there and thank you for joining us for the third in the Open Learn podcast series. Now, we've got something very exciting today. Today we are going to be looking up as well as forwards and you will find out more why in due course, but we are talking to Dr. Joe Barstow, who is an Ernest Rutherford Fellow here at the Open University and we're going to be talking exoplanets. So that's the reason for looking up and welcome Joe.

Jo
Hi Ben, thanks very much for having me.

Ben
Now, that's an absolute pleasure. Now I've had the absolute joy of talking to you before about exoplanets. So you are someone I definitely wanted to invite here to have a further conversation. So I want to start off with and just sort of say exoplanets. I mean planets, I think a lot of people are familiar with exoplanets, maybe not so. So exoplanets, what are we talking about?

Jo
All we're talking about is planets that happen to orbit a star that isn't the sun. So all the stars that you see when you look up in the night sky, probably most of them, although you don't realise it actually have one or more planets in orbit around them. And that's what I spend my days studying. I try and find out more about those planets in other star systems.

Ben
Okay, I mean, you said that's what you spend your days doing. So let's go down that route a little bit. And you as a research fellow at the Open University. What do you spend your days doing? What are you working on? What is your work?

Jo
Well, I'm an atmospheric physicist and a planetary scientist. So what I do is use light that's come from usually space telescopes like Hubble and JWST, light that has been captured by those telescopes, coming from those distant star systems that has passed through the atmosphere, the sort of outer shell of gas surrounding some of these planets.

Jo
And that gas, that sorry that light contains sort of fingerprints of what the composition of that atmospheric gases. And that can actually tell us an awful lot, not just about what the atmosphere is made of, but about how it might have evolved, how it's behaving, how it's moving around, how it responds to different conditions. So actually, these objects, they're kind of our laboratory for understanding how planets and their atmospheres work as a whole.

Ben
Wow, okay. So there's a few people out there, I think, have already kind of googling how to become an atmospheric physicist, perhaps, and what's new. That sounds a pretty cool thing to be doing with your day. So what does that actually involve? What are you using? How do you measure this light?

Jo
So as I said, usually we use space telescopes. This can be done using telescopes on the ground as well, but the trouble with that is that our atmosphere has a bit of a tendency to get in the way. So space-based observations are immune to that, and that makes it somewhat easier. And mostly at the moment, I'm using data from the relatively recent space telescope, the James Webb Space Telescope, that was launched quite memorably, actually, on Christmas Day in 2021.

Jo
And the reason that that telescope is so impressive and useful for this particular type of science is that it's an infrared telescope. So it's not sensitive to the kind of light that our eyes can see, it's sensitive to infrared radiation. So that's the radiation that those little forehead temperature sensors we all got so used to during COVID, that's the kind of radiation that they are sensitive to as well. But JWST is sensitive to a vast range of different colors, if you like, of that radiation. And that is really, really handy for detecting things in planetary atmospheres like, for example, water vapor, which you probably agree is a pretty important chemical. It's certainly very important for life on Earth. Actually, it's pretty much everywhere. We've seen it in nearly every exoplanet that we studied, but also other chemicals like methane that you might be familiar with, carbon dioxide.

Jo
So I'm looking at light that has passed through the atmosphere, being collected by that telescope. Fortunately for me, that somebody else has usually cleaned up and made into a fairly nice, neat sort of wavy line with little bumps and wiggles in it. And each of those little bumps and wiggles corresponds to the fingerprints of one of these gases.

Jo
And what I actually do day to day is mostly get very annoyed with computers because I use computers at the Open University, but also some of our national high performance computers to run simulations of light passing through an atmosphere and then compare those with what we've actually observed from the telescope.

Ben

So on the telescope, you mentioned a couple of James Webb and Hubble, I think they're probably names that people would recognise. Just tell us a little bit more about those telescopes. How powerful are they? And you said that's what you're looking at to detect the gases and so on. Are these telescopes used to find out more about exoplanets that we already have discovered or is that how we actually find them in the first place as well?

Jo
Oh, this is very much looking at planets that we've already discovered. These are not really detection engines, although that's not to say they couldn't serendipitously by chance detect a planet, but they're not detection engines. These are looking at planets that we already know about. And certainly in the work I do, the subset of planets that I'm looking at are ones that have been detected using a particular method and that's what we call the transit method. And that's basically where a planet passes in front of its star from our perspective. And when that happens, it blocks a little bit of the starlight. So if you're monitoring the star and you're measuring the amount of light coming from the star, then you can see a dip. And if you see the dip happen again and again and again, it's always got the same depth that tells you that there's a planet orbiting the star. And the kinds of telescopes that make those measurements are sometimes in space, sometimes on the ground. There have been two really key space missions so far, Kepler and TESS. There is another one that we'll be launching in the next few years called PLATO, that's a European Space Agency mission that aims to look for planets that take longer to go around the star than most of the ones we've found out about already. Because it's much easier to do this for planets that only take a few days to go around their star because they come back around nice and quickly. They're also more likely to transit. PLATO is actually going to be looking for planets a little bit more like the Earth potentially, so periods of several months to potentially several years. And also there's several ground-based telescopes that do that detection as well. What I do is very much following up on those detections and looking for more details.

Ben
Can you give us any kind of comparison? Even the good telescopes that we might have, the people who can go down to the bottom of their garden and you're a big chunky telescope. Not like the old ones that I used to remember, the 10 pound telescope in my Christmas stockings that you could barely see to the end of the road with. How do these super telescopes compare with the best things that us as amateurs can give our hands on? How much more can we actually see?

Jo
Well I guess ultimately it comes down to mirror size. The bigger the mirror, the more light you're collecting, the more sensitive you are. So JWST has a mirror that's about 25 square meters in area. I think that's pretty big. That's certainly bigger than the telescope that you might have stuck in your garden shed or hopefully not stuck in your garden shed, hopefully being used on a regular basis.

Jo
It's bigger than quite a lot of telescopes on the ground but actually we're now starting to get into the era with ground-based telescopes of the extremely large class of telescope which will be actually more sensitive in terms of mirror size at least than JWST. But with that handicap that I mentioned earlier that they are on the ground therefore they can't see stuff that doesn't make it through our atmosphere which is quite a lot of stuff in the infrared. That's why it's so important JWST is in space.

Jo
So it comes down to collecting area, it also comes down to things like the precision of the alignment of the mirror. So you may have seen pictures of JWST and if you've seen a picture you'll know that it's actually it's not a round mirror it's hexagonal and it's not a single mirror either, it's made up of hexagonal segments that tessellate with each other and something that had to be done after launch while it was in space but before it started taking science data was to actually make sure that those mirrors were all absolutely perfectly aligned. So each of those mirrors has a little actuator on the back that allows it to be tilted and moved to make the alignment absolutely spot on. It has to be very very good to get the the quality of image that you want from a telescope like that.

Jo
So to give you an idea of the kind of signals it can detect if you've got a planet that's the size of Jupiter orbiting a star the size of the sun it blocks out about 1% of the total light coming from the star. So not a lot but also I mean that's that's actually a reasonable amount. So for a Jupiter transiting a sun just to detect it just to say yes it's there you can do that with a fairly small telescope and in fact students at the OU regularly use our own telescopes that are on Tenerife which are not particularly big to measure transits of planets. So this is something you can do with a relatively small telescope but if you're doing what I'm doing and you're looking for the atmospheric signatures what you're measuring is not what you're interested in measuring is not the overall depth of that transit it's the variation in the depth of that transit in all of those different colors of light and that's about another factor 100 at least smaller. So that's now about one part in 10 000 and that's for an easy planet for a difficult planet so when we're starting to get down to things that are smaller than Jupiter we're not even quite at Earth yet Earth is still really difficult. Earth around a sun is very hard even for JWST but for say something a bit smaller than Neptune you're talking maybe 10 parts in a million a few tens of parts of a million so it's a tiny tiny signal that we're interested in measuring and that's something that you you simply can't do with a smaller telescope.

Jo
So Hubble which is obviously a space telescope it's been doing absolutely exquisite science for more than 30 years now it couldn't make some of the measurements we can now make with JWST it's mainly partly because the mirror is too small partly also because it's it's in a much sort of less stable area of space it's orbiting the Earth it's orbiting the Earth once every 90 minutes whereas JWST is at a little sort of sweet spot in the Sun-Earth system where it's permanently shaded by the Earth from the Sun and that makes it much more stable. So JWST is really at the very limit of what we can do right now and it's been an absolute game changer.

Ben
Right the reason I said at the start about sort of looking up and looking forwards was because well just to let everyone else in on this and just before we started Joe messaged and they said oh if it's of interest I was in the US last week and we were talking at a conference I believe about sort of NASA's next new telescope or observatory so that's why I've gone down this route of telescopes and wanting to know where we are now and what's coming next so perfect opportunity brag to us about your your time spent in the US talking NASA and observatories and the future of exoplanet exploration I guess.

Jo
Oh yeah I mean so I had I had a very very intense but an absolutely brilliant week last week in Washington DC and the reason I was there was that there was a conference that was being held to bring together scientists and engineers to talk about the next great

observatory that NASA wants to launch so we're talking this is going to be in about 20 years time so if any of you on the listening to this podcast now and you're sort of in your late teens and maybe thinking about your career listen up if you're interested this you know this could be the thing that you're working on in 20 years time it's very much looking at the future and this is called the habitable worlds observatory so the aim of this next great observatory is to put a telescope in space that's not got a much bigger mirror than JWST a little bit bigger but the the real advantage of this telescope is it's going to be able to take a picture of an earth-like planet around a sun-like star in our relatively near neighborhood around our sun not just one of course several so this is hopefully going to be the telescope that tells us if there is another earth out there if there is another rocky planet out there that has an atmosphere that's anything like ours and when i say take a picture i don't actually just mean take a picture although it will do that it will also be able to give us information about the atmosphere of a planet like this so it will tell us does its atmosphere contain oxygen ozone methane it could also tell us potentially is there liquid water on the surface of this planet because liquid water has a very specific reflection signature and this will be a little bit like Hubble on steroids actually so it's not an infrared telescope it's it's an optical telescope with a little bit of ultraviolet sensitivity and a little bit of infrared sensitivity so it's it's going to be a general purpose telescope lots of astronomers doing lots of different exciting science are going to be using it but its main sort of goal it's resundee is to to do this it's to find another earth and potentially find indirect evidence of life outside of the solar system which i think would be absolutely transformational science on so many levels

Ben
oh yeah i mean i mean that's one of the questions that everyone is always most interested in isn't it is is is there is there life out there is is there another planet so then have we come close not not close to thinking we found another earth but have we found other planets out there have we found anything that has given us that the idea that yes it will exist we will find it anything that sort of even resembles earth

Jo
so we found evidence of earth-sized planets around a number of different types of star so we know the earths are out there that that's not in question pinning down the exact sort of frequency the number of them the reason that's so difficult at the moment is that all of the methods we've got for detecting them most of them are very heavily biased towards planets that are bigger heavier and close to their stars so i mentioned the transit method already it's it's biased towards larger planets because they have deeper transits but also just because of geometry the further away a planet is from a star the less likely it is to be lined up just right to transit that's just a fact and other methods that we use some involve measuring effectively how much the star is wobbling due to the the gravitational interaction with the planet that's also very much biased towards closer planets heavier planets so it's not that they're not out there they're just very difficult to detect with the methods we currently have and that's partly why plato the mission that i mentioned earlier that's going to potentially be able to detect longer period transits that's why that is so important and also the other way we can hopefully detect these is to use some of these extremely large ground-based telescopes that are coming up over the next few years which will be more sensitive both to measuring wobbling stars so it might start to push down to earth earth mass things but also will have at least maybe some capability to if not to characterize to maybe directly detect something small as well maybe so the way that when i talk about direct detection the big problem that we have is that oh well as everyone knows right stars are much much brighter than planets it's just a fact it's a given and we're trying to spot something next to something that is very very very much brighter than it a long long long way away and they're very very close together from our perspective it's really really difficult to do which is why most of our detection methods so far are they're indirect if you like they're measuring the influence of the planet on the star rather than looking at the planet directly and the way that we kind of have to do this is is effectively i mean you if you've ever i don't know if you've ever played tennis or something in bright sunlight when the sun's starting to set and you're trying to see the ball you automatically you put your hand up to shade your eyes because you're trying to block the sunlight so that's basically what habitable worlds observatory and what some instruments on ground-based telescopes will do they have something in them it's called a coronagraph it was designed originally to be able to see the outer layers of the sun's atmosphere which is called the corona by blocking out the central the light from the brightest bit of the sun it's exactly what happens actually during a solar eclipse where the moon provides that blocking facility and you can see the solar corona and so basically it's a it's a stop it's a block in the optics of the telescope that allows you to get rid of the light from the star and only see the things around it it's of course far more complicated than that it's not as simple as just having one block because if you when when you put anything with a sharp edge in telescoped optics things diffract they scatter off the edge you get all sorts of mess if you like little speckly patterns on your on your detector that you don't want so you have to get rid of those it's a very very complicated piece of engineering the habitable worlds observatory will have a coronagraph that will enable it to detect something that's no not one part in a million not even one part in a billion a hundred parts in whatever a thousand billion is which i can't remember that's the kind of contrast we're talking about between the earth and the sun and it will be able to detect that so phenomenally tiny little signals

Ben
that's yeah incredible numbers i mean i think we will know that it's you know it it must be yeah you take incredible technology incredible power to to detect these things but yeah that's that's just unbelievably like i think of the right word to describe it i first it's beyond something that you can kind of even do picture work out isn't it it's it's uh that's unbelievable i when we spoke before there's a couple of things i remember you telling me so there's some some sort of bit more simple answers now perhaps in the coronagraphs and hundred parts in a hundred billions and and so on you told me that there was around about i think when we last make around about six thousand exoplanets that have been discovered is is that is that where we are how often are exoplanets actually being found if when we last spoke it was around six thousand is this an everyday occurrence are they popping up all over the place

Jo
i mean it's it's still around six thousand it tends to go in waves so when there's a brand new mission like something like kepler for example that's optimized for doing this you get a sudden sort of gush if you like of detections because each each new mission is is designed to look at i guess a little a different bit of discovery space so we had a gush with kepler we had a gush with tess and both of kepler is now finished and tess is still going but it's it's found most of the low hanging fruit now that's easy for it so that gush is sort of slowed to a trickle but there is still a trickle there are still planets being discovered all the time and ground-based telescopes that are looking at wobbling stars they're also discovering planets of the time so it's at the moment we're at we're in a steady trickle phase with something like plato coming along in the next few years i imagine there'll be another gush so i don't i don't know because i forget exactly what the the yield is supposed to be from plato but it's it's a lot we're talking you know hundreds thousand and there's also the the gaya spacecraft that has now finished its mission but the the data are still being sort of looked at and what gaya did was measure the positions of stars on the sky incredibly precisely

Jo

and so once that has all been sort of processed and analyzed by monitoring little positional changes on the sky of some of these stars that will also lead to planet detections as well so we're exploiting every possible method there's also a telescope launching from nasa in the next couple of years called the nancy grace roman space telescope that is also going to find planets using the same methodology as habitable worlds but also by looking at what we call gravitational lenses so if you've got anything that has mass it will be bending light very very very slightly you probably won't notice it most of the time but if you've got a a star and a planet and something much brighter behind them that passes behind them

Jo
then they can act as a lens so you see this little temporary brightening of your distant star and if you've got a star and a planet you get uh you get two bumps instead of one that's a really powerful detection method for planets and then nancy grace roman will be doing that as well so all the time we are finding new planets but it very much is it's waves right there's a mission you get loads then it slows down

Ben
uh before we finish i mean i just want to ask you what what is the episode you're most excited about coming forward we can i can sense your excitement your enthusiasm to talk about this this subject which is fantastic but yeah what's what what's the most exciting thing for you that's coming up

Jo
oh i mean obviously i'm particularly after last week i'm so excited about habitable worlds because it's yeah it's getting down to looking at not just other planets which are all fascinating but solar systems because it's not just earth we'll be able to see it's jupiter's saturn's venus's one of the things i've always wanted to to know to learn because i started out my career actually studying venus as a solar system planetary scientist is how many venuses are are out there relative to earth how many how many are you know the earth gone wrong scenario with venus that lost its liquid water really early on got too hot now is an absolute hellhole with sulfuric acid clouds and how many of them actually stayed a reasonable place to live i really want to know we have absolutely no idea actually about the split there at the moment and maybe eventually we'll be able to learn that and that will be really really exciting but in the in the nearer term so the telescope i just mentioned the Nancy Grace Roman space telescope it's it's a little bit like a sort of pathfinder for habitable worlds so it's it's not going to be as sensitive it's not going to be detecting any earths but it might be able to give us a first look at some planets that are like true exo jupiters so we've seen loads of jupiter sized things that are much closer to their stars so they're really hot or things that are jupiter sized and hot because they're young what we haven't really seen yet are things that are actually like jupiter in our own solar system that are cold gas giants and i'm really hoping that Nancy Grace Roman space telescope it might actually start to give us the first little bit of information about one of these cold jupiters and that would be really cool

Ben
fantastic well then let's hope that that comes to fruition let's hope you you get to find out what it is that you you want to know if there's any more out there and yeah that's been absolutely fantastic thank you so much for joining us today joe and that's been that's been brilliant and just want to finish by saying if you want to know more about joe's work there is a course a free course on exoplanets on open learn so please do go and check that out like the videos give us a subscribe click on that bell to make sure you don't miss any new ones coming up and yeah thank you very much today for joining us today joe it's been absolutely brilliant really appreciate your time thank you

Jo
great thanks bye

Ben
and we'll join you to join us again soon on the open known podcast thanks very much bye