# Astronomy Cast Episode 34:
# Discovering Another Earth

**Fraser Cain:** This is a huge week in astronomy. I would say one of the biggest weeks we've had in a year, let's say *n* years … it's an enormous piece of news: the discovery of an Earth-sized planet orbiting another star inside the habitable zone. So it's possible there's liquid water on the planet. So, is that it? Are we really close to finding out another world out there with life on it? Pamela? Let's start with talking about what was discovered this week.

**Dr. Pamela Gay:** There's this little baby star called Gliese 581, it's one of the hundred closest stars to the Sun, it's about 20.5 light years away in the direction of the constellation Libra. It's just a little red dwarf, about 30% the Sun's mass and only about 1.3% the Sun's luminosity. We're talking little, tiny, faint, baby, cute star. One of the neat things about these little stars is because they're so low mass, we can detect the gravitational effects of smaller planets tugging around these smaller stars. Scientists have started looking around red dwarfs to see if they can find Earth-like worlds. In this case, they got exactly what they were looking for.

Using a really neat set of instruments down in Chile, where it seems like nowadays all the really cool stuff is going to live, they were using HARPS, the High Accuracy Radial-velocity Planetary Searcher, and they found this planet, and in fact 11 of the 13 planets less than 20 Earth-masses have all been found by this instrument. Not only did they just find one Earth-like planet, they've actually found an entire solar system of worlds orbiting this other star. There are three different planets (at three different distances, obviously, from their Sun).

The first one they found was about 15 Earth-masses. It's a Neptune-like planet that orbits it's star every 5.4 days. Then, the next one they found is about 5 Earth-masses. It orbits the star every 13 or so days, and then they also think there's a third planet that's about 7.7 Earth-masses that is located out at a distance that allows it to orbit every 84 days.

**Fraser:** What was the methodology that they used to find it? Back in one of our earliest shows we talked about the search for extrasolar planets. What does this tool do?

**Pamela:** They were looking at the radial-velocity changes in the stars' stellar spectra that were created by the gravitational pull of these different planets on the central star.

**Fraser:** So if I recall correctly, the radial velocity is the speed that the star is moving toward and away from us because it's being yanked about with the gravity of it's planet.

**Pamela:** Exactly.

**Fraser:** And this is a very accurate measurement – they're measuring the Doppler shift of the light, right?

**Pamela:** This instrument is extraordinarily precise. It can detect velocity changes that are slower than some people walk. It detects velocity changes as low as one metre per second. So we can walk around at the same rate that these planets are pulling on their central star, and that's kind of neat to think about.

So we have these three little tiny worlds, orbiting this little tiny star. When scientists sit down to model and ask "what do we think these planets might look like?" they do calculations and say "a planet this tiny can hold on to these elements, a planet this close to the star should be able to support these sorts of things." They're thinking the smallest of the three of these planets might be either a solid rocky world or perhaps it's something that's completely covered in oceans.

Now, we don't currently have the ability to look and see if it's a "water world" but it's neat to think about and hopefully this sort of discovery will motivate NASA and the European Space Agency to invest the necessary dollars to build the missions that can look at this little tiny planet and say, "yes, we finally found a water world just waiting to have a bad movie filmed on it."

**Fraser:** What do we know about this world itself then?

**Pamela:** Well, we know it's there, we know it's small

**Fraser:** How small? What's it's size compared to the Earth?

**Pamela:** Well, according to the science paper I'm looking at, they put a limit on it of 5.6 Earth-masses, and we can't directly determine it's radius or anything like that, but based on models of what this planet should look like, we're guess-timating/estimating that it probably has a radius about one and a half times the size of the Earth's radius, which makes this a really dense planet. When you're standing on it's surface, you're going to want to sit down. Any life that could've developed on a world like this will have developed with a much stronger skeletal structure to support them underneath the weight of the heavier gravity.

**Fraser:** How long does it take to go around the Sun?

**Pamela:** It's just sort of zipping around it's star every 13 days and it's really close in. It's only about $1/14^{th}$ of an AU away from that star. Now, it sounds like it's zipping around at high velocities, and really close in, so it's got to be a really hot planet.

**Fraser:** This would be in that Hot Jupiter category, right?

**Pamela:** But because this such a faint star, because this is a star that is 1.3% the Sun's luminosity, this close a position still allows the planet to have relatively cool temperatures. The estimates range from an average temperature anywhere between 0 and 40 degrees Celsius. Potentially the planet's environment is no different than where I am near St. Louis or where you are near Vancouver.

**Fraser:** So, if there's water, based on how far away that planet is from it's star, it would be liquid water.

**Pamela:** It would be liquid water. There's the potential for seasons, there's a lot of things waiting to be discovered. Now, that doesn't mean we'll find them. Our hopes could be completely dashed and this could be just another Mercury, another Venus, another dead world where life can't exist. But at least now we have some place to dream about, and some place that we know we need to look at as soon as the technology exists to actually look and actually measure which of our wishful dreams are actually real and which chemistry has decided to deny us.

**Fraser:** If we've already gotten to the point that we can detect a planet around this other star, why can't we just use more sensitive equipment and just start uncovering some of those additional things? It should just be like, that's the place to look now.

**Pamela:** Well, it would be if we had the right cameras. The problem is we need something that's capable of looking at immensely small angular resolutions. It's sort of like if I look at the Moon with my naked eye from here on Earth, looking through our cruddy atmosphere, I can make out some small craters but I can't look at grains of sand on the Moon. Now, we're looking at wanting to make out oceans on a planet 20.5 light years away.

In order to look for those oceans, we need to have the ability to zoom in on little tiny features and block out the light of the star that this planet is orbiting. We know how to do it: you take a coronagraph, the same sort of thing we use to look at the outer atmosphere of the Sun. So you block out the main part of the light from the star, and then you detect the very faint light of the planet and you have to resolve it. The way you can do that is you take a set of telescopes and you put them in orbit around the Earth. The angular resolution that you're able to achieve is directly related to the colour of the light you're looking at and the diameter between the furthest two points on the telescopes.

If you have just one telescope, or just one eyeball, and you want to know what it's resolution is, you measure the diameter of the opening the light can get in, the diameter of the mirror. Now, if you have two telescopes, you start at the furthest left side of one telescope and you measure all the way over to the furthest right edge of the other telescope and you use that diameter. As you move the telescopes further and further apart, you're able to achieve higher and higher angular resolution; smaller and smaller objects can now be clearly seen.

To do this, we have to launch them into space, otherwise our atmosphere is going to take away all the advantages we've gained by moving our telescopes apart. So you have to spend the money to launch basically three Hubble Space Telescopes into orbit.

They're actually looking to put multiple systems that are multi-metre telescopes in orbit, working together to look at these planets.

It costs a lot of money, and NASA originally was planning to spend the money on something called the Terrestrial Planet Finder, but in the 2006 budget, the project was put an indefinite hold. We had the plans, we had the desire, at one point we had the budget and now it's all been sort of set aside for other priorities: things like putting men on the Moon and men on Mars have been given budgetary line items that had to come out of something, and the money to do those things came out of our desire to explore other worlds (or at least NASA's ability to use congressional funds to look for other worlds).

**Fraser:** So the problem that we have right now, for example with the – is it the HARPS instrument?

**Pamela:** Yeah

**Fraser:** --the HARPS instrument on the ESO's telescope, is that it's only looking at the velocities; its only able to measure that velocity back and forth. It can't see any aspect of the planet. It only tells us, what, the orbital period and the mass?

**Pamela:** We'll use the orbital period to calculate the mass. So basically we're getting one piece of information. From that one piece of information we can do a lot of calculations and then we can look at a lot of models. At the end of the day, the only things we know with certainty are the period. Everything else, well, we're estimating the mass, we're estimating the orbital size because we don't know the exact inclination, we don't know if we're looking at the orbit as though we were looking at a plate edge-on or at a plate held at 20 degrees relative to us.

**Fraser:** Have there been any examples where telescopes have been able to see atmospheres? If we pointed Hubble at Jupiter, or a mega-Jupiter, would we be able to see the atmosphere or is it still the same problem: even with those big planets, they're whipping back and forth and that's how we're able to detect them.

**Pamela:** Here we've actually been able to get lucky. We can use spectroscopy again, we can again look very carefully at the constituent lines in the rainbow of light from the planet and the star. This was first done way back in November of 2001, where the Hubble Space Telescope looked at a planet orbiting a star with the wonderful name HD 209458.

This sun-like star, yellow, $7^{th}$ magnitude (you can see it in any amateur telescope), is about 150 light years away toward the constellation Pegasus. Its planet happens to move straight across the disk so when we look at the star we can see the planet truck across the surface of the star and we don't see the planet directly. What we actually see is the light from the star decreases, and we also see when the little planet tucks itself behind the star, we also see it decrease.

When we take multiple images, images with the planet behind the star, and images with the planet in front of the star, we can look for differences in what is visible. Those differences are going to be things that are coming strictly from the planet.

We're able to actually make measurements of what's in the atmosphere. So, for instance they look for things like sodium, water and we're finding this things. In fact, back in January you reported on finding water but now we're looking at it with a higher resolution.

**Fraser:** Right, but the technique here is this transit method, right? Where the planet moves across the front of the star and you get this additive effect for the duration that the light from the star dims, the chemical composition that we can detect has changed.

**Pamela:** Yeah

**Fraser:** And it's almost like it's the addition of the star with what's in the planet; it's almost like you subtracted and you get what's in the planet and in this case Hubble saw water, right?

**Pamela:** So far, the only way we can find these atmospheres is when we just happen to be looking at a system that has the exact right alignment and the planet is big enough that we can see the eclipse of the planet going in front of the star and know when the planet is behind the star and then we can look for the differences in the two things. We're finding all sorts of neat stuff. There's another star, HD 189733b – that's the planet's name, without the 'b' is the star's name. Looking at it, we've been able to figure out that there are probably silicates in this star's atmosphere. There's this dusty cloud layer surrounding the planets. So everyday we're learning new and exciting things, but currently we're only learning them about the big Jupiter planets.

**Fraser:** Would we be able to use (and by 'we' I mean 'they') be able to use those techniques to look at this new Earth-sized planet? Wouldn't it be able to watch it move across the front of it's parent star and be able to measure the constituents of its atmosphere?

**Pamela:** So here I have to admit that the discovery is so new that I haven't really run the numbers on what's possible in terms of using the large spectrographs that exist here on Earth.

**Fraser:** I guess it depends on if it's moving across the face of the star or not.

**Pamela:** It also matters how much light we can get into our spectrographs. In order to look for the little tiny lines that come from the atmosphere of a planet, you have to spread the light out huge, huge amounts, in some cases you're spreading things out such that if you made a single rainbow, that single rainbow would be metres in length. So you're taking all the light from this really faint star, spreading it out over metres and metres, and then trying to make measurements.

We can do this with bright stars. With bright stars, it's no big deal: you take their light, you turn it into a rainbow, it's a bright rainbow – you can even see it with your eyes if you're in a dark enough room. Here, we're looking at such a faint star that I'm not sure that we have any telescopes big enough that it can gather the light from the star, spread it out, and still have enough light to be able to make a detection. I don't know: I'm hoping, hoping, hoping that we'll be able to do it, but I don't know for certain.

**Fraser:** Let's go back and talk about what the future holds for this. This planet isn't – we say it's Earth-sized, but you say it's what, five, six times the mass of the Earth –

**Pamela:** And only one and a half times the radius, so you're definitely looking at a high gravity world.

**Fraser:** Right. So will this technique be able to find an actual Earth-sized planet?

**Pamela:** If we look around the smallest stars. That's the neat thing: the smallest stars are actually the largest in number. If you look at the hundred nearest stars, 80ish of them are these little tiny red dwarfs. So we have lots of things to look at and a little planet can easily yank around a little star, so we're going to keep finding more and more of these.

It's a new day in planet discovery, and it's a new day filled with the Earth-like planets and the potential exists to find a planet the size and density of Earth close in to one of these little stars, inside of it's habitable zone, that just might be waiting to have life on it.

**Fraser:** So let's talk about – how would you know if you see life on a world?

**Pamela:** The critters on our planet do neat things to the atmosphere. For instance, we take and trees output oxygen. People output all sorts of pollutants that aren't normally found in nature. By looking for these special molecular and chemical signatures that we're going to know there's something there taking the raw atoms, the raw molecules that come out of solar system formation, and are transforming them into things that can only come from organic life.

**Fraser:** So there are no natural processes that could fill our air with oxygen?

**Pamela:** The oxygen could be there, but the ratios are going to be different. The carbon dioxide is getting broken up. It's these changes in the form that you end up finding the oxygen in that are signatures of trees, signatures of algae. All these specific things that you just tweak the ratios as soon as you add single-celled bacteria into an atmosphere, into a terrestrial ocean, an entire ecosystem is modified by algae bacteria. Human beings, we just make a disaster of our environment and that's really easy to see from space.

**Fraser:** I guess people always say, "maybe we'll see light not as we know it, there might be some other chemical process that functions on those world that we don't understand, like using silicon as a base as opposed to carbon" but I guess in those situations maybe we'll find those as well, but I think that if we can see the free-floating oxygen in the atmosphere, at the levels that we would have here on Earth, there's almost nothing else you can assume, then: there's life.

**Pamela:** Right. Peter Ward wrote an excellent book called *Life As We Do Not Know It.* It's all about the ways that life changes it's atmosphere, and ways that we might look for life. It's a good read, it's a hard read, but the science is really juicy and it addresses all the questions about life that a lot of us just have rattling around in the back of our heads all of the time.

**Fraser:** So, we went into this a bit before but, right now there's no observatory on Earth or in space that we could point at Gliese 581 and see if it has water or see if it's atmosphere has oxygen. So what plans are in the works, then, to try and put some observatories up there?

**Pamela:** Well, the European Space Agency has a program called Darwin. They're hoping to launch in about 2015. It's going to consist of three, three metre telescopes – that's bigger than Hubble for each of these three telescopes – as well as a fourth telescope that works as a communications hub. These are going to get put out at a point that is beyond the Earth, so you can go Sun, Earth, this point. It's called L2, one of the Lagrange points. It will keep this family of satellites always with the Earth behind it and the Sun behind it and the Moon behind it, so they can look out and study the sky constantly, unhindered and unblocked. These satellites have the potential to start finding rocky worlds and being able to image them. These are what we need. Hopefully, Terrestrial Planet Finder will someday, under perhaps a different Congress, get resurrected.

**Fraser:** Terrestrial Planet Finder is the NASA mission that would sort of kick Darwin up to the next level, right?

**Pamela:** Exactly. It's the little shiny star that will find planets and allow us to study them directly. Hopefully it will come back, hopefully the NASA budget will become friendlier to science someday in the future.

**Fraser:** It seems amazing to me. I think this discovery of this world is ahead of its time. I don't think that astronomers were expecting that they would turn up an Earth-sized world in the habitable zone, going around another star, for a decade or more from now.

I think this came as quite a surprise and I think that, with the timelines for Darwin and the Terrestrial Planet Finder, and some of these others, they were sort of more synced up so they'd come online to help pitch in with the science. Now, with this discovery (and I'm almost ready to write the next stories on Universe Today), I'm sure within months, within years, it's just going to be one after the other: smallest rocky world discovered so far. There's going to be a lot of demand, a lot of pressure to get those visible observing missions going so we can start to confirm.

All it takes is one: you just get the Terrestrial Planet Finder, get it in space, turn it and you look at Gliese 581 or any that are about to be discovered and you'll know whether there's life in the Universe outside our solar system or not. What more fundamental question could we answer?

**Pamela:** I'm right there with you. Unfortunately NASA has been tasked by forces outside of them, to put people on other worlds we've already visited in our own solar system. I'm cool with that.

**Fraser:** Don't make me choose. Don't make me choose between space exploration and astronomy.

**Pamela:** But the commercial sector can pay for the people. Tourism will produce revenue. I'm all for exploring our solar system with human beings, I just want to see the commercial space flight do it. This is the type of place that can be self-funding. I don't see the Terrestrial Planet Finder being self-funding. I think it needs NASA, it needs educational centres and universities behind it.

**Fraser:** I just think it's crazy that the two sides, science and exploration are forced to compete with one another. I find that kind of infuriating because it's almost like it's unfair and it sets those two different purposes at odds with each other. I personally think the science side should fall under the general (in the US, anyway) under the general science and the National Science Foundation and let NASA's exploration be completely separate. They shouldn't be battling over budgets, it drives me—I don't want to be forced to choose, and I think it's unfair.

**Pamela:** It's complicated where NASA controls all of our launch vehicles, so right now we live in times where a lot of stuff doesn't make sense, there's war going on, there's budget constraints, but now we've found a little planet that could potentially hold life and maybe we have something to dream about.

**Fraser:** I think, within the next couple of months as well, I wouldn't be surprised when people start to hear that a mission like the Terrestrial Planet Finder, which was ready to confirm these discoveries, has been shelved, I think there's going to be a lot of demand and a lot of pressure to try and get that mission specifically back online. So if anyone knows of any signature site to sign or any letters we can write, let us know and we'd be happy to pitch in because let's get the Terrestrial Planet Finder back and rolling.

**Pamela:** And for now, let's be thankful that the European Space Agency is out there shining the way, they have COROT up there looking for planetary transits and Darwin is scheduled for launch in 2015. There is still a plan to be able to see these things directly.

**Fraser:** All right. Well, I hope that gives everyone some information about this discovery and we'll stay on top of it as new stuff unfolds and try to explain that as well.

*This transcript is not an exact match to the audio file. It has been edited for clarity.*