Astronomy Cast Episode 202

The Planets at Gliese 581

Fraser: Astronomy Cast Episode 202 for Monday October 11, 2010, The Planets at Gliese 581. 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 are you doing?

Pamela: I'm doing well. How are you doing, Fraser?

Fraser: I'm doing really well. So one thing that we wanted to let people know... just people who are wondering how can they help the show... just a reminder... Anytime you want you can go to iTunes and write a review for Astronomy Cast so that other people can see that people like this show. Especially... especially in other countries than the United States and the United Kingdom. So if you're in Australia or Ireland or Canada or New Zealand or South Africa, and even in countries where English is not the main language... that would be a huge help. So, just go to iTunes, search for Astronomy Cast and write a review. That can help other people find out about our show. If you could do that, that would be awesome. Ok, so with the discovery of a planet in the habitability zone of Gliese 581, the chances of finding life on other worlds is just getting better and better. Let's take a look at the discoveries made at Gliese 581 and provide some perspective on the real chances of life and talk about what might come next. Pamela, let's first talk about the system itself and the discoveries that have gone on so far, leading up to the momentous announcement in the last few weeks.... if you could...

Pamela: Well, this is a star that has been studied for a long time for a lot of fairly straightforward reasons. First of all, it's fairly close. This is the 87th closest known star system to the sun. So, that means that even though it's 20.3 light years away, as faint as it is, we can get accurate measurements of what this little star is doing. People started studying it... looking at its radial velocities... how does it move to and fro along our line of sight. Hopefully, because it's getting yanked about by little worlds. As early as 2007, these radial velocity curves, these measurements of its Doppler shifting, began to reveal that there is something pretty interesting going on in this system. Back in April in 2007, it was announced by Udry et al. that it's not a star... there is a planet that's probably only 1½ times the radius of the earth that's orbiting this one-third-the-size-of-the-sun star.

Fraser: So that was the first planet discovered around the star.

Pamela: That was the very first planet.

Fraser: But this was just the beginning.

Pamela: It was. And the more they looked at this little planet, the more and more little worlds began to crop up. Not actually that little... they'd be pretty big if they were in our own solar system. So as we continued to look, new press releases slowly came out one by one indicating first a second planet, then a third planet, then a fourth planet... each one a little bit bigger and a little bit more interesting. The fourth planet, Gliese 581e, which was announced a little over a year ago back in April of 2009, it was estimated to have a minimum mass of just 1.9 times the mass of the earth. It's the lowest-mass exoplanet identified around a normal star so far. So that was pretty interesting.

Fraser: Just for people to appreciate how complicated this is... the astronomers are using the radial velocity method, as we mentioned. This is how they study the wavelength of the light that's coming from the star as the star is being yanked back and forth towards us a little bit and away from us a little bit. That shifts the spectrum of the light to the blue or to the red. But this isn't with one planet like a hot Jupiter zipping around the star, it's going back and forth really quickly.... but in this case you're looking at five planets... six planets... and each one is contributing a little bit of the signal. It's being pulled towards us, but it's also being zigged a little bit and zagged a little bit and each one... they have to tease out that signal from the wavelengths of the light... what a job!

Pamela: And this is luckily a star that's at least doing most of its back and forth movement on a fairly short period. So when that first planet was found, it had an orbit of just 5.4 days. That second planet that was found... it had a 12.9 day period. So here we have little planets being discovered, one by one, but it started to get interesting with the second discovery. What made the second discovery interesting was the planet they found they thought might have formed just beyond the frost line, just beyond the point at which water-ice was able to survive the formation of the star, and then slowly migrated in until it was outside of the habitable zone, but still tantalizingly close that, well, maybe if the atmosphere was screwed up in all the right ways, maybe something interesting...

Fraser: And what about the other planets?

Pamela: Slowly as we began to find them, they seemed to bracket the habitable zone. We ended up with planets that were just outside the habitable zone... just outside the habitable zone... until the most recent discovery was made. We had "c" which was a little bit too far inside, we had "d" which was a little bit too far outside. These were both planets with masses about six times the mass of the earth. So, potentially rocky worlds... potentially Neptune-like worlds. It's hard to tell with that mass.... but just one side and the other of the Goldilocks zone, sort of like Venus and Mars where the atmosphere can matter but there's probably no life.

Fraser: Right... so the habitable zone... this is that area... like a ring... a band around the star where inside that band it's too hot for water to be a liquid on the surface and then on the outside of that band, water would freeze and there's no chance that it could be liquid on the surface. But, inside that band, you could have, theoretically, liquid water. But it's more complicated than that, right?

Pamela: Right. You have to worry about... well, first of all, is there an atmosphere? If you have no atmosphere, you have no magnetic field. Ice that exists on the surface of the planet, first of all, if there's no atmosphere, there's no pressure... it's just going to sublimate away.

Fraser: Right. The moon is in the habitable zone of the sun... and there are many asteroids as well. And we're not looking for life on them.

Pamela: So as soon as you expose ice on these non-atmosphere-containing worlds, that ice just sublimates away into gas. Now if you have gravity you might hold onto it, but if you have no magnetic field, the second the star flares the slightest bit... that flare activity is going to wipe away any atmosphere that's there. So you need enough gravity to hold onto an atmosphere, and you need a magnetic field to protect any atmosphere that you're able to garner.

Fraser: And if you've got those things... if you've got the mass, if you're within the habitability zone, if you've got an atmosphere, if you have some kind of magnetic field... now we're cookin'.

Pamela: Unless we cook too much like Venus did.

Fraser: Right... right.

Pamela: So, these planets... they can condemn themselves either way. They can either have too much atmosphere or too little. If you end up with an atmosphere that has too much methane, too much of any of the greenhouse gases, too much carbon dioxide, even too much water vapor, you can end up baking the planet so that liquid water doesn't exist in ways that are amenable to life.

Fraser: So then the discovery of Gliese 581g which... normally we try to stay away from covering breaking news, but this is sort of a story which has been ongoing for a couple of years, and I'm certain we've not heard the last of this place. I'm sure there's going to be a lot more research coming towards it. So let's talk about the discovery that was made and the announcement and what this means.

Pamela: So, a series of observers have been very carefully, from the surface of the earth... that's one of the things that I love about this discovery... they were using Keck Observatory for a lot of their research...

Fraser: Take that, Hubble!

Pamela: Well, take that, Kepler! They were very carefully observing this little star... taking radial velocity measurements, one after the other. They looked at this ~~planet~~ star for a number of years and they looked at it from the surface of the earth, using Keck for a lot of the observations, very carefully measuring all of these to and fro motions, pulling out... ok, here's the dominant curve. That would be the first object that they found... "b." Ok, let's take this high-mass object at 15.6 earth-masses, fit the curve that it's causing in the radial velocity motion, remove that, look at the residuals. Ok, so now we have "c" cropping up at 5.6 earth-masses. Let's fit that with a curve, subtract it off. They worked their way all the way through all of the residuals for several years worth of data until what were left was residuals... little up and down motions in the velocity of the star that corresponded to a 3.1 earth-mass planet at a distance that is kind of laughable in our solar system... it's only 0.14 au away from its sun, and it orbits every 36½ earth days.

Fraser: So, 14% of the distance from the sun to the earth is this planet's distance, and it's orbiting in just a few days. But still, it's in the habitable zone.

Pamela: And that is really one of the awesome things about this. So even if this object is orbiting at about half the distance of Mercury, the star that it's orbiting is a whole lot smaller than our sun, and by being that close in, it's able to have liquid water. Now there's some caveats on this. Gliese 581 is a red dwarf star. So this means in the early days of its life, it went through basically the "terrible twos." It went through a phase of massive flare activity, sending out high-energy bursts of light. If Gliese 581g, this 3.1 earth-mass object formed in that habitable zone, it would have been blasted rather violently for a little over a billion years and that's not really healthy for life trying to form on a planet.

Fraser: Now would a red dwarf star... we've talked about this before... the red dwarf stars produce these really powerful flares, like proportionally more powerful than the sun or just more powerful than the sun did?

Pamela: It's a combination of duration and, for their mass, they're proportionately stronger. So they're not stronger than what the sun was producing, but they produce more of the x-ray flares, and they produce them for a longer period of time.
Fraser: You're saying like a billion years, while our sun probably only did it for a few hundred million.
Pamela: Right. And so with this billion years of violent UV, x-ray, high-energy light, that basically would sterilize a planet. Now one of the things that's theorized is we know planets move. We know that planets don't stay in the exact place that they formed. So what if this little Earth-like planet today might have formed further out away from the sun where it might not have gotten sterilized during this terrible-two period of its home star? If this was able to happen then maybe any volatiles, anything like water, any gases that were a part of this planet's atmosphere, might have survived. So that's one possibility for allowing for life... but we don't know. And that's so annoying!
Fraser: Now you said that the planet itself has just over three times the mass of the earth. How big is it, then?
Pamela: Well, that's unfortunately something we can't actually get at. We don't see this planet transit its star. And when I say three Earth masses, that's actually the lower limit on it. It could actually be bigger than that if the orbit is... So we don't know its density, and not knowing its density, we can only make guesses. It's definitely going to be bigger than the earth, but how much bigger—we don't know. It could be the density of water... it could be the density of rock.
Fraser: But you're not looking at three times the size of the earth... it would only appear a little bigger.
Pamela: Well, unless it was made of ice.
Fraser: Ice or snow or marshmallows... and then in terms of gravity, once again, even though the mass is a little over three times, because it's going to be larger, the gravity on the surface isn't going to be three times Earth's gravity, it's going to be somewhere between one and three.
Pamela: Right. It just depends on the size.
Fraser: But the point being that it wouldn't be... you could probably stand briefly on the surface of this planet and not die.... immediately.
Pamela: And if it's made of ice, you could stand for a long time and be happy. It's just a mater of how dense is the sucker.
Fraser: But everyone is imagining... and this is I guess where we start to run into the madcap speculation. Actually, before we get into the speculation, there's a few more things. The world is tidally locked to the star!
Pamela: Right. And so here's one of the frustrating things about being that close to a sun. Every dynamic model we've run... unless by some random miracle, and we don't anticipate that... the planet is an absolutely perfect sphere with no deviations from perfect sphere, not one single mountain... a perfect sphere. Unless that perfect sphere happened, various torques over time are going to force this planet to be tidally locked the same way our moon is. This means one side of the planet is always experiencing daylight. One side of the planet is always experiencing darkness. This means that there is a horrible wind going from one side to the other and you get these giant convective cells.
Fraser: Right. You've got the side of the planet that's being heated non-stop, and the side of the planet that's being cooled non-stop.

Pamela: Right. So it's thought, according to some weather models, that maybe, just maybe, there's a permanent rain fall, an ongoing storm on the dark side of this planet. We're still figuring out weather, we can't even tell you what the weather's going to be like tomorrow on our own planet. But, that's what the weather models are showing. So, any life that could survive on this planet would have to first hope that the planet survived the billion or so years of high-energy flare activity, was able to come out of it with some volatiles... some water on the planet.... has to then hope there's a magnetic field. It's believed that the 30-day rotation of the planet, if it's tidally locked, is enough for a magnetic field. So you need that magnetic field. Then, once you survive all of that, even if you have the atmosphere, you have the magnetic field, you have the water, you have everything else... any life forms that exist have to then withstand this constant torrential wind and rain and everything else that's going on around it.
Fraser: Now if it did have an atmosphere, wouldn't that help to balance out the temperature around the whole planet? We look at a place like Venus.... the temperature on Venus is exactly the same temperature no matter where you are on the planet because the atmosphere's so thick... that's what's regulating the temperature across the whole planet. But here on Earth, the atmosphere isn't so thick and so at night the temperature is cooler than at day. Near the equator it gets hotter... near the poles it gets cooler. What kind of temperatures would you see on a world like this where one side was always facing the star and one side is always facing away?
Pamela: Again, it's gonna depend on how thick that atmosphere is. If the atmosphere is too thin, then you are going to end up with massive temperature differences between the two sides. If it's too thick and you have these massive convective cells, you will have a temperature gradient from one side to the other. But the temperature gradient will be much less, but then the chances of life will be much less, as well, because now you're baking the planet so that liquids aren't going to exist because it's too hot for liquids. So it's this balancing act that's so annoying to try to sort out.
Fraser: Would you see life wanting to live around the terminator... that sort of half-way point between daytime and nighttime on the planet? Or is that not necessary?
Pamela: It's really not necessary in many ways. Life.... we used to think required light. But now as we're digging down or I guess swimming down to the bottom parts of our ocean we're finding that really it seems what life needs most is some sort of a liquid solvent... something that allows nutrients to flow from one place to another. You need some sort of an energy source, and you need some sort of temperature gradient to inspire chemical reactions to take place. Light isn't part of the requirements. Light is just one possible energy source but if you have lava vents, if you have something creating that temperature gradient... that can perhaps be the answer that you need.
Fraser: So in other words you're saying that the concept of a habitability zone is kind of misleading. Here on Earth we have the habitability zone that we experience with the liquid water up on the surface of the planet, but the other one that we have is the one that is inside the earth, the one that's right by the deep sea ocean vents that's a completely separate biosphere... kinda connected to the life on the surface but really, if the earth got a lot colder, that would all still be there.
Pamela: Well, if the earth got a lot colder, we might lose some of our geophysics and stop having volcanism. So again, it's a tradeoff. But this is where we can talk about there potentially being life on Titan, potentially being life on Europa.

Fraser: Yeah, and Enceladus and all of those. So, in other words, on the one hand, we're all focused on why this planet is so bad for the habitability zone of Gliese 581; then on the other hand, the whole concept of the habitability zone might be thrown out the window because you've got all these other ways. But I think, you know, when we think of life, we think of trees and animals roaming around the surface and using the surface of the planet. I don't think that life clinging around vents would... I mean obviously it's life, but I don't think that's what we're looking for. We're looking for cities and some kind of elephant monsters and Godzilla...
Pamela: I'm not personally looking for elephant monsters or Godzilla, but you know I could deal with a good walking tree now and then, and an ant would be my friend.
Fraser: Perfect.
Pamela: But this is where you need energy to have civilization, and when we start looking at these small planets, or big planets compared to the earth, but going around small stars, the sunlight that they're getting... it's not really that much in the visible. The majority of the light is in colors so far to the red that it's beyond what we can see with our own eyes. And in these infrared environments, where you're constantly plunged into darkness, the amount of energy that you're going to get for photosynthesis, the amount of energy you're going to get for solar energy, for all the major forms of energy that life has come up with to either consume in large forms or turn into energy in large forms. Oil is really recycled dinosaurs which consumed plants which ate sunlight. It all goes back to we get a lot of solar energy. This planet isn't going to be getting that really effective light. It's getting low-power, cold, wouldn't even heat your hamburger effectively infrared light from a small dwarf star. That makes it hard to start thinking, well, in gale-force winds could trees that are in deep, deep, deep, deep shadow effectively ever really grow... ever really evolve. Everything is so tantalizing, and we don't know the answers to so many of these questions. But the idea of an advanced civilization is one where if it is there, it's there by the grace of the fact that this planet will live for billions and billions and billions and billions of years and will have a chance to evolve much more slowly than we have the chance to evolve here on Earth.
Fraser: And I think that was the real take-away that we're hoping that people will get from this. There already has been a lot of bad science reporting... is the reality, you know... and hopefully with Universe Today we're doing a good job of science reporting in trying to put everything into perspective. But we want you as the knowledgeable ones, listening to Astronomy Cast, and you hear your friends talking.... hey, did you hear that they found life on that planet? Well, no... they didn't. They found a very exciting discovery, but more data is necessary. So let's talk about the more data, then. What would you say is next? What are scientists going to be working on next and what can we hope to hear?
Pamela: Well, really all we can do with this system at this point is keep watching it and better refine the data we have. The problem is that these planets quite annoyingly do not transit their star. That means that we're never able to look at the planets as they pass through the starlight and thus study if they do or do not have atmospheres. So this little star sits there taunting us... nyah, nyah, nyah, I have planets and I won't tell you anything about them.

Fraser: So, these planets are... I mean, you say you can't see them by the transit method... so there is no real simple technology that will let us see the atmospheres of these planets.
Pamela: No, and this star is giving off so little light that reflected light isn't really that much of an option. Especially when these things are so close into their parent star. But what is amazing about this is that we've studied so very few stars in the detail that we've studied Gliese 581 that the fact that this early into having the technique with this few stars studied, we found a system with this many planets, tells us that we're looking at ten or more percent of stars having multiple systems with habitable... possibly... planets.
Fraser: That is the take-away.
Pamela: That's the take-away.
Fraser: That's the real news here is that astronomers are really refining the percentages of planets of different sizes orbiting around stars of different sizes. A decade from now, they'll have really good models on if it's this kind of star it's probably going to have this kind of planet configuration... if it's that kind of star it's probably going to have these kinds of planets, and that really helps narrow down the search for the habitable worlds. But in terms of, like, will we know if this star has life... we're going to need, for now, we're going to need those worlds that pass right in front of their star, obscuring it, and giving us a chance to take a look at its atmosphere as it goes past.
Pamela: And that's, to me, the Holy Grail of exoplanets... finding the planet in the habitable zone that is transiting, that is a large fraction... half the size of the earth to a couple times the size of the earth... that has that atmosphere where we can start seeing oxygen and we can start seeing pollutants that are indicating there's technology.
Fraser: There's a lot of people that are predicting... and I think, you know, I feel pretty confident about this as well... these discoveries are going to come fast and furious. We are not far away now from being able to start detecting atmospheres around other worlds. If we get lucky... possibly the most important scientific discovery in human history will get made in all of our lifetimes. So... I can't wait.
Pamela: And as much as you and I have sat here and said... Terrestrial Planet Finder, Terrestrial Planet Finder... one of the things that this set of discoveries really shows is how powerful a tool the radial velocity technique really is. Yeah... Terrestrial Planet Finder... WANT! But the other thing we really need is a dedicated 8-10 meter telescope that does nothing but radial velocity measurements, that can be out there finding the systems like this one that just might be what tell us the rest of the story.
Fraser: Yep... but I'd rather have the Terrestrial Planet Finder, thanks! I know it's a harder sell. Well, that's great, Pamela. Thank you very much. As we get more discoveries on this I'm sure we'll sneak a few into some episodes. We'll talk to you later.
Pamela: Sounds great, Fraser. Talk to you later.