Astronomy Cast Episode 190

The Kepler Mission

Fraser: Astronomy Cast Episode 190 for Monday May 17, 2010, The Kepler Mission. Welcome to Astronomy Cast, our weekly facts-based journey through the cosmos, where we help you understand not only what we know, but how we know what we know. My name is Fraser Cain, I'm the publisher of Universe Today, and with me is Dr. Pamela Gay, a professor at Southern Illinois University Edwardsville. Hi Pamela, how're you doing?
Pamela: I'm doing ok... it's been an amazingly stormy, scary, awful weather day but we finally got to record.
Fraser: Yeah, during the summers we always have to do our recordings in between tornado warnings. In fact if people go back through our archive, it's like... oh, yeah... in the summer... tornadoes... and then, you know, the year before... It's like your summer pastime is to somehow get work done while nature is trying to tear your city apart.
Pamela: Yes... this is why backup systems and laptops with 9-hour batteries are both useful things, and if you can couple it with a 3G wireless, you can weather it out in the basement.
Fraser: Ok, stop shilling for the networks.... unless they want to pay us, then we'll shill for them. Alright, so last week we studied Kepler, the man. This week we take on Kepler, the mission. Launched in March 2009, this is the spacecraft designed to search for Earth-sized planets orbiting other stars. So we'll take a look at the history of this mission, the launch, and the science gathered so far. I like this kind of one because the spacecraft is already up, it's safely launched, it’s operating, it’s already got some science data... the best is yet to come, so we can both talk about things that have already happened but also predict the future, which is always great. It's also, as I mentioned in the last episode, it's not that connected to Kepler, except that you learn a lot about planets.
Pamela: Well, yeah... he's kind of the originator of the whole planet idea... so, yeah, it's cool.
Fraser: So then let's go back to the history of the mission and the science that's coming together here.
Pamela: Well, the idea for the Kepler mission actually originated in the 1980s. The idea probably originated well before that, but they started pulling together the science team, assigning roles, writing up white papers, that sort of work in the 1980s. Then, it finally got funded, got put through, lots of ideas detailed... we have another tornado warning, if you heard that ding in the background.
Fraser: Focus, Pamela, come on... stick with things that are really important here...
Pamela: They started pulling together the really good team in the '80s and '90s, these things got funded. I've been able to find papers back in the early 2000s detailing what they planned to do. They originally had a planned launch date for 2007, but as happens with many NASA missions, there were budget cuts, there were budget delays, there were mission delays... yeah, they finally launched in March 2009. Today we have this fabulous mission, and the biggest thing that didn't survive all the way through the multi-decade process from conception to birth was the radio transmitters flexible gimbals. So, instead of being able to point their radio receiver without having to move the mission... they

actually lose one day a month of being able to collect data just in sending data back to the planet Earth.
Fraser: Everything else is intact.
Pamela: Yeah, and it's doing great science.
Fraser: I can remember, actually, when I first started Universe Today... so we're talking 11 years ago now... I can remember writing articles about the upcoming plans for the Kepler mission. I mean early, early on... early 2000.... so it has definitely been around for a long time. So, lets talk about the purpose and see if we can somehow connect it to Kepler the person. What is the purpose of the Kepler mission?
Pamela: It is to discover planets by looking at planetary transits and more importantly to discover planets as small as the planet Earth. The way it's doing this is it's looking at a field of stars in the direction of the constellation Cygnus. So, if you know how to find the summer triangle, right now you can go out and look up and look in the same direction that Kepler's looking in. And in this fairly crowded field of stars it has picked out... well, it hasn't... the science team has picked out a hundred thousand stars that they're studying, taking new images every 30 minutes, and looking to see... do any of these stars have the dimming that you expect to get when a planet passes in front of the star, blocking a small fraction of its light.
Fraser: So they say they've got a 100,000 star targets, but they're focused in a very tight region of space, so the spacecraft is not really having to... it's not turning up, down, left, right, and all the way around... it's really just zooming around in this one little spot of the sky. But it can't gather the whole space at once, can it?
Pamela: No, it's actually getting all 100,000 stars all at once!
Fraser: Oh, wow! Ok...
Pamela: And that's... and one of the things that causes me a bit of sadness is that they could actually be collecting data on a whole lot more stars... it's a 10-degree field of view... this mission has a giant mosaic of detectors that are looking at a large chunk of the constellation Cygnus...
Fraser: Right, that's like 20 times the size of the moon... so measure a circle 20 times as big as the moon, and that's the space... and it's just staring at that whole space all at the same time.
Pamela: Right, and it's taking image after image... co-adding them as needed, to allow us to see all of these stars. But it actually has even more stars in its field of view than just those 100,000, and it would be kinda weird if a mission had exactly 100,000 stars in its field of view anyways. But the reason it's only looking at these 100,000 is it has to pick and choose how much data it can save because it has to keep all of its data stored up on its hard drive until that once-a-month download of data, and then that download is limited in time to how much time they can get on the Big Ear... the network of radio telescopes that we use to communicate with various space missions. So if there was unlimited time on the Big Ear dedicated to Kepler, we could be looking at even more stars than we're currently looking at.
Fraser: Right, so then let's kind of imagine this mission... it's pointing at this spot in the sky... it's gathering all this light... it's seeing all these stars... Some of them are going to be constant in their brightness, and others are going to be changing in brightness, right? But there's going to be a whole bunch of reasons... there's going to be variable stars, there's going to be novae, there's going to be all kinds of things going on, right?

Pamela: So they're initially actually looking at a larger number of stars... First of all they surveyed the field very well from the ground, eliminating all of the variable stars they knew about... didn't observe any of those... and then during their early parts... the first tens of days of the mission, they looked at over 140,000 stars and eliminated over 40,000 stars because they weren't ideal candidates. They were either binary stars that just weren't discovered, they were variable stars that weren't discovered, they were stars that were not your classical pulsating nice regular easy-to-look-at variable, but were rather stars that had flare activity... all of these things... the properties of the star were erasing any potential to find planets. So they weren't useful for planet-searching science... they were still useful for lots of other science. That science is now going to be based on a very short window of data... and that's ok... we're still getting good results.
Fraser: And they're using the transit method, right? This is the method where you're looking at the star and the planet happens to pass directly in between this star and Earth and slightly dims the amount of light that we see coming from that star in a very specific pattern as that planet dims... you know, passes in front of the star... dims the star, then goes behind the star, then we see another pattern... that's what they're looking for. And they've used other... they've used like Spitzer and they've used other methods for finding planets in this way.
Pamela: Right. And this is actually going to be an amazing set of data because we can detect transits from the planet Earth. In fact if you have a good 4-inch telescope with a really good, really sensitive detector you can make observations of some of the planetary transits that we already know about. The catch is, well, there's only a few stars that are bright enough that we can see the tenth of a percent... the hundredth of a percent... if we're lucky the one percent dimming that occurs with planetary transits. Most of the transits are so faint that if you have a star that's not very bright to begin with, and you're looking for a very slight change in its brightness... that's really hard to detect. So by sticking the mission in space, you don’t have to worry about atmospheric effects, you can constantly watch objects around the clock, but mostly you avoid the effects of our atmosphere. You can end up with a fake planet just by clouds passing by.
Fraser: So, how sensitive is Kepler? And let's put that in context in what's been found already using other techniques, or using the transit technique, what will it find... hopefully...
Pamela: We know that it can find planets the size of the planet Earth...
Fraser: Wow...
Pamela: They've been able to cross-correlate the early results and look at things that we know exist, and based on the things that we know exist and the signal-to-noise... planets the size of Earth can be found.
Fraser: In the same orbit as Earth?
Pamela: In the same orbit as Earth...
Fraser: Right. And so... but from what I understand so far, it's kinda like you're grabbing the low-hanging fruit... it's harder and harder to notice the smaller planets moving in front of the star and to get that pattern. It's easy to catch the big ones that are moving... the mega-Jupiters that are moving really close to their world because they're going to darken the star quite significantly and we're going to see it fairly often so you can start to pick out that pulse almost... but the Earth-sized planets... you can imagine, you'd only detect

Earth moving in front of our star once a year, and you'd need to confirm that for several years before you'd have a good candidate.
Pamela: So you're hitting on two different problems that we have to deal with. And one of the problems is that planets like Earth... they don't cause that much of a dimming of the star that they're passing in front of. So, that in itself is hard to detect. The planet Mercury, for instance, causes a transit depth of 0.0012 percent. Jupiter causes a 1.01 percent. So Jupiter... even with the orbit it's at... that's a whole lot easier to detect. Now, in addition to the "it's hard to detect because it's just not wiping out enough light from the star," the other issue is... they want to have ten repeating transits before they confirm an object. Four is pretty good, ten is ideal. With four, that means you're waiting four years before you're able to confirm a planet like the planet Earth. You have to wait for four transits.
Fraser: Right, so you see a little blip in the data and you're like... ok, let's come back in a year and see if it happens again.
Pamela: Yeah. And that's a long wait. So right now they're releasing stuff based on... their confirmed planets are all 3, 4, 5 days... but the longer ones... we're going to have to wait. All of the planets so far announced are between 3 and 5 days of period.
Fraser: I want my science now!
Pamela: Well... sorry. But at least we know it's coming. That's the cool thing is we know it's coming. And just today... that's one of the cool things about... we meant to record yesterday... ended up recording today... today Kepler released 706 probable candidates for exoplanets. They think that probably only half of these systems will actually pan out to have exoplanets, but several of them could be multi-planet systems. Prior to today, we only had 460 candidates. We've more than doubled the number of possible planets that we know about just with one mission. Fifty years of work produced less results than the few months that Kepler's been orbiting.
Fraser: This is the whole point... you build a really specialized tool, gets results. So then kind of looking forward, what can we expect from Kepler? How long is it supposed to operate for?
Pamela: It has a several-year mission. As with many NASA missions I'm reluctant to say exactly how long it's going to last.
Fraser: But is it going to be one of those situations where like... well, you know, it was supposed to last now, but we've kept it alive another ten years.
Pamela: That's kind of what I'm hoping for. It's current mission length is 3 ½ years, and one of the problems that we're going to deal with is its orbital period is 372.5 days, which means it's lagging behind the planet Earth, orbiting the sun, and over time is going to drift further and further away from us. If they extend this mission it's just going to keep drifting, which means that the radio signals coming from it are going to get fainter and hard to catch. But that's not as big a problem as... well, should this mission choose to do like the Mars Exploration Rovers, which is harder for a spacecraft, but should it choose to behave like that it'll eventually drift behind the sun.
Fraser: Right, or like SOHO... there's a lot of missions that have definitely outlived their timeline, but it's not like Spitzer where it's got a set amount of coolant and then when that runs out, that part of the mission has to end. Or, like Deep Space 1 that had a set amount of Xenon for its ion engine, and when that ran out you really couldn't navigate or maneuver anymore, or like Phoenix is a good example... designed to land on the north

pole of Mars, but when the Martian winter set in, it got crumpled by several meters of ice and snow... this is one of those situations where they've got a set timeline, but there's no real reason why the spacecraft can't last longer than that.
Pamela: It's working in optical wavelengths... 400 – 865 nanometers. It will have the standard... it could eventually, well it will eventually run out of thruster fuel, but we'll see how long it lasts. They can be conservative... NASA always finds ways to surprise us and keep things going. But it's currently scheduled for 3 ½ years, and we're all going to hope that it just keeps on going and going and going...
Fraser: So then let's say we take all the data that Kepler kind of pulls together, what does this tell us about the Milky Way... about the nature and number of planets?
Pamela: Well right now we're only looking at a set of stars that are in the same orbital type that we're in. One of the things that gets talked about is well maybe planets don't form as well towards the center of the galaxy, maybe they form differently at different distances from the center. So, we're looking at a set of stars that are in similar orbits to our own sun, and what we're hoping to be able to say when we're done is that this is the frequency at which star of these different types and these different... well, spacings in binary systems, have planets. One of the things that I'm really hoping will come out of this is a new model for planetary formation. Growing up, I like everyone else learned the solar nebula model... you end up with rocky worlds close to the sun then gas giants beyond that then icy giants beyond that and then out at the edge there's the Oort cloud. Well, we now know that gas giants like to hug their stars. But where do the rocky worlds live? If you have rocky worlds, do the gas giants stay further out? How exactly do we build models to explain all the crazy varieties of solar systems that we're finding? This may give us the data that's needed to answer those types of questions.
Fraser: Right, so you can really get a sense of what does a typical solar system actually look like? What are the possible configurations that you can have? Could you have giant planets up front... rocky planets in the middle... or like what we have, the other way around... or if you have giant planets up close maybe you can't have rocky worlds... and so on and so forth.
Pamela: Right.
Fraser: And then what percentage of stars just have planets? What percentage of stars have giant planets? What percentage of stars have... because if we took the Drake equation, we could theoretically fill in one number and call it a day, right?
Pamela: And this will allow us to fill in a lot of the numbers that don't pertain to biology... and to do it very accurately. One of the things that I remember watching evolve scientifically is the idea of well, what metallicities of stars can have planets? What temperatures of stars can have planets? It was thought that the smallest stars couldn't form planets, and the largest stars probably couldn't form planets because they had massive outflows when they were young. And now we're finding exceptions to everything we ever thought. But somewhere there's got to be a parameter space of planets vs. no planets. We know that globular clusters, for instance, show no signs of having planets. This will help us start to get a handle on these things. And one of the interesting results that's already come out is we've learned that stars aren't as violent as we'd thought, in some cases. There was concern about just what fraction of stars show violent flare activity, the type of high-energy outbursts that prevent life forming on planets. We're now finding that these outbursts don't occur at the same rates that we'd

worried. These outbursts are also the type of thing that make it hard to detect planets. So Kepler looked at this and we found more candidates for looking at planets and thus more candidates for systems that wouldn't squelch life... and that's a cool result.
Fraser: Will Kepler be able to help answer the life question at all?
Pamela: Not by itself. But the thing with Kepler is that it's only detecting transiting planets. And transiting planets are the only type of planets whose atmospheres we can study. So if we start looking at these worlds that transit in front of their stars with telescopes that are capable of doing spectroscopy, we may be able to pick out the atmospheric lines of those planets from the stars' stellar spectra and say this world has oxygen. And you only get free-ranging oxygen in an atmosphere if you have plants or some sort of microbial life. Otherwise it likes to form organic molecules. So we could conceivably, thanks to Kepler, find planets whose atmospheres we study with something else, that we start finding signs of pollution of plants, of all sorts of different things...
Fraser: Does that spacecraft exist? That tool?
Pamela: Sort of... Spitzer works for the biggest planets. It's actually been able to detect atmospheres previously. And depending on the planet, once James Webb gets launched it will be able to aid in the battle. But a spacecraft dedicated to looking spectroscopically at stars with planets... that's not up there yet. Although it would be really neat if someone planned it and launched it...
Fraser: We should call it like the Terrestrial Planet Seeker... or something like that...
Pamela: Right, right... we're just going to keep saying that until someone builds it.
Fraser: We're just going to keep nagging until somebody makes the Terrestrial Planet Finder and puts it back on the books and launches it and finds life... doesn't anybody want a Nobel prize?
Pamela: It would be cool...
Fraser: Yeah, anyway... most important scientific discovery ever...
Pamela: Wouldn't you rather be able to look at a planet and understand its industrial based on its atmosphere rather than catching random hard-to-make-sense-of and highly controversial radio signals that might get blamed on atmospheric noise?
Fraser: But you can see the Kepler mission helping even the SETI... because all these planets are known to be Earth-sized worlds orbiting other stars, so let's just point SETI at them.
Pamela: Even more than that, just finding that there's a planet... it could be that one of these Jupiters that we find out in the habitable zone, it's not necessarily capable of sustaining life on its own because it's a gas planet... it could have moons... it could have Endor with its own civilizations growing up on the moon.
Fraser: Hmmm.... yeah. I think there's going to be a lot of data that's going to come out, and there's going to be so many interesting stories... I can see "First Solar System Resembles Our Own Solar System Found," and it's going to be with many of the same kinds of planets and the same kinds of orbits.... and hopefully then that will really spark a whole other layer of research of funding and so on... this is just to whet people's appetite, I think...
Pamela: And the small planets look like they may be in the candidate list. And this is one of the amazing things, and a bit controversial as well, is they've found so many planetary candidates that they've released half their data early. The scientists behind Kepler were able to get a special dispensation and were given an extra 6 months to release their data

beyond the one year that you normally get with a NASA mission. And they realized that we have 706 candidates, and they released 306 of those out to the public. Anyone who wants to can start following up on these objects. And they kept the 400 best for themselves. So 6 months from now hopefully we'll be able to see what's so amazing that they held it back, because the hints in the preprint that's up on ArchiveX... they're already pretty amazing. The average size is half-Jupiter.

Fraser: And this is what we've said... they're just getting going... it's all about the period... the length of time these planets are taking to go around their star. So they're finding the quick ones... but now that we're more than a year into the mission, they're starting to find the slower ones. This is going to get pretty exciting. Alright Pamela, well I think that covers the Kepler mission... hopefully everybody understands it and will then know what they're looking at when they read space websites talking about it, so that's great... thanks Pamela.

Pamela: It's been my pleasure.