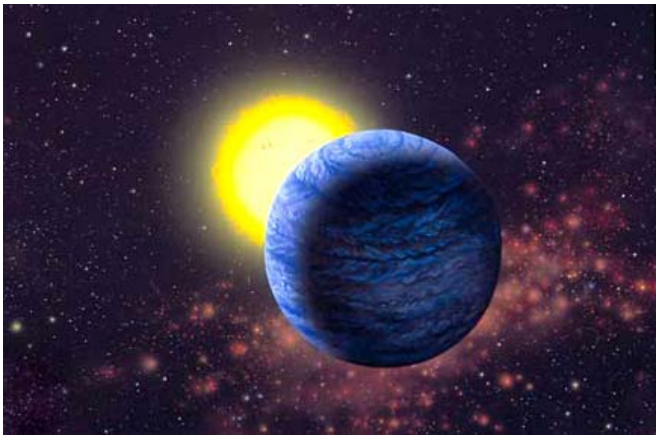
Six More Planets Discovered 60 to 190 Light Years Away

"There are an estimated 10 billion large gaseous planets in our Milky Way galaxy alone and at least one trillion galaxies in this universe. Even if only one out of a trillion of those galaxies had life, you'd still be talking about 10 billion places where life exists."

- Steve Vogt, Ph.D., Astronomer,
Univ. of California at Santa Cruz -



Star HD195019 is located in the constellation Delphinus. The large gaseous planet that orbits the star once every 18.3 days is estimated to have a mass equal to 3.5 Jupiters and is referred to as HD195019b. The planet is about .14 Astronomical Units from the star. One A. U. equals the mean distance from the Earth to the Sun, 93 million miles.
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http://www.spaceart.org/lcook/extraso2.html

December 1, 1999 Santa Cruz, California Since 1995, astronomers have had instrumentation and calculations precise enough to measure wobbles in distant stars that might indicate the presence of orbiting planets. Several astronomers now call themselves "planet hunters." In the past five years, twenty-nine planets beyond our solar system have been discovered. Six of those were announced on Monday, November 29th by a team that will have their research published in the Astrophysical Journal. The planet hunters include Geoffrey Marcy of the University of California, Berkeley; Paul Butler of the Carnegie Institution in Washigton, D. C.; Kevin Apps of the University of Sussex in England; and Steven Vogt of the University of California at Santa Cruz. This week I talked with Dr. Vogt about the new planets and why more and more are being discovered now.

Interview:

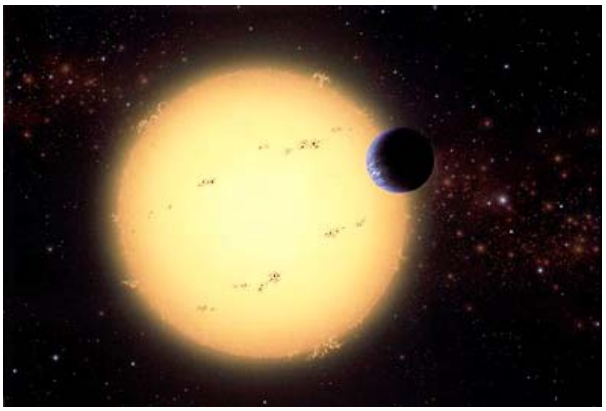
Steve Vogt, Ph.D., Astronomer and Planet Hunter, University of California at Santa Cruz: "We've been involved using the Keck Telescope out in Hawaii - the world's largest telescope - for the last three years in a very dedicated and focused search for planets around all of the brighter nearby stars. And we've been monitoring a group of some 530 stars looking for planets and have now gotten to the point where six of them show obvious orbits and we've just released these to the public.

THE SIX ARE STARS THAT WE MIGHT KNOW BY NAME?
No, none of these stars are known by name. These are stars that are fainter than you can see with your naked eye in general. In fact, most of the stars that we find planets around are not visible to the naked eye. A few of them are, but most of them are not.

WHY IS THAT?
Basically it's because most of the brightest stars we see in the sky are much too hot to be amenable to showing planetary signatures. They are very bright, hot stars. We are mostly interested in stars that are like our sun, or cooler. And those kinds of stars at the average distance of nearby stars are just too faint to be seen with the naked eye.

I UNDERSTAND THAT EPSILON ERIDANI AND TAU CETI AND ZETA RETICULI 1 AND 2 AND OTHERS IN OUR ARM OF THE GALAXY ARE IN THE SAME SEQUENCE AS OUR YELLOW SUN AND RANGING OUT TO MAYBE 50 LIGHT YEARS FROM HERE. HAVE YOU BEEN STUDYING ANY OF THOSE SUNS?
We certainly have stars like that on the list. And we are monitoring many of those. And we are also monitoring stars that are closer than that. Some of the stars you mentioned are very active. They are young and have active photospheres, so they are very difficult to see planets around because they have noisy surfaces basically. We avoid those young stars and try to concentrate on old, slowly rotating stars.

WHAT WOULD BE THE DISTANCES FROM THE EARTH?
Well, this particular crop of planets varies from - the closest is about 60 light years from earth and the farthest away is about 190 light years. And we have detected planets around even closer stars. The record actually is a star called Gleise 873 that is at fifteen light years - that's the nearest planet we've found. But these (new) guys are a little bit further out.



Planet HD187123b is one of the "hot Jupiters," described as extrasolar planets which orbit very close to their suns. It is believed that such planets are blue in color. With an orbit of only 3.097 days, this large gaseous planet has half of a Jupiter mass. Artwork © 1999 by Lynette Cook, used with artist's permission.

YOU HAVE DETECTED THESE VISUALLY OR ONLY BY THE TUGS AND PULLS AROUND THE STAR?
In general, when we detect planets we detect them simply by the tugs and pulls they make on their parent star. But there is one case two weeks ago when we made an announcement that one of these planets we had detected by the tugging

and pulling indirect method actually transited the disc of the star and eclipsed it. And when that happened, the planet sent a shadow across the earth. It took about two hours to transit the disk of the star and that was kind of a direct confirmation of that particular planet and allowed us to measure its diameter and density directly.

YOU SAID IT SENT A SHADOW ACROSS THE EARTH?
Yes.

OUR EARTH?
Absolutely. Most planets are in orbits that are inclined randomly with respect to our line of sight. It could be tipped at any angle. And in a very few number of cases, the orbit is exactly edge on. And when the orbit is exactly edge on, we are in the plane of the orbit. Then as the planet comes around in front of the star, between the star and us, it crosses right across the disc of the star. When that happens, it actually throws a shadow out through space - an infinitely long shadow that sweeps across the earth. And that shadow is actually a dimming of the light of the star because there is this dark planet that has crossed in front of the star and blocked out part of the disc of the star. And we can measure that shadow as it comes by - how long it takes to go by - and the depth of that shadow tells us the diameter of the planet.

These shadows have moved over the earth all the time for countless millennia. But until this point, we've never been able to detect one of those shadows because we have to know exactly where to look. We have to be looking at exactly the right star at exactly the right time. And it's a very small effect. It's only about a percent of dimming of the light of the star. So, this was the first shadow we caught.

WHAT WAS THE FIRST YEAR THAT ASTRONOMERS WERE ABLE TO HAVE PRECISE ENOUGH MEASUREMENTS TO CALCULATE THE TUGS AND PULLS THAT INDICATED PLANETS GOING AROUND DISTANT STARS?
I think planets around stars like we know, the sun - that all happened in 1995. And that was the culmination of about eight years worth of dedicated research by a team of people. And up to that point, they had found nothing. Finally, they got to the point where the precision was high enough so they could begin to see these tugs and pulls. And that was the beginning of the era of extra-solar planet discoveries.

BUT WE REALLY WEREN'T THERE BEFORE 1995?
No. It's been a long, hard road to develop the necessary instrumentation and precision of analysis to be able to see these effects. They are very subtle effects.

THIS SHADOW CAST THAT WE WERE ABLE TO DETECT JUST IN THE PAST COUPLE OF WEEKS THIS BEING THE VERY FIRST SHADOW THAT TRANSLATES AS BEING THE VERY FIRST PHYSICAL EVIDENCE OF ANOTHER PLANET THAT GOES BEYOND MEASURING TUGS AND PULLS?
Absolutely. Not that we ever had any doubt that tugs and pulls were planets. I mean, those of us who do this kind of work know there really is no other way to get what we call a "Keplerian Doppler signature" out of the star other than to have a body orbiting it. So, the physics describes it absolutely perfectly and we were, of course, certain enough that these planets existed. But, there are always naysayers in the community who say, 'Well, this is only indirect. You really have no proof that it isn't something else.' And so now, the shadow pretty much removes any doubt from any naysayer.

WILL YOU NOW BE CALCULATING ORBITS IN ORDER TO PLACE INSTRUMENT OBSERVATION AT MORE PLACES, MORE SUNS TO GET MORE HARD EVIDENCE OF THESE SHADOWS CAST?
Yeah. Unfortunately, the shadow thing is a fairly rare thing. We've been in this business now for quite a number of years and there are only certain types of planets that are likely to throw shadows and those are the ones that are very

close into their star. Because if a planet gets out very far away from its star, the likelihood that it would cross the disc of a star becomes very small. So, for all of those planets we've found there are about five of them now out of the 30 or so that we know of that are real close in to their star say that have orbital periods of three to five days. In each of those cases, there's about a 10% chance that each one of those might cross the disc of its star. And we have looked in each case for such transit and we've never found them before because their orbits weren't exactly edge on. This was the first case in which Nature was kind and threw us a bone the orbit was edge on and we got a transit. But in general, only one out of every 1000 stars that you could survey for planets will show this kind of transit thing. So it's pretty rare.

THE HEADLINES SAY, 'SIX BIG NEW PLANETS FOUND; FIVE COULD HAVE LIQUID WATER.' IF YOU ARE FINDING THE PLANETS BY SIMPLE TUGS AND PULLS, HOW DO YOU INFER THAT THEY HAVE LIQUID WATER?
That's a very good question. One of the first things we always do when we detect a planet is we work out the size of its orbit. That tells us how far away it is from its star. And then from some very simple principles, knowing the temperature of the star which we can measure and knowing the radius of the star which we can measure and knowing the brightness of the star which we can measure putting that together with the size of the orbit, we can determine how much heat that planet is receiving from its star. And from that, we can derive the temperature that that planet has to be at from its heat source, the star it's going around. And usually when we do that, we find that planets are very hot, maybe thousands of degrees. Or they are very cold - maybe hundreds of degrees below zero. And usually there is not much in between because the universe is a place of extremes things are usually really hot or really cold.

But if you get the planet at just the right distance from its star not too close, not too far away it will have a temperature that's in what is called the "liquid water region" - between zero and 100 degrees Centigrade, or if you like the Fahrenheit scale, between 32 degrees F. the freezing point of water and 212 degrees F., the boiling point of water. That's a very narrow temperature range. But it turned out that five out of the six of these planets were in that temperature range. Now, I'm not saying they have liquid water in their atmospheres or on their surfaces because they are in that temperature range. In fact, these newly discovered planets are like big gas balls similar to Jupiter, so they really don't have surfaces. And it's probably unlikely there is liquid water in their atmospheres. You have to have the right combination of temperatures and densities and pressures.

But it is quite likely that if they are accompanied by moons that the moons could well have liquid water on their surfaces. If you look at our own solar system and you look at all the gas giant planets in our own solar system and that includes Jupiter, Saturn, Uranus and Neptune each of these four giant gaseous planets has dozens of moons. So, it's quite likely that these kinds of planets we are finding are also like Jupiter or Saturn and also have lots of moons. And then, if they have moons and are in a habitable zone, it's quite likely to imagine that their moons do have liquid water.

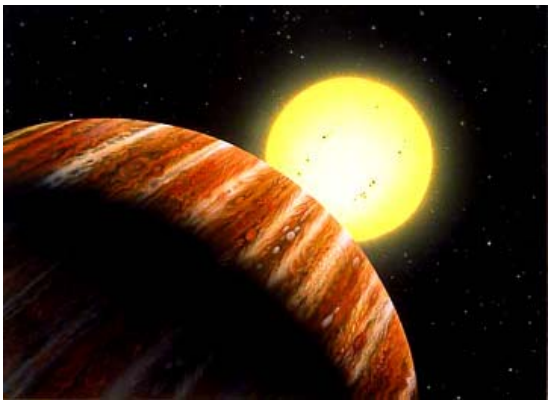
WHY IS IT THAT THESE PLANETS DON'T HAVE SOME SOLIDITY? WHY DO YOU SAY THEY ARE ALL GASEOUS?
Well, we know their masses that we can measure from our orbits. And the masses turn out to be large. They end up to be like Jupiter 300 times the mass of the earth. So, these are BIG planets. These are not small planets like earth and Mars and Venus.

COULD THEY BE AS LARGE AS JUPITER AND BE A SOLID EARTH-LIKE PLANET?
I suppose they could. I don't see any reason why a planet couldn't have an earth size terrestrial structure and be as big as a Jupiter. I don't know of any physics that would stop that. I think our theories of planetary evolution do not predict that, but it's possible that Nature has figured out a way to do that. On the other

hand, the one case we know of now where we got the transiting planet's shadow, we were able to work out the density of that planet and it turned out to be very similar to Saturn's - a little less than water. So that planet would actually float if you could put it in a big enough ocean. And that tells us that it's basically a puffed up gas ball and not a giant rock.

SO FAR, HAS THERE BEEN ANY INDICATION IN ANY OF THE WOBBLY TUG AND PULL DATA TO SUGGEST THAT WE HAVE DISCOVERED ANY SOLID, HARD PLANETS YET?
No. There is no information about that at all. Our best ideas are that each of these gas giants that we detect do have rocky solid cores that are a few times bigger than the earth. But the planet itself is mostly just a big gas ball.

WHY AREN'T YOU FINDING SOLID ROCKY PLANETS LIKE EARTH?
The thing you have to keep in mind is that there is a bit of a selection effect going on here. If we were looking back at our own Solar System from 50 or 100 light years using our technique, we wouldn't see Earth, we wouldn't see Venus, we wouldn't see Mercury, we wouldn't see Mars. But we would see Jupiter, we would see Saturn, we would see Uranus and probably even Neptune. But we wouldn't see the small rocky planets. And that's because of the technique. It has some limitations. So when we go out surveying for planets, we really are blind to all but these big gas giant planets.



Artist rendering of huge gaseous planet with a mass of about four Jupiters which orbits the 4.5 magnitude yellow star Tau Bootes every 3.3 days. Artwork © 1999 by Lynette Cook, used with artist's permission.

"Killer" Jupiters

Basically 5% of all the target stars we look at show these giant planets. Now, it's also true that these systems that have these gas giants in them, most of these gas giants are in very oval orbits, very elliptical orbits and they are not the kind of systems you would expect to find earths in. In fact, you can play the numerical games. You can put an earth in one of these systems and see what happens to it and very quickly it gets thrown out of the system. It basically just gets tossed out by the elliptical orbit of the big Jupiter. So, they are not the kind of systems we expect to find earths in. And that's kind of a sad thing. These are kind of like "killer" Jupiters in a way.

More Than 10 Billion Planets in Milky Way Galaxy

On the other hand, you have to keep in mind that's only 5% of all the target stars. That means that 95% of the target stars don't have these killer Jupiters in them. Now whether they have earths or whether they have Jupiters like our own which is in a nice, big circular orbit safely parked far away from the earth we don't know. We don't really have any information about that part of the story yet. It's kind of like the blind man feeling the elephant. You can feel the end of one tusk and you're trying to figure out what the rest of the elephant looks like. We're sampling just one end of one tusk right now. And it tells us, Number One

there are a lot of planets out there. In fact, of the few hundred billion stars in our galaxy, it tells us that there are at least 10 billion planets in our own galaxy. Now, many of these will be killer Jupiters like the kind I've described. But there are probably an equal number or more of systems that don't have these killer Jupiters in them and so it makes me think in all this planetary work that there are, first of all a LOT of planets out there. And secondly, there are probably a lot of places where water can exist in liquid form and where life will eventually emerge.

Solar Systems Like Ours?

DO YOU THINK THAT INNER PLANETS LIKE THIS SOLAR SYSTEM OF EARTH AND MARS, VENUS AND MERCURY ARE MORE RARE THAN GASEOUS PLANETS?

We don't know. We have no information about that whatsoever. We are really blind to seeing anything except the Jupiters. I think that one of the interesting things is that our own solar system has four Jupiter-sized planets in pretty large orbits out beyond five astronomical units - or five times the size of the earth's orbit. These big gaseous planets are nested in nice co-planar circular orbits, whereas the stars we're finding planets around have Jupiters in very elliptical orbits. So, they are different in that respect. They are not like our own solar system.

What we would like to find are solar systems like ours that have a Jupiter like ours in a big circular orbit. That allows you to have terrestrial-like planets like the earth down in the habitable zone where big gas planets wouldn't disturb it. And those are the real signposts I think of the kind of solar system that we're most interested in finding earths in. And so, we're looking very hard for those kind of solar systems.

The problem is that in order to find a solar system that has a Jupiter like ours and is in a 5 Astronomical Unit orbit with a period of about 12 years, you need to look for twelve years. You can't find it any earlier than twelve years because you have to see a whole orbital cycle. So, we have to be patient. We have to look for another ten to fifteen years before we can begin to see those systems that have real Jupiters like ours. And when we find those systems, those will probably be systems likely to have earths in them.

WHAT REFINEMENTS WILL HELP YOU LOOK FOR SMALLER, ROCKY PLANETS?

Well, there are really only two ways on the drawing board right now that could find earth-sized planets with any sort of meaningful data. One would be to put up a satellite in orbit that could look for this transit, or dimming, effect. It would be a very small effect if an earth-sized planet crossed across the disc of its star, but you could measure it if you had accurate enough instrumentation above the earth's atmosphere. To get a reasonable probability to find such a transit, you would have to look at an area of space that had tens of thousands of stars in it. And you'd need to look at all the stars all at once all the time, 24 hours a day, for probably three or four years. And there are missions that are designed to do that which may be funded and may fly and they will show evidence occasionally out of the handful of those tens of thousands of stars of places where earth-sized planets are transiting the discs of their stars.

Terrestrial Planet Finder, TPF

The second method which is even more ambitious is something that's on the drawing boards at NASA and is a thing called Terrestrial Planet Finder, or TPF. And this is something that will probably go up in the next 15 to 20 years a very, very ambitious mission that will fly a fleet of telescopes out in space that will be a free flying array maybe four or five individual telescopes that will all work together as a single unit and they will be spaced maybe a kilometer or so apart

and they will hold their distances in free flight formation to an accuracy less than the width of an atomic nucleus of an atom. These are incredible precision demands on such a thing. But, NASA is figuring out ways to do this. And if they can do this, these free flying telescopes will be able to combine their light to such exquisite accuracy that they will be able to block out, or null out, the light from the star and be able to peer in very close to the star and see the little individual planets directly and then analyze the light from those planets, take spectra from them and look for presence of things like water and oxygen in their spectra that would tell us if there were life processes going on there.

IF I UNDERSTAND CORRECTLY, AN ANALOGY TODAY ON THE EARTH MIGHT BE THE VERY LARGE ARRAY OUT IN DATIL, NEW MEXICO WHERE BIG DISHES LISTEN TO SPACE?
Exactly. It would be using optical light rather than radio waves, but would be a similar array of telescopes basically that would be in free flying formation - probably in orbit about the sun, trailing the earth at one of the Lagrangian points, not actually orbiting the earth. And it would be combining light as an interferometer in exactly the same way that the array of radio telescopes down in New Mexico does it, but with much higher precision. The tolerance requirements are picometers, which is the fraction of the size of an atomic nucleus.

Space Interferometer Mission SIM

There's another mission that's going to go ahead of that which is kind of a stepping stone along the way that will fly about the year 2003 called SIM, or Space Interferometer Mission. And that's a mission whereby they will learn a lot of the technology they will need in order to carry out this much more difficult mission.

YOU WERE QUOTED IN A NEWS ARTICLE AS SAYING, 'PLANET HUNTING IS A LOT LIKE MAKING WINE.' COULD YOU ELABORATE ON THAT?
Yeah, that was in response to a question that I've been frequently asked about 'How come we're seeing so many planets all of a sudden coming out? It looks like the pace of planet finding has suddenly accelerated.' And my answer to that was that like in making wine, at first you get nothing. For the first few years, as you plant your grapevines and you watch them mature, you really don't get any harvest at all. And eventually when they become able to bare fruit after a few seasons, then you have to wait until the fruit has ripened sufficiently on the vine. And once it's ripened, then you can harvest it in and make your wine. So, you don't get any wine initially until that happens.

Same with planets. We need to observe a large number of stars, hundreds of stars for several years before we can gather enough data on many individual stars to sense the presence of these periodic wobbles which then gives us the orbit. So, we're now at that point after three years in our planet search where it's harvest time. The grapes have matured on the vine, the data is ready, and it's time to make the wine.

HOW MANY PLANETS IN TOTAL HAVE BEEN DISCOVERED IN THIS PROCESS SO FAR?
There's been a total I think of 29 extra-solar planetary discoveries now. We've made about 22 of them, our particular group. There are a number of other groups also working on this. So, this latest batch of six increased the known number about 25%.

Other Intelligence Out There?

THERE IS A FORMULA FOR CALCULATING HOW MANY INTELLIGENT CIVILIZATIONS THERE ARE IN OUR GALAXY

CALLED THE DRAKE EQUATION AFTER CARL SAGAN'S COLLEAGUE AT CORNELL UNIVERSITY, FRANK DRAKE. DO YOU THINK THE ODDS ARE IN FAVOR OF FINDING OTHER INTELLIGENCES OUTSIDE THE EARTH?
I have no doubt in my mind that there is intelligent life out there. The question of how likely it is that we will ever be able to discover such intelligent life is a really tough question to answer. The problem with the Drake equation is there are a lot of great unknowns in many of the terms. And when you start to multiply a bunch of unknowns together, you end up with a very uncertain answer. And you can take two different approaches to the Drake Equation. You can be optimistic and see what kind of numbers you get and you get big numbers. You get thousands or millions of systems out there. Or you can be a pessimist and choose smaller numbers and you end up with none. And so, that equation, even though it helps organize your thoughts, doesn't really lead you to a number that you can depend upon, unfortunately. One of the interesting things about the Drake Equation is that it does tell you that I think the number of intelligent civilizations that are capable of developing radio communication in our galaxy is about equal to the average lifetime of the civilization.

How Many Planets?

5% of the stars we look at in our galaxy do show gas giant planets. So that means there are at least 10 billion planets of that kind in our galaxy... which means the universe makes *lots* of planets.

IN THIS GALAXY ALONE, THERE ARE TEN BILLION GASEOUS PLANETS?
That's right. In our own galaxy, there are at least ten billion planets and that's only the 5% that show planets. So, that means that there are a LOT of planets out there, many like these gaseous giants we are finding, and probably lots of other ones that are much smaller that we can't detect. And probably lots of earths, too. So, planetary formation is a very common thing. And that bares directly on things like the Drake Equation. Planets, I think, are easily made and there's a lot of them out there.

HOW MANY GALAXIES ARE THERE ESTIMATED IN THIS UNIVERSE?
Well, our best count used the Hubble Deep Field, which is the deepest image we've ever taken of the universe. It surveyed an area of the universe that is about the size of a grain of sand when held at arm's length. That's the size of the area on the sky that it's looking at. If you count how many galaxies there are in that field and then assume that's typical of the entire sky and multiply by the area of the sky, it tells you there are about a thousand billion galaxies in the universe a trillion universes. So, you can take that number of ten billion and multiply it by a trillion, if you want.

THE NUMBER OF POTENTIAL PLANETS IN THIS UNIVERSE?
In the universe, yes.

IF ONE PERCENT OF THOSE HAD LIFE, IT WOULD STILL BE A VERY LARGE NUMBER OF PLANETS.
It would be an *incredibly* large number of places that life could exist. If there are an estimated 10 billion large gaseous planets in our Milky Way galaxy alone and at least one trillion galaxies in this universe. Even if only one out of a trillion of those galaxies had life, you'd still be talking about10 billion places where life exists. Whether or not we will ever be able to find it and communicate with it to know that it's there, that's a whole other problem. If there is a civilization in a galaxy that's 10 billion light years away, it's probably going to be very hard to ever know that civilization exists because it would take 10 billion years to send a message to it and another 10 billion to get an answer. So, we're really isolated across those kinds of distances, incredibly, so it's hard to know if such civilizations existed.

UNLESS THERE ARE ADVANCED PROPULSION SYSTEMS YET TO

BE DISCOVERED IN WHICH PERHAPS ANOTHER INTELLIGENCE HAS ALREADY LEARNED HOW TO BEND SPACE AND TIME AND MOVE IN SOME KIND OF POINT TO POINT SYSTEM THAT WOULD MAKE THE DISTANCES NO LONGER SO IMPORTANT.
Yes. None of our present day physics allows us to do that sort of thing, but we're still fairly young in our understanding of the universe and it may be that there is a whole new set of physics out there that would allow us to do things like travel across infinite distances in almost no time and maybe other beings have figured out how to do that. One can only hope that will be the case, because if we don't find other physics that allows us to do that sort of thing, we're going to be pretty isolated on the earth. And even if the universe is teeming with life, it would be hard for us to ever contact it and to communicate with it without some kind of new physics.

OR ANOTHER INTELLIGENCE'S DECISION TO COME HERE AND LET US KNOW IT'S THERE.
Exactly. And it may be that they are already doing that. Who knows? We think in terms of our known laws of physics and think they might use radio telescopes to send information across space. But maybe they have other methods. Maybe they use dreams to communicate or something like that and we don't understand how to do that yet."

More Information:

Dr. Vogt is now working with other colleagues on a proposal for a 30 meter telescope that would have ten times the reach of the Keck telescope in Hawaii. It would greatly increase the ability to study the origins and evolution of the universe. If funding is approved - a billion dolars is needed - construction could begin in another year or two and be completed around 2010.

Dr. Vogt said, "We're going to try to find enough planets so we can begin to understand the statistical correlation between the shapes of their orbits and their masses and what kind of stars they form around to allow us to answer questions like: How typical is our own solar system? Are there other solar systems like it? Is it unusual? Is it rare? Does Nature make solar systems like ours very often? Or does it not? Because that will bare most closely on our understanding of whether life as we know it might form in other places. So, that will be the goal as far as the planetary systems are concerned."

Websites:

http://www.spaceart.org/lcook/extraso2.html

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