"HUNT FOR ALIEN WORLDS"

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GEOFF MARCY: Since I've been a little child, I thought to myself, wouldn't it be wonderful if we could learn whether or not there are other planets out there, like our own, and I thought, if so, all of the science fiction novels that we all read might, in fact, have some bearing on reality. There may, in fact, be other beings out there who are indeed thinking about us and wondering if we are here.

DANIEL GOLDIN: I just relate my own experiences and experiences of people who I've talked to around the world who look up at the night sky and wonder, "Are we alone?" We may never know the answer to that question, but we're at such an exciting time. We are on the cutting edge of having the technology to begin to understand this.

NARRATOR: Throughout the century, astronomers have been searching for evidence of other planets beyond the solar system. Finally, their telescopes have become so powerful—with the ability to capture images light years away—the worlds they have dreamed of finding are now within reach. The only planets that we can directly observe are those within our own solar system. Some can be seen with the naked eye. Those in the farthest reaching orbits took centuries to discover. With the aid of telescopes, Uranus was found in 1781, Neptune in 1843, and not until 1930 was Pluto finally found—captured in this telescopic photograph—a speck of light moving against a stationary background of stars. So distant was this small, frozen world, it would take another fifty years to discover its moon—only clearly visible in this 1990 Hubble Space Telescope photograph. Faced with the task of looking beyond our solar system for evidence of other worlds, astronomers in this century hit a technological brick wall. But now, that wall is tumbling down. A new breed of planet hunter has come upon the scene with better telescopes, faster computers and new ideas of what to look for. The first problem to overcome in detecting distant planets is that you can't see them, so astronomers have come up with techniques to get around this. At Allegheny Observatory in Pittsburgh, George Gatewood.

GEORGE GATEWOOD: Well, you can't just simply image a planet. An ideal thing would be to just simply take the telescope and look at the star and see the planets moving around it. The difficulty is that planets do not give out much light. It's entirely reflected light. A good analogy of the difficulty is to consider the problem of trying to spot a firefly sitting on the edge of a huge searchlight. You can see the searchlight. If the searchlight wasn't there, you might be able to see the firefly, but in the presence of the searchlight, the glare just overpowers you, and this is why we can't just simply look directly.

NARRATOR: Because they cannot see what they are searching for, planet hunters must look instead for the very subtle effect a planet's gravity has on the star it orbits. Here, the Hammer Thrower represents a star, like our sun, being pulled at by the gravity of a planet. Every time the planet circles, the star wobbles from side to side. In space, we cannot see the planet, but we can, in theory, detect the influence it has on its parent star. In this scaled-down version of a solar system, we watch as the planet orbits the star. Each time it circles, the star is pulled. Much exaggerated in this demonstration, astronomers must strain to see these subtle shifts. Detecting wobbling stars is the main technique astronomers have for finding planets. It was established earlier this century. But as optics and data collection have improved, so have its chances for success.

GEORGE GATEWOOD: The technique we use here is called astrometry. Basically what we're doing is collecting single frames in a movie. We look at a section of the sky and we, on a particular night, find where each of the stars in that section of the sky are, and we measure the relative positions. Then on a later night, we do the same thing again. We take another measurement of the relative positions of all the stars in this area of the sky. To search for the planet, we then compare all of these frames, as though they were put together in a single movie, to see if the stars motion is linear or if it has that very small, wavy pattern that we're seeking.

NARRATOR: The wobbles these observers are trying to find are minute. Even a giant planet like Jupiter, a thousand times the size of earth, would have a barely discernible effect on a star. It's like trying to see a man waving on the moon. The problem is made even worse by the swirling atmosphere of the earth. It causes starlight to twinkle, and even those tiny variations are enough to obscure the wobbles caused by orbiting planets. Observing stars from space helps eliminate the problem.

FRITZ BENEDICT: Well, we're using a space-based device, the fine guidance sensors on Hubble Space Telescope, to do roughly the same kind of work, looking for the wobbles. If you get up above the earth's atmosphere, the hope is that the signal that the earth's atmosphere impresses on any astronomical research that's done from the ground won't be there, and so, we'll get perhaps slightly better results. Yeah, we're down to a third of a Jupiter for a six hundred-day period.

NARRATOR: Fritz Benedict started using the Hubble Space Telescope three years ago. It's the most expensive telescope ever built, and orbiting high above the atmosphere, it should give him the edge in planet detection.

FRITZ BENEDICT: The problem is you don't get a lot of time with the Hubble Space Telescope. I can't go to a Telescope Time Allocation Committee and say, "I want to look for little green men." But I sure can go to a Telescope Time Allocation Committee and ask to look for planets. And even though the planets that I may find aren't habitable, they would be examples of solar systems, and if they're solar systems like ours, they'll have planets like the earth. The chemistry on the surface of that planet will be the same chemistry as on the surface of our planet. It's a start. It really is a start.

NARRATOR: But Fritz Benedict's efforts are frustrated. The Hubble is much in demand and planet hunting is not its main priority. To date, the Hubble has studied only two stars for signs of wobbles. Because of these time constraints, Fritz Benedict has seen no more success than his counterparts on the ground, despite his unencumbered view.

FRITZ BENEDICT: We say that going above the earth's atmosphere is the best thing in the world, but perhaps the best thing in the world is to be smart enough to figure out how to make these observations from the surface of this planet, because it's the cheapest way to do it.

NARRATOR: Working from the Lick Observatory near San Francisco, astronomers are perfecting another technique less vulnerable to atmospheric distortions. Instead of photographing a star to look for changes in its position, the Lick astronomers measure variations in the color of the star. Changes in color would indicate that the star is in motion, wobbling from the gravitational pull of an orbiting planet.

GEOFF MARCY: When you look up at the stars at night, those white dots actually contain an enormous amount of information, each one of them. The white light can be spread into all of its composite colors, blue through red, much like the sun's light is spread into all of its colors in a rainbow. In the star's light, however, we have additional information due to the fact that the star's light must pass through the star's atmosphere on its journey toward us at the earth.

NARRATOR: Atoms and molecules in a star's atmosphere absorb part of its light before it passes into space. Each time Geoff Marcy observes a star, he splits the star's light into a spectrum. The wavelengths absorbed by the star's atmosphere show up as lines called absorption lines. By recording the absorption lines, Geoff Marcy can create a kind of fingerprint of the light that can be precisely fixed to one location. And if the star is being pulled by an unseen planet, Geoff Marcy will see this image shift from side to side. This technique is called spectroscopy. Precision is essential, for if the star is wobbling, he must be able to detect a shift plus or minus a handful of atoms.

MAN: I think it's going to be about a hundred and fifty to one.

GEOFF MARCY: There's a glorious effect in physics called the Doppler effect. When the star's coming at you, the spectral lines, these absorption features due to atoms and molecules, shift one direction, and when the star's moving away from you, the spectral lines shift in the other direction. We actually measure the radial velocity of the star, the speed with which it's coming at you and away from you, and we measure this radial velocity by watching the amount of Doppler shift. Now, the interesting thing is is that the larger the Doppler shift back and forth, the more massive the planet. A low mass planet can hardly shove the star around at all, and so we hardly see any Doppler shift at all. On the other hand, if the mass of the planet is large, we see a great, large, easily-detectable Doppler shift.

NARRATOR: Given that giant planets like Jupiter would be, in theory, easier to detect, the odds were great that the first planet found would also be immense, and like Jupiter, lifeless. That did not deter Geoff Marcy, for Jupiter-size planets may be the key to finding inhabited worlds like our own.

GEOFF MARCY: Jupiter acts as a sort of cosmic vacuum cleaner. As Jupiter orbits around, it would sweep up the early planetessimals out of which the planets were forming. The comets, the asteroids, would all get gravitationally scattered out or sucked into Jupiter, cleansing the solar system of all of this debris, and the debris, of course, is death for the evolution of organic material, which requires a very quiescent sort of atmosphere and environment. So, it may be that Jupiter itself is a requirement for the development of life.

NARRATOR: Despite improvements in technology, planet hunters remain constrained in their search. In order to find a planet, they must look for a wobbling star. And in order to find a planet like our own, they must look for one much larger. Geoff Marcy had been hunting planets for over ten years. George Gatewood had been running his astrometry project in Pittsburgh for even longer. And Fritz Benedict was using the world's most expensive telescope. All together, they studied more than thirty stars. So precisely how many of these giant planets have they uncovered?

FRITZ BENEDICT: Haven't found any planets yet.

GEORGE GATEWOOD: We've not found any.

GEOFF MARCY: We were shocked at this.

GEORGE GATEWOOD: This is really quite surprising to us, because when we began, we assumed that every star, every single star, probably, had a planetary system, and they must all have Jupiters. Indeed, Jupiter was probably just an average, run-of-the-mill-size large planet. But they don't have them.

GEOFF MARCY: It sent chills up my spine, frankly. And the reason was is that I thought to myself, 'Hey, we haven't found planets of a little more mass than Jupiter. Who's to say that when we begin detecting planets or have the ability to detect planets slightly less massive than Jupiter, who's to say that suddenly we're going to find them?' Perhaps our own Jupiter is itself a rarity, which then may imply that our own solar system has some very rare characteristics, which bodes ill for life in other planetary systems.

NARRATOR: But planet hunters still believe that out of the billions of stars that surround us, ours cannot be the only sun with planets orbiting around it. Although astronomers have not found these planets, they do have evidence of new planetary systems being born. In 1983, a specially-designed space telescope called IRAS was sent into orbit above the earth's atmosphere. Rather than photographing visible light, IRAS took pictures in the infrared, capturing images of the heat generated by distant stars. One startling discovery was a star surrounded by a strange band of solid particles captured in the star's gravity. It is believed the planets in our solar system were formed from the same kind of star dust. More evidence of young planetary systems followed once IRAS showed us where to look. This is beta pictoris, also surrounded by a ring of dust. But it was the Hubble Space Telescope that later gave us the most vivid images of yet-to-be-born planetary systems.

DAVID BLACK: We know that there are stars being formed. We've seen this in ground-based telescopes for many years. We've had it confirmed in a spectacular way recently with the Hubble Telescope. We know that stars are formed in what we call giant molecular clouds. These are immense regions. The average cloud is a thousand to a million times the mass of the sun. But what happens is that some of this material gets together by a process that we, frankly, don't fully understand, becomes unstable to its own gravity and begins to collapse. When it collapses, it has a little bit of rotation. Not much. These clouds would typically take about two hundred million years to go through one revolution. As the collapse proceeds with these clouds, they spin faster and faster, and as they spin, they flatten out into, just like when you make a pizza, it tends to flatten out. And so, we think that that process leads to a disc-like structure. The center ends up making the star, the sun, in our case. And you have a disc out of which the planets get formed. So, this was a natural view, then, that suggested that planetary systems should occur almost every time that a star forms.

NARRATOR: These images, taken by the Hubble Space Telescope, look deep into stellar nurseries. The telescope showed evidence of dust discs around young stars. In fact, these tell-tale smudges were found around more than half the stars observed. If stars shrouded in dust are that common, so, the thinking goes, must be the planets they produce. This new evidence confirmed old beliefs. Astronomers have always imagined a universe full of planets, even though they were never able to find one. Some astronomers, in fact, were so sure that other worlds existed, they skipped the planet search entirely and chose instead to listen for signs of intelligent life. Almost forty years ago, SETI was born—the search for extraterrestrial intelligence. The reasoning behind it was simple: if E.T. did exist, he might be giving us a call. The project started out in 1960. With a single radio telescope, astronomer Frank Drake made the first radio search, scanning the interstellar airwaves for messages from other civilizations. Over the years, the project grew. Steven Spielberg even joined the effort, providing funds to help construct a radio telescope dedicated to finding extraterrestrial life. Eventually, scientists devised ways of listening to thousands of radio frequencies simultaneously. But these advances have yielded only a handful of results, none of which were ever confirmed. No matter how much money or equipment is put into it, SETI has always suffered a major flaw.

DAVID BLACK: Part of the argument with SETI is that the absence of evidence is not evidence of absence. We may be out to lunch when the signal comes.

We may have picked the wrong channel for the observing. There are whole hosts of things in the chain of assumptions that goes through SETI where a no result doesn't necessarily constrain your understanding. The beauty of the planetary detection problem is that a no result does constrain your understanding. If we don't find the signals down to the level of capability of the telescopes, the planets aren't there, the massive planets, or however low the mass would be based on the technique, just don't exist. And that's the significance. A no result from this technique is truly a no result.

DANIEL GOLDIN: We don't even know if in this vast cosmos of ours there is an earth-like planet. We're in 1996, and we still don't know. So, before we even think about people sitting on planets transmitting radio waves, shouldn't we see if there are planets?

NARRATOR: Ironically, it was not a planet hunter at all who was the first astronomer this decade to find evidence of a planet beyond our solar system. Andrew Lyne was listening to the heavens, but not for signs of intelligent life. Lyne's interest was in exotic stars known as pulsars.

ANDREW LYNE: Here we hear the pulses cross as a beam from the rotating pulsar crosses the line of sight to the earth. In this case, it's about once every .714519 seconds. Very precise rotation. This pulsar is a younger one. This is a pulsar in the Vela Supernova. We can still see the remnants of the explosion in which the pulsar was. . .

NARRATOR: Andrew Lyne has found more pulsars than anyone else in the world. These strange astronomical objects are thought to be dead stars, stars that have exploded in a super nova. All that's left behind is a core of material the size of a city spinning up to six hundred times a second. As it spins, the pulsar emits a beam of radio waves that can be detected on earth as regular pulses. It's because of this regularity that pulsars are considered the most accurate clocks in the cosmos, predicable down to the last microsecond.

ANDREW LYNE: But one such object, the pulses were arriving earlier and later by a few milliseconds. The natural interpretation here was that this body was moving by a couple of thousand kilometers, or something like that, and it was doing it periodically. About every six months, it moved away, towards us, and back again.

NARRATOR: Incredibly, Lyne seemed to have stumbled across evidence of a wobbling pulsar being pulled at by a planet. He published his findings in the journal *Nature.* The announcement, however, was just too fantastic for some to believe.

ANDREW LYNE: Not only people's, but our own reaction, was one of great surprise. On the whole, we would not expect planetary bodies to be around pulsars, certainly normal pulsars, because of the violence of their formation.

NARRATOR: In preparation for an upcoming meeting of the American Astronomical Society, Andrew Lyne went back to examine his data to make sure his calculations were correct.

ANDREW LYNE: I was doing some more work trying to find ways in which we might be able to confirm or otherwise the hypothesis that it was a planetary body we were looking at. And for some reason, I had a flash of insight as to what might cause this. Unfortunately, my insight was correct, and I found that when appropriate correction was made, the six-month periodicity disappeared, and of course, so did the planet.

NARRATOR: Lyne had, indeed, found a wobble, but it was the wobble of the earth as it orbits the sun. A computer error had failed to take this into account. When Lyne made the correction, the wobble in the pulsar disappeared.

ANDREW LYNE: I was just completely numb for half an hour, an hour. I just sat there going through everything that I'd said over the last six months to all sorts of people, realizing that it was mostly complete rubbish and that I'd really made a really fundamental error. I had to let them, let everyone know as soon as possible so that they would not dwell on an object which did not exist and would not tax their ingenuity for understanding it.

NARRATOR: Andrew Lyne went to the Astronomical Society meeting. Hundreds of astronomers gathered to hear about the new planet from the man that had beaten them to it.

FRITZ BENEDICT: I was in this room with five hundred astronomers, very excited. Here was a guy who was going to announce the discovery of a planet around a pulsar, and we expected to hear the technical details of that and share in his triumph, because we're all in this game together. And he stood up there and he listed three things that this signal could be, and the last of them was a mistake, and he said, unfortunately, it's the last of those reasons. And I went, "Aaaaah!" And five hundred people in the audience went, "Aaaaah!"

GEOFF MARCY: This poor scientist had to get up there and tell the world that he had been wrong and publicly wrong. And I felt very proud, frankly, to be a member of a group in which, in the end, honesty was the most important thing.

FRITZ BENEDICT: Andrew Lyne's example was a terrific object lesson, that you've got to be absolutely sure. You can make a living at a certain level saying "maybe" for a long time, but if you're going to say "absolutely yes," you'd better be absolutely sure.

NARRATOR: Lyne was received with a standing ovation. Many in the room knew what it was like to have years of work suddenly fall apart. But there was another pulsar watcher prepared to speak that day. But, unlike Andrew Lyne, he had indisputable proof of not just one planet orbiting a pulsar. He had evidence of a whole planetary system.

DR. ALEX WOLSZCZAN: I found it much more challenging, and less relaxing than it would be, simply because a certain atmosphere was set after what Andrew had said, certain climate around the whole story, and I had to break through this.

NARRATOR: There was an important difference between the two claims. Rather than finding a simple wobble, Wolszczan's looked far more complicated and could be explained by the combined effect of three different planets orbiting the pulsar. In the end, it was the relationship among the orbits of these planets that provided the final proof of their existence.

DR. ALEX WOLSZCZAN: Very, very fortunately, the planets sort of meet together once every two hundred days. They get very close to each other and interact gravitationally stronger than in any other situation.

NARRATOR: Each time they met up, the two larger planets pulled on each other, producing minute changes in their orbits. Wolszczan knew he was right about the planets when he was able to predict their gravitational influence on the pulsar.

DR. ALEX WOLSZCZAN: The very nice thing about this is that it's just celestial mechanics. It's Newtonian mechanics, so you can build the model of perturbations, and it has to work exactly. There's really no way out of it. It either does work and it's planets, or it doesn't and it must be something else.

NARRATOR: For the first time in history, a planetary system had been detected elsewhere in the universe—but not everyone was enthusiastic.

GEOFF MARCY: Pulsar planets really don't move me emotionally. The reason, of course, is that ultimately, the big pay-off in this game is to find a harbor for life. And we all know that life can't form around those so-called pulsar planets. The environment is far too harsh with X-rays and radio waves beaming onto the planet. And so, for those reasons, it's almost certainly the case that such a planet doesn't yield the possibility of the real excitement, namely, intelligent life.

DR. ALEX WOLSZCZAN: If we want to be optimistic about it, and I think we have every reason to be optimistic, then the message simply is: There are many more planets to find around all kinds of stars. If you can make planets in such a strange and maybe even hostile environment as the environment of a rotating neutron star, the product of a super nova explosion, a dead star, if you want to use really big and dramatic words, then what's wrong with making planets around such nice and quiet stars like our sun?

NARRATOR: For those in search of planets with conditions conducive to life, the trick is finding the "right" kind of wobbling star. It's a natural tendency to assume that life elsewhere has the same requirements as life on earth—a sun like our own and a planet the same distance from it.

GEOFF MARCY: We select stars that are more or less like the sun, bright enough, close enough to be examined carefully with an optical telescope, and the problem is is that there are literally thousands of stars that are more or less like the sun. Fortunately, they're all catalogued in this world-renowned source of information called the *Bright Star Catalogue,* and so we actually looked through all of the thousands of stars in this catalogue that I've been using now for years. And we selected out those stars which are solar-like. I think since it's clear, we should do the faint stars.

NARRATOR: All planet hunters have their own list of favored stars, one that can focus their observations for years to come. Choosing the right stars to examine can mean the difference between failure and success in the race to find the first habitable world. Geoff Marcy was not the only one measuring color shifts in starlight to look for planets. Over in France, two Swiss astronomers were starting up a search of their own using a similar technique. Their observing list had 140 stars on it, an ambitious number given the potential time commitments required for each observation. But the Swiss team had luck on their side. One of the first stars they chose to observe was in the constellation Pegasus. Called 51 Peg, this star began showing promise just a few months into their search. Their data suggested the star was wobbling, but so frequently, astronomer Didier Queloz was certain he had made a mistake in his calculations.

DIDIER QUELLOZ: In fact, the first reaction that you have at that time is, "Oh, something is wrong with the experiment." You never think about the planets. And you observe it again the day after and the day after, and then it was more and more awful because it was moving every day, and you say, "All right. There is really a big problem with the experiment."

NARRATOR: Month after month, Mayor and Quelloz made the drive from Geneva to the observatory. Each time they looked at the star, they plotted its speed on a graph. And each time they looked, the speed had changed. Every visit to the observatory gave them more data, and eventually, a pattern emerged. When they looked at the graph as a whole, it showed not just one wobble; there were dozens of them. The planet around 51 Peg seemed to be racing around the star every four days. Difficult to believe, but the evidence was there. It didn't take long before Quelloz and Mayor were ready to not just observe, but predict 51 Peg's every move. On the first night, the reading for 51 Peg was exactly what they had expected. The second night, it was the same. By the end of the week, they had all the proof they needed. They decided to break the news at a conference in Florence. The response was overwhelming. Mayor and Quelloz became the first astronomers to discover a planet orbiting a living star, a sun like our own. They had won the race. . . and the press had a field day.

MICHEL MAYOR: In fact, it was completely crazy time with calls from papers, from television, from radio, from all, all the world, and e-mail. A hundred e-mail per day, or something like this. It was absolutely completely time where we had no possibility to work at all.

NARRATOR: Astronomers, however, had trouble fathoming the news, for the planet around 51 Peg was much too large to be in such a close orbit. It defied all expectations about the location of Jupiter-size worlds.

FRITZ BENEDICT: It was in the wrong place, and I was frankly irritated by this result. Many people have worked for many years to come up with a theory that explains planetary systems, and we're kind of stuck, because we've only got one to explain, and that's ours. And here is a discovery that throws it all into a cocked hat, basically. 51 Peg is a counter example to everything I—I don't know if I should use the word "belief," but everything I had accepted up to that point. So, it shakes things up. If it is a planet, it shakes things up.

NARRATOR: One explanation for its close proximity is that the planet around 51 Peg evolved further out and then got dragged in as it mopped up dust surrounding the developing star. When no more dust remained to draw it in, the planet stayed in its close orbit.

GEOFF MARCY: Well, when I first heard about 51 Peg, I thought of at least five or six different ways that the detection of this planet might have been totally wrong.

DIDIER QUELLOZ: It could be a mistake.

GEOFF MARCY: First, maybe the data is bogus.

MICHEL MAYOR: Yes, maybe.

GEOFF MARCY: If the data points are bad—Poof!—the whole thing disappears.

MICHEL MAYOR: In fact, the most—strongest argument against this possibility is the fact that two other groups in the States have observed exactly the same phenomena.

GEOFF MARCY: As a star pulsates, when it gets large, it gets much brighter, and when it gets small, it's much fainter.

DIDIER QUELLOZ: We don't see any variation from the light.

GEOFF MARCY: The star could have alternatively had spots on the surface that rotate around.

DIDIER QUELLOZ: Sunspots.

GEOFF MARCY: That could have mimicked a planet.

MICHEL MAYOR: If we have a star with a huge spot, and you have a rotation, we can observe some apparent change of the velocity of the star.

GEOFF MARCY: Well, the explanation for these velocity variations around 51 Peg can't be due to star spots, because the star rotates around once every thirty days, and yet the velocities come back and forth every four days, so those two periods are not the same.

DIDIER QUELLOZ: You can say that there is a real consensus of saying this is a real low mass object orbiting around the stars. That's the main point of it. Everybody agrees that this is a real object. This is not pulsation or rotation.

GEOFF MARCY: The broad consensus now is that we're left with a planet, probably between a half of a Jupiter mass to two Jupiter masses, orbiting one-twentieth of the earth-sun distance from the star, and there's almost no question that this thing is best described as a planet.

NARRATOR: Geoff Marcy had been confident that he could find planets as immense as the one orbiting 51 Peg. So why had the Swiss team gotten there first? Both teams had used the same technique and had chosen stars from the same directory. But Geoff Marcy had removed 51 Peg from his own observation list.

GEOFF MARCY: And we rejected it from our sample because in this particular 1982 edition, 51 Peg is classified as a G2 sub-giant star, meaning it's an old, evolved star. Old stars begin to puff out and their atmospheres become frothy and gurgly, much like a pot of boiling water, and when an atmosphere is gurgling like that, there are Doppler shifts. The light is suffering Doppler shifts due to these motions, and it obscures the signal from the planet, and therefore we rejected it. We threw it out of the sample.

NARRATOR: As it turns out, 51 Peg had been mis-classified. Later catalogues correctly entered the star as an identical twin of the sun. 51 Peg had been a perfect candidate for a planetary search. The Swiss astronomers' search differed in another vital way. They could get their information faster.

MICHEL MAYOR: The most important difference between Geoff and our own technique is mostly the reduction processes, the way to extract the information of the huge quantity of data we are measuring with the spectrograph.

DIDIER QUELLOZ: We have a black box and with this black box, we compute right after the observation, the speed of the star. Say, ten minutes after. And that's very original compared to Geoff Marcy. And that's a key point, because you—As you have your results, right after the observation, you can interact very rapidly with your data.

NARRATOR: Geoff Marcy had not worried about interacting quickly with his data, because he had been looking for planets like Jupiter that took years, not days, to orbit a star. 51 Peg turned his preconceptions upside down.

GEOFF MARCY: Well, I think the planet around 51 Peg is a great step forward. Certainly, it'll go down in history as the first planet ever found around a normal star. But it doesn't quite hit home for me, because it's not like any of the planets in our own solar system. And so, the question still remains, after all of this: Do we find among other solar-type stars, planets that are like the earth, like our own Jupiter? And that question has not yet been answered.

NARRATOR: Despite his dissatisfaction, the discovery prompted Geoff Marcy to change his own procedures. He went back and took a fresh look at some of his past observations. At the next gathering of the American Astronomical Society, two weeks after the discovery of the planet around 51 Peg, Geoff Marcy was ready to make an announcement of his own. In the world of astronomy, if there's anything to be said, this meeting is the place to say it, and soon the rumors spread among the delegates that something big was indeed about to break.

MAN: OK. Dr. Geoffrey Marcy from San Francisco State University.

GEOFF MARCY: Today, I would like to announce here for the first time, the definitive discovery of two new planets around two other stars. The first is the star 47 Ursa Majoris in the Big Dipper. . .

NARRATOR: After almost ten years of planet hunting, Geoff Marcy found evidence of not one, but two new planets orbiting suns like our own. And finally, one of those planets showed some promise of life.

GEOFF MARCY: And then finally, I'd like to show you another planet that we feel even more strongly about. What's fantastic about this planet is that it is in close enough, but not so close, at this Mercury/Venus distance, that the planet's surface will be warmed up to a temperature that is, well, almost comfortable for all of us, and in fact, here are. . .

GEOFF MARCY: Yeah, well, the really exciting planet, I think, is the one that's around the star 70 Virginis. The planet is about 80 degrees Centigrade, which is about the temperature of warm tea, and it means that water would not be in steam form or ice form, but instead, water would be in liquid form.

NARRATOR: But Geoff Marcy's real hopes were pinned not on the planet around the 70 Virginis, but on the moons he believed would be circling it, moons perhaps as large as Mars, or even the earth. Warmed by their parent star, Marcy believed these moons could have enough mass and atmospheric pressure to contain small bodies of water where the slow crawl of biological evolution could be taking place. This hypothesis was strengthened with recent pictures from the Galileo spacecraft which hint at the possibility of liquid water on two of Jupiter's moons. The frozen surfaces of Ganymede and Europa may conceal deep global oceans and perhaps some form of primitive life.

DAVID BLACK: Well, yeah. I think if you look at the temperature in these giant planets, certainly in some regions, they may be cool enough where you might have liquid water. But, I'm—We need to be very careful about suggesting that that's a place then where you might find signs of life. Certainly, if you look in our own planetary system, where we only know of life with certainty in one place, and that's here on the earth, our prejudice suggests that water's very critical to the existence—the formation of life, in fact. And not just water in any state, but water in the liquid state. So that arguably bounds it between the freezing point and the boiling points of water. That, though, is not enough to guarantee that you might have life.

NARRATOR: But the question of life will remain unresolved until we can observe the planets directly, a breakthrough in technology that NASA is now firmly behind.

DAVID BLACK: Much of the increase, I think, in the interest in the activity you see associated with searching for other planetary systems has come about in no small part because the NASA administrator has expressed a strong interest. I remember one day, I had a conversation with him in his office, and he looked at—He actually pointed to a picture behind his desk, that famous picture from Apollo, Earth Rise. And what struck Dan was that if we can find images like that of other earths around other stars, just as that striking image has, in a way, signaled the fragility of the earth on which we live, finding images, getting images, of similar planets around other stars might convey a sense of hope.

DAVID GOLDIN: Could you imagine if in twenty-five, thirty, or forty years, we could take a picture of a planet that's perhaps fifty light years from earth, and if that planet had—And if the resolution was high enough to measure, to take a picture of oceans and clouds and continents and mountain ranges—breathtaking! Breathtaking!

NARRATOR: This grand vision for a portrait of an alien world may be possible in the future. The more immediate goal is to capture the light of distant planets, a kind of family snapshot of another solar system.

DAVID BLACK: If you think of the challenge of actually being able to detect an image, a planet around a distant star, you're led by the laws of physics to consider something that's large in scale. We're here talking about something that's fifty to a hundred meters in scale, and you immediately think, 'Well, I have one large telescope.' Well, that would be a very tough job. Most people think that doing this with one large telescope would be very hard. So, you're led in then to the notion not of a large telescope, but several small telescopes, which we can put together in what we call an interferometer.

GEORGE GATEWOOD: An interferometer is made of small telescopes with the various apertures spaced apart, so that by looking through this telescope and comparing the image you see through that telescope, you can put together what the image would have been in a large instrument at the same time.

GEOFF MARCY: That's the glory of an interferometer is that it behaves as if the whole telescope were the size of the distance between the two telescopes. With that possibility, we might be able to directly image another planet.

NARRATOR: Testing for such a device has begun in California at the foot of the Palomar Observatory. From these modest beginnings, astronomers hope to develop an interferometer one hundred times more powerful than any ground-based telescope now in use, one less susceptible to atmospheric distortions. NASA also has plans to send an interferometer into space. There is hope that this telescope will be strong enough to capture the dim light of distant planets, and once we can directly image a planet, we can study it for signs of life.

GEOFF MARCY: Well, there is just a glorious prospect if we can actually detect a planet itself, because then we can take the planet's light, shove it through one of our spectrometers and analyze that light for the presence of chemicals, the chemicals of life, such as oxygen, methane, and most importantly, actually, water. The neat thing about detecting methane and oxygen in a planet's atmosphere is that we know that those two chemicals react with each other almost instantly, so if you find both oxygen and methane in a planet's atmosphere, you know that those two chemicals must be in the process of being produced literally every minute, every month, and obviously, one strong possibility for the production of those chemicals is life itself.

VOICE: . . .looks like it's going pretty good.

VOICE: OK. That's great news, Shannon. Thanks.

NARRATOR: Finding chemicals signs of life from outer space is not merely wishful thinking. In fact, it's already been done.

VOICE: The spacecraft is stable. Galileo is on its way to another world. It's quite safe.

NARRATOR: In case there was ever any doubt, the Galileo space probe proved there is life—on earth.

DAVID BLACK: The notion that we can actually look at planets and say something about the existence of life is, of course, a theoretical one, for the most part. But we had a great opportunity with the Galileo space craft on its way as it went out to Jupiter. It was able to swing by the earth and we had the idea of actually doing an experiment using the Galileo sensors to look back at the earth and to try and see whether these signposts, these signals that we think would clearly indicate the presence of life could, in fact, be detected and were clear indicators, and the Galileo experiment was very successful in that regard. You couldn't see highways. You couldn't see the structures that would be the things that most people might associate with life, but the signatures, these molecular signatures in the atmosphere of the planet were very clear and very readily detected. Now, those instruments themselves wouldn't be the ones that would allow us to detect that sort of signature on planets around other stars, but it was the proof of concept that I think was quite dramatic.

NARRATOR: Science has finally broken the barrier between our world and the worlds beyond our sun. Now, we have proof that other planets do exist, and we have hope that soon, we'll discover what life, if any, inhabits them.

GEOFF MARCY: What's happening, in effect, is that a number of technological advances are sweeping by us at amazing speed. Computers are much faster. We need fast computers. Light optics, spectrometers, diffraction gradings, are much better than they were before. Lenses are much better. And finally, our software is slowly but surely progressing, so that we can analyze the data that we collect to find lower and lower mass planets. So, I hope someday they really will be coming out of our ears, or at least euphemistically speaking, but we have a ways to go.

NARRATOR: Since Geoff Marcy's announcement in early 1996, new planets have been found almost every month. And with more powerful telescopes, we may someday gaze upon these worlds—images we can now only imagine in these artist renderings. Alien landscapes that could hold the promise of life.

DANIEL GOLDIN: There's more to life than survival. We all search for our God. We all search for meaning to life, and *if*—*if* we would even have a discovery that there is a habitable planet, let alone life on it, I think it would uplift the human spirit.

DR. ALEX WOLSZCZAN: If we end up finding enough evidence that we are not alone, or if we find a convincing proof that we are, the consequences of that find will be revolutionary. There is no question about it.

GEORGE GATEWOOD: It's a little like the excitement of a hunt. You're looking for something. You haven't found it yet, but you always feel it. Just over the next horizon, it's going to be there. It's not frustration. It's excitement.

GEOFF MARCY: The diversity of planets is much greater than we ever imagined from theory or even from our imaginations. We're going to find a universe filled with different kinds of planets than we ever dreamed.

DANIEL GOLDIN: We are on the threshold of a new age and I think in twenty-five or thirty years, when my grandson has children and those children are in kindergarten, there's a high probability there'll be a picture on the wall of a planet with oceans and continents and mountains and clouds. And those children will look at that picture and then they'll look up at the sky. I think we could do it. We're not afraid.

_______: The evidence is out there. Scientists now know there are other solar systems, and NOVA can show you how to find them in the night sky. Point to NOVA's website at pbs.org.

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