DJORGOVSKI: Let us see what we can learn about those planets or planetary systems. Now all the pictures that I'll show here are artist's impressions. We haven't gotten pictures like this of exosolar planets and will not for a long, long time.

There are many interesting individual cases. The one that was in the news recently was planet was found around the nearest stars to us, Alpha Centauri, which is actually a binary star. So it's the b-component that has at least one planet going around it. So if and when someday we have interstellar travel, this will likely be one of the first destinations to go to.

More recently, there was this five planet system that they've seen eclipses with Kepler satellite, that correspond to not one, but five, planets in a row. And some of them actually are in the habitable zone. There was a very recent case of first earth-like planet, by mass at least, in habitable zone around a red dwarf star.

So what is it that we can do about studying? From radial velocities, you can measure velocities obviously. You measure period because that's the variation. Therefore, you know what the size of the orbit is, what we've got velocity and period. And then from that, you can infer mass using Kepler's laws, especially if you know what kind of star it is. And we have some understanding of solar masses. But also depending on the shape of its regular velocity curve, is it an ellipse. And how tilted it is too, you can also infer something about the shape of the orbit, so measure eccentricities of orbits.

In transits, you obviously can measure planetary radius because it's the square of the radius that matters how much light is obscured, just from the depth of the eclipse. And now if you already have mass and radial velocity measurements, you can infer density. If you know the density, you can start making statements about possible chemical composition, like we know in our solar system the rocky planets might have densities of the order of five grams per cubic centimeter, gaseous giants more like 2 and so on.

And so you can start making some statements then in combination with likely temperature, since you know the radius and distance from a star, and what would be physical state of it. If you know how far the thing is from its parent star, you can infer its temperature, again module video. And there is a very clever trick of measuring composition of the atmosphere. I'll show you in a moment.

But first these basic quantities, the sizes and the masses. And so this is the distribution of the known exoplanets in short period orbits, periods that they're like Mercury. Because planets on larger orbits takes longer time to discover them. And so there is an obvious selection effect and distribution of their masses.

You can see that planet sizes tend to pile up at the low end. This is not a surprising thing because you expect there'll be more smaller planets than big ones. But now we know for sure. Since the selection effect is against finding smaller planets, the bigger planet is easier to detect, the majority of planets in our galaxy are smaller. And the same thing applies about the masses which are on there for comparison of Earth, Jupiter, and Neptune.

Now what about planetary axes and shapes? Well, here there is a very strong bias to find planets on smaller orbits, because this is where you see higher radial loss. This this is where you see more often the eclipses. And so most planets that we now know are these small orbits like within Earth's orbit radius. But we do see some further out, and so there's probably many, many more at larger distances.

One surprise that came out of this is that many of the exosolar planets have very eccentric orbits. Orbits of planets in our solar system are almost circles. They're very slightly eccentric ellipses. And that turns out to be actually something with one exception. And there's been a lot of interesting dynamical studies why this could be and how gravitational interactions with planets and there are planets darkened, migrate planets closer in, and so on.

But if there's been one important upshot of these studies and it's this. And this is the plot of distribution of sizes. And now because you know the geometry and you can assume that on average orientations of orbits the planets will be isotropic. So you can make statistical statement, how many there has to be, in order for us to be able to see them from our direction. That's pretty simple geometry. So you can boost up the numbers using that argument. And when doing that the estimate is that there are more planets than there are stars in the Milky Way by at least a factor of two. And this is lower limit because it's based on the other stuff that we know.

In other words, planets and planetary systems are very, very common. So there are at least 400 or 500 billion planets in the Milky Way, probably many more. Now I mentioned to you they can measure atmospheres of exosolar planets, and that's pretty cool.

Heather Knutson, here at GPS Division, is one of the people working on that. And the idea there is that as the planet is transiting the disc, the planet's star, some of the star light will go through the edge-on atmosphere, and the absorption spectrum will change ever so slightly.

So if you take a really high signal to noise spectrum of the star before or after the eclipse and during the eclipse, and subtract the two with proper scaling to account for the dip in the transit, then you have differential absorption spectrum is due to planet's atmosphere alone.

Now you think this is going to be really hard, and you're right. This has never been possible before, until we had super high precision photometry with Kepler and large telescopes like Keck, to measure the spectrum.

So then, of course, everybody wants to know how many of these hundreds of billions of planets can support life? And so there is a big variety of those. They tend to be little big because that's a selection effect, but as time goes on, we keep finding more and more planets that are in their star's habitable zones. And so, in principle, they could have liquid water on their surface. What they do with that is another story.

And one last thing, a relatively new discovery. And this is where gravitational micronizing really play an important role is that there are planets with no stars.

There are just loose planets floating between stars in interstellar space.

And how do we know that? Well, because they can cause gravitational micronizing events, but their masses are much, much smaller than even brown dwarfs. And so if you can observe them in infrared and so on, you can infer their physical properties. And now there is maybe a few of these now. And so there are planets that's just outside any planetary system.

Now how did they get there? The likely possibility is that they got ejected from their solar systems through dynamical interactions. Just like say Jupiter in our own solar system perturbs orbits of comets and asteroids, occasionally some of them get enough kinetic energy to get kicked out.

Well, in the early days of planetary systems such things could have been more common or if you have a planetary system forming around a binary star, similar things can happen. And it can clear out some of the planets and push them interstellar space. Or they may have been formed independently during the star formation process. They weren't even massive enough to become brown dwarfs, but they've become interstellar Neptune's or something like that.