DJORGOVSKI: Well, then let's move to galaxy formation property, earliest galaxies that we can see. And there is no natural division between galaxy formation and galaxy evolution. But usually we think galaxies have really high redshifts a few percent of the age of the galaxies, and so on. And they form along with large scale structures in which they live. But they have extra complications in form of star formation, dissipation, and so on.

And massive galaxies have done forming by and large. Occasionally, they may have a major merger, but some of the dwarf galaxies maybe just initiating star formation now. So galaxy formation is happening even now, not very much.

All right, so now but nowadays, we are studying this at redshifts greater than about 7, which means the universal was 1/8 of its present size, and earlier, or roughly speaking first billion years of the age of the universe.

So this is what we think happens. Early on, there are no galaxies. There are no stars. There is dark matter. There is some non-uniformities in it. Those grow under their own gravity, attract baryons, the gas. They become dark holes, which then are containers inside of which normal stuff comes in. And then at some point star formation ignites. And the ultraviolet radiation from those young stars ionizes the gas.

Before then, gas is transparent to radio waves and infrared, but not to ultraviolet radiation because it's easily absorbed by hydrogen. After you ionize the hydrogen, it's transparent to UV light too. And that time is called the reionization era.

So this is sort of a cartoon version of it. You start with the big bang. There is microwave background. And there is what we call "Dark Ages." There is nothing, shining light in the universe. Dark holes are slowly assembled, gas into them. Star formation ignites and just removes all the neutral hydrogen. And the universe becomes transparent. And then this is what we observe as galaxy evolution from then on.

So if we want to observe them, the first thing you ask is where does the energy come from? And there are four potential sources of energy for young galaxies. First of all, you're collapsing larger cloud into something smaller, you have to get rid the binding energy. That turns out to be about the order of 10 to the 59 erg for the typical galaxy.

But the real energy is in nuclear burning stars, an order of magnitude more, so integrated, or however it want to, star formation, it could be 10 to the 60th erg for a typical galaxy.

Now it's probably coincidence that the amount of binding energy that was released in converting interstellar clouds into stars is about the same as it took to assemble the galaxy, about 10 to 59 erg.

And then if you have active nucleus, quasar, black hole, that can do anything for nothing all the way to about 10 to the 60, 61 erg, depending how luminous it gets. So there's plenty of energy.

Some of the energy then ionizes the gas, just like star forming regions like Orion Nebula, and the gas emits in fluorescent lines, the combination lines, hydrogen, oxygen, what have you. And by far the strongest of those would be Lyman alpha line, the first transition of neutral hydrogen, level 2 to level 1.

So that was seen as the primary tracer way to find star-forming galaxy of redshifts. Because high red shifts-- that means it's been now red shifted into the visible part of the spectrum. And so you can observe it with normal telescopes on the ground. And you're expected to be pretty strong.

So there are two ways in which that was done. One is you take spectra of the sky, occasionally you run into one of those things, like that line you just see the emission lines, the emission line and nothing else.

Another way to look at them is to take pictures in narrow band filter that's centered on that line and compare that with broader image. So that's how it looks like. So this is field of some quasar. And the top image on the right is just regular broadband red filter. The one underneath is picture taking in a narrow band filter that corresponds exactly to Lyman alpha line. You can see everything else is suppressed. But this one galaxy really stands out. And that turns out to be emitting companion of that quasar of that same redshift.

Both of those have been used extensively, mostly this kind of narrow band imaging. This is one of the most distant-- it may be still be the most distant confirmed galaxy with the spectrum, so a redshift of 7. This was done by a Japanese group and a Subaru telescope.

You can see the pictures. There are two filters. There's nothing between those bars. And then you take a narrow band image and boom, there is a galaxy shining at the emission line.

Another method, which is now even more popular, is so-called Lyman-Break method. And that was first really done effectively by Chuck Steidel here. And it works like this. You have young stars, There is interstellar medium, inter host galaxy, some neutral hydrogen. That hydrogen is going to absorb very effectively all the light blue or the Lyman continuum break at 912 angstroms.

If you look far enough, there'll be even plenty of Lyman alpha forest lines to take out everything blue or the Lyman alpha line.

Now spectra of star-forming galaxies tend to be kind of flat. And then you are looking for object that have flat spectrum in red and then sudden drop in blue, which is due to this absorption by the gas. And the example is shown there. This galaxy looks more or less the same in three field visibility or visual infrared. And it's completely gone in the ultra violet. So this turns out to be a very efficient way of finding distant galaxies, which is now being pushed through the high stretches that people actually can do.

These are examples of some candidates for galaxy on red shift 8, 9, 10, 11, from Richard Ellis's work. And you can see that starting from the left, there's nothing. And then suddenly something shows up. And that's interpreted as one of those Lyman breaks. And that gives you the approximate red shift.

This is not certain. We'll only know after we get the real spectra with the 30 meter telescope. But it's not crazy idea. So this is what we can do today.

And so this is the kind of observation that was then averaged to ask the question, what happens with star formation history with at the highest red shifts we can probe, deepest images with Hubble and that's those points to the right.

So there's some uncertainty in those models, but the qualitative behavior is more or less what you expect.