DJORGOVSKI: And the first concept to cover here is the so-called HR diagram, which stands for Hertzsprung-Russell diagram. This is why everybody calls it HR. And it is the main arena in which we study stellar evolution and stellar models.

But before we get to that, you may recall that stars have different spectral types. And they were originally classified without anybody knowing what was behind it, before atomic physics was really well developed. But they can be sorted in the order of how different spectroscopic lines appear. And now we know that those are a sequence of photospheric temperatures, with so-called O-stars being the hottest and M-stars being the coolest. And if you look at this, you can read this, you can recognize some of the famous lines. But as the cooler you go, the more lines start to show up. And that's just because those molecules or ions are excited by those wavelengths.

The hydrogen lines, which you can recognize near the top, the alpha on the right and beta, gamma, delta, and so on disappear by the time you get to cooler stars because there isn't enough energy to pump those energy levels up of hydrogen. So now we know how to interpret this. And stellar temperature is obviously an interesting variable.

So way back when, these two astronomers Hertzsprung and Russell, after luminosities of some stars were measured by measuring their distances, discovered that if you plot spectroscopic class, properly sorted, which really is a measure of temperature, versus the luminosity or absolute magnitude, stars don't fill up that space randomly. They line up on a couple different quasi-linear sequences. And most of them sit on so-called main sequence. Then there are giants, which are so-called because they are extra bright, super giants even more so, and there are dwarf stars or white dwarfs which are much dimmer. So this turned out to be a really powerful tool to try to understand stellar structure and evolution.

And there are different sequences here. Now we know what they are. They're actually due to a different type of energy generation in a stellar core. The main sequence, which is where most stars spend most of their lives, has then turned off-- those are stars that they're now evolving off to become red giants. Then giants can evolve off to the horizontal branch, and it can come back to asymptotic giant branch, and so on.

So here we have the similar plot expressed now in a slightly different way. Now one thing you need to keep in mind is that this correlates absolute luminosities with temperatures. Neither one of these two is directly measured. Absolute luminosity is something we have to derive after we measure flux of some magnitude and have a model of stellar atmosphere. Temperature is also something you can derive from spectroscopy or from photometry.

And generally speaking, nowadays we use colors as a measure of stellar temperatures. Colors are quantitatively defined as the difference of magnitudes in two different filters. Because magnitudes are logarithmic measure of flux, that actually means it's a log of the ratio of the two fluxes. And so bluer stars will have higher blue to red ratio, and vice versa. So for example, B and V are two commonly used filters in photometry, visible light corresponding to blue in visible light. And they can be used as an excellent proxy for stellar temperature.

Absolute magnitude is the most directly determined measure of luminosity if you know the distance. This particular HR diagram is for all stars for which parallaxes were measured by the Argos satellite, which is pretty much all the stars with measured parallaxes today, until Gaia starts producing results. So there is an important catch here, that if you want to compare these measured quantities with theoretical models-- theoretical models give you temperature and luminosity. Those are not measured quantities, so you have to do some interpretation. And I think we know how to do this.

Now stars of different mass are in different places along main sequence. And each of them has a particular type of track along which it moves as it evolves. Where they end up, it forms in one of these low sides like horizontal branch, or what have you.