DJORGOVSKI: I have to introduce the concept of magnitudes. Now, first let's talk about rational things, like fluxes. So you have a source of radiation, like thermal black body or synchrotron or whatever, and it's going to-- flux is a function of frequency. And if you integrate over all frequencies or all wavelengths, you get total luminosity.

Now, that's what usually you measure-- how much flux to get at the given frequency or wavelength. Whether it's radio or optical, it doesn't matter. And radio astronomers have introduced unit of jansky in honor of the first radio astronomer. And it's given here.

So the first radio sources were measuring kilojanskys. Now, people are talking about microjanskys or even nanojanskys. So technology marches forward.

So this is flux density-- specific flux per unit frequency, or sometimes, per unit wavelength. And to get the total power, you have to integrate over a spectrum. But usually, you don't integrate over the entire spectrum, because you can't observe from 0 wavelength to infinite wavelength. There's always some finite bandwidth over which you do that. Invisible light, that's different filters. In radio, there is, again, bandwidth, and so on.

Now, we come to magnitudes. Sometimes, I say that magnitudes are invented by astronomers to keep physicists out of the field because they're so utterly irrational. But their historical reason for them is ancient Greeks, being scientifically minded, quantified the brightness of stars. And they decided that, with the naked eye, good vision, dark site, like a Greek island or something, not too much wine, you can distinguish six different levels of brightness among the visible stars. And the very bright as they called 0 magnitude, or first magnitude. And the faintest were sixth.

Now, it turns out the human eye is not a linear factor. It's actually a logarithmic detector. And the steps of one magnitude correspond not to a linear shift by a certain amount, but by a multiplicative shift. And one magnitude corresponds to roughly 2.5. It corresponds precisely to 10 to the 0.4 power. This was quantified in the 19th century.

So another way to look at it, if you are minded like an engineer, a magnitude is minus 4 decibels. It's 10 to the minus 0.4 power. So it's a logarithmic scale. And that means there is a 0 point. And that 0 point is where things get really weird, because in principle, it can be anything you want.

So before we can actually do absolute calibrations of things, it was just decided as a convention that Vega, which is one of the brightest stars in the sky, will have a magnitude of 0 regardless of which filter you use. Now, the spectrum of Vega is not flat-- not at all. But that was the convention.

So the 0 point varies with wavelength. But to make life even harder, some other people introduced different 0 points. But let's not even go there.

But at any rate, what happens is when you have a detector, like CCD and taking a picture through a given filter, like a B or blue or something, you're integrating flux over a certain wavelength regime. And that total amount-- take the log of that, multiply by minus 2.5, and add the 0 point, and you go to magnitude.

So it's upside down logarithmic scale with a weird unit and even weirder 0 point. But a handy way to get some idea is that for visible magnitudes for Vega, 0 magnitude is roughly 1,000 photons per second per square centimeter. And if you like janskys, it's about 3,500 janskys. All these things are tabulated in the proper places, so if you actually ever need to do it, you can look it up.

So how do we use this? Since this is a logarithmic measure-- it has to do with the ratios of fluxes expressed as a logarithm-- it tells you how much is one thing brighter than the other. And because there is that minus 2.5 log 10, that means that a factor of 100, which is two orders of magnitude, would be five magnitudes. So don't confuse it with orders of magnitude. Astronomical magnitude is 0.4 orders of magnitude, right? And it goes upside down. So the higher magnitude means fainter objects.

Now, the sun is the brightest source in our sky and as an apparent magnitude of minus 26 and change. That means it's really, really bright. And the very faintest things that we can observe, like the Hubble Space Telescope, are 28, 29 magnitude. You can figure out how many orders of magnitude that is. It would be a good thing to work out, say, during section.

OK. Now, let's make life a little more complicated and introduce the absolute magnitude, which is now a measure of luminosity, not flux. Magnitude is measurement of flux. It doesn't tell you how far something is. It's just how bright it appears to you.

But you'd really like to know how luminous things are, so therefore, you need to know how far they are. You'll used the Stefan-Boltzmann formula and all that. But before we could actually calibrate any of that, people figured out, well, we can use magnitude, so we can introduce the concept of the absolute magnitude. And absolute magnitude is an apparent magnitude your source would have if you put it 10 parsecs away.

Why 10 and not 1 is anybody's guess. It just makes life more complicated. So the formula is given here. Obviously, you have to be proportional. But then, there is 5 times log of the distance. Why that? Because it's the square of the distance that matters in the square law. And it's minus 2.5 times 2, so it's minus 5 log of the distance. And then there's this plus 5 offset to account for the silly 10 parsec 0 point.

Be that as it may, the conversion is given here. If you put our sun-- star-- just like sun, 10 parsecs away. It will have apparent magnitude around plus 5. So a pretty dim star, but still visible with the naked eye.

So Vega, which is 0 magnitude-- I forget how far the Vega is, but it's not very different from 10 parsecs. So roughly speaking, how much more luminous is Vega than our sun? Anybody has a guess? Think about it for one minute.

And now, we can express the distance as a function of absolute and apparent magnitude. Why do we do such a silly thing? Because you can calibrate for certain types of objects what are their absolute magnitudes? Say, stars of a given type--

because of their color or spectrum, somehow you know that that kind of star we have established is 365 65 times the luminosity of the sun or whatever.

And so by measuring their apparent magnitudes, you can infer from the known or absolute magnitude how far something is in crazy units of 10 parsecs. And that difference is called distance modules. Sometimes, you encounter that.

So ideally, you'd like to know absolute luminosities, as in solo luminosities or [INAUDIBLE] per second or whatever and distances in parsecs or centimeters. But instead of that, we use these somewhat strange units.