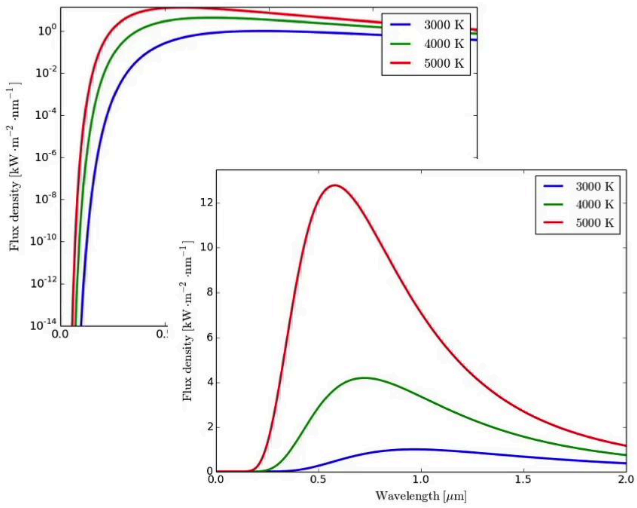
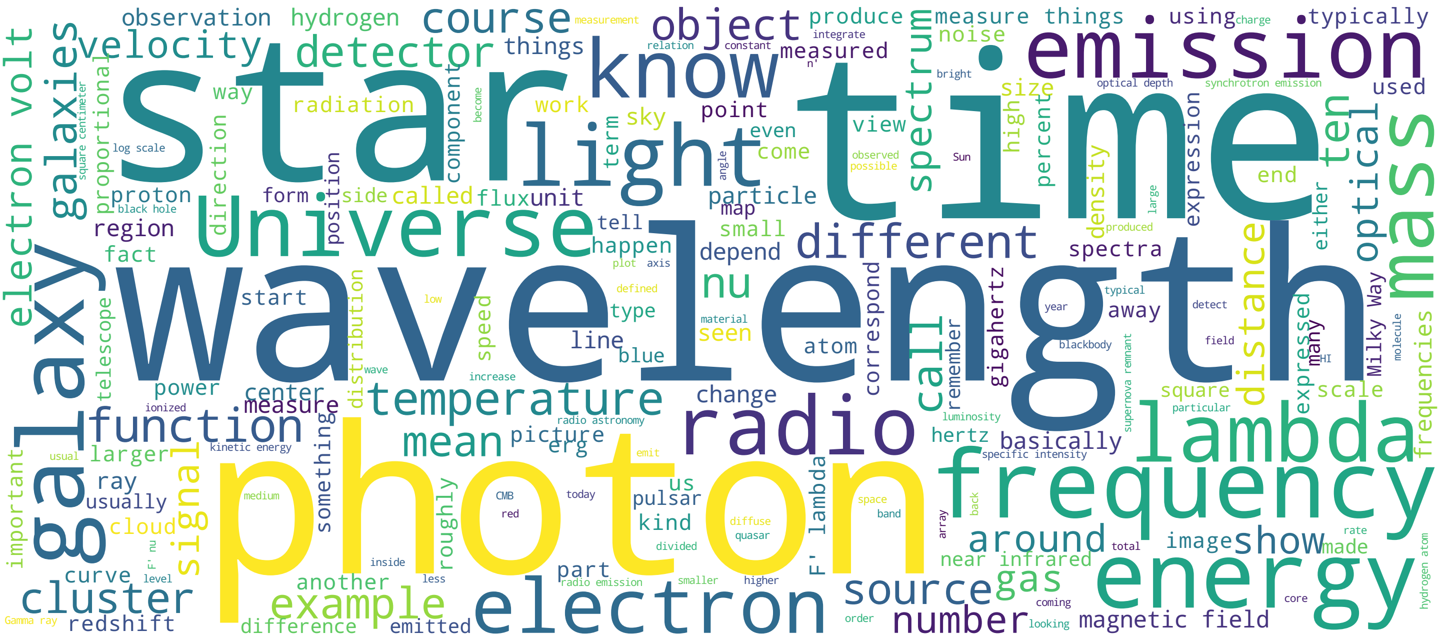
Spectra in different units

The Universe At Radio Wavelengths

Frédéric Courbin



Black body spectra seen on different scales



Search MOOC

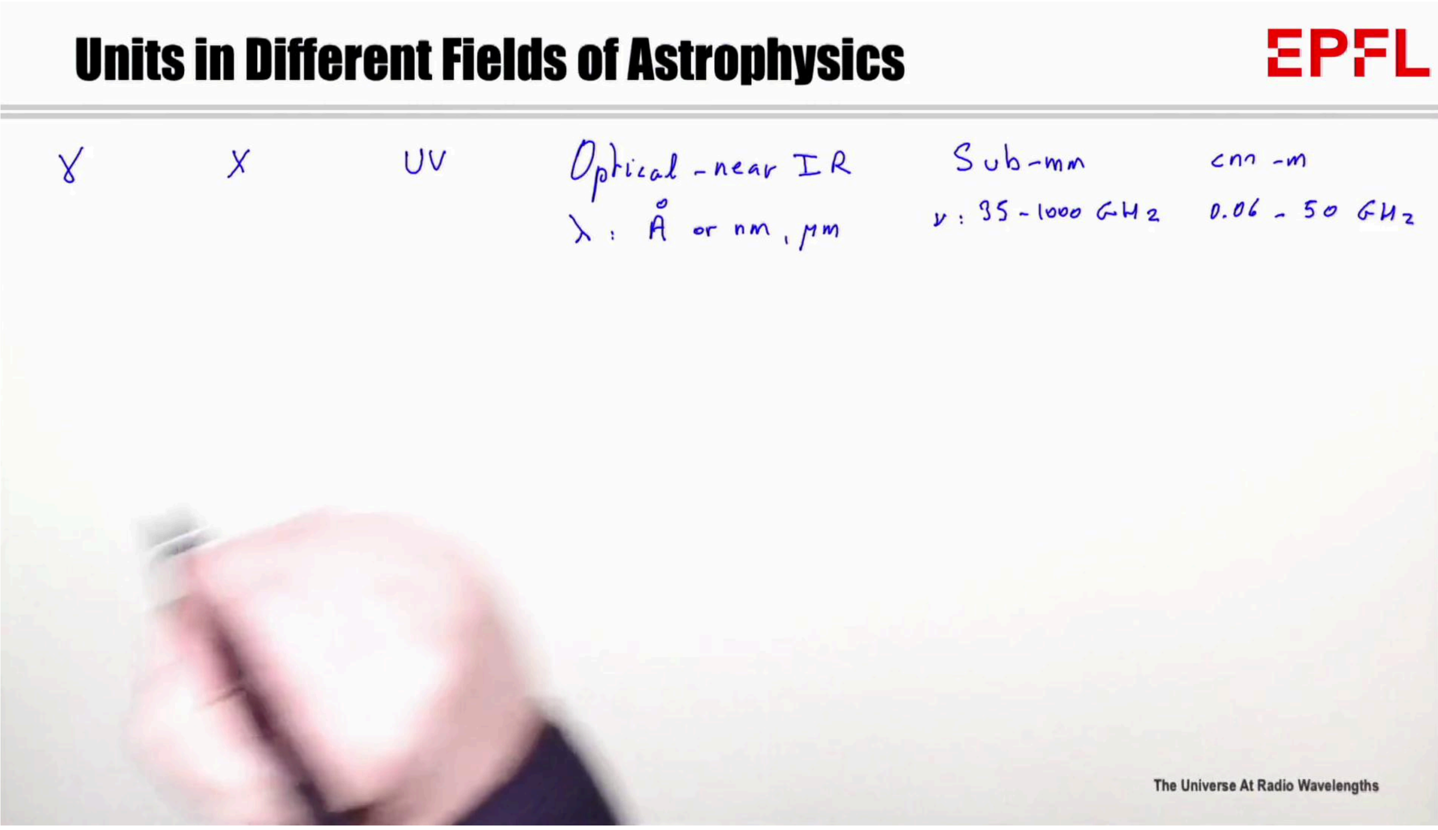
Video

In this video, we will show how we measure photon fluxes in astronomical observations so, in particular in the radio, of course, but also in the optical and near-infrared domain and all the way down to X-ray or to the more energetic Gamma rays. We'll also show how spectra, for example, so spectra are one of the main data type in astrophysics so we'll show how this spectra look different when expressed in different units or even in different scales.

Notes

Summary

0m 05s

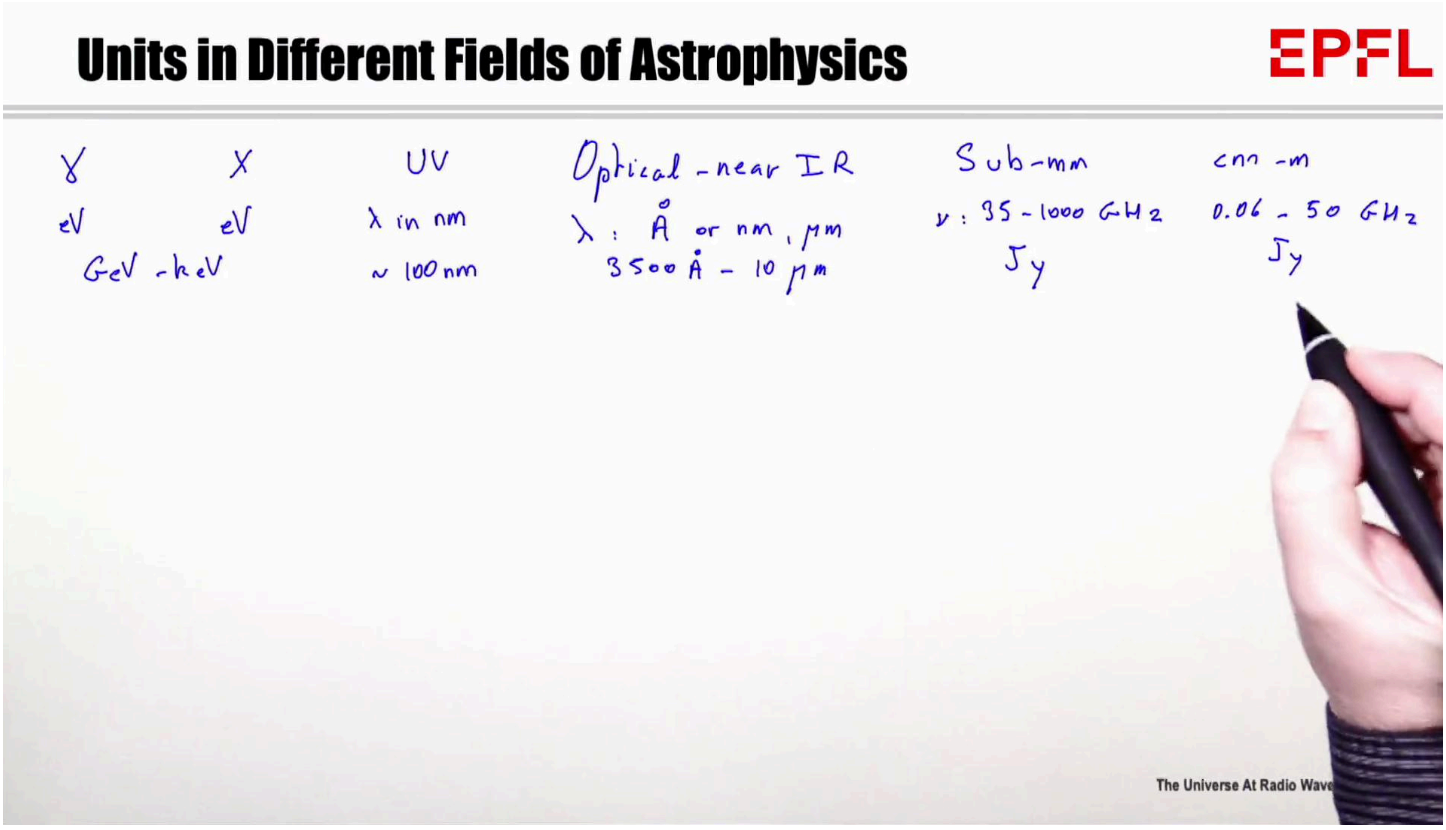


So first different units in different domains of astronomy of astrophysics. So we are used to the optical and near-infrared domains. That's where traditional telescopes operate. So here things are measured in wavelength and the units used are usually angstrom or sometimes nanometers and that's when people go more in the UV part of the spectrum or microns when infrared wavelengths are used. Now in this mooc we speak about radio astronomy and that's in the sub-millimeter or millimeter astronomy or we go to longer wavelength with centimeters or wavelength of the order of the meter. And in this case we speak in frequency so in the sub-millimeter domain or millimeter domain we go typically from 35 to 1000 gigahertz and in the centimeter domain we also measure things in frequencies. Radio astronomers measure things in frequencies and we go from 0.06 to 50 gigahertz depending, of course, on the different specific telescopes or arrays of telescopes. Now on the other side of the spectrum we, of course, observe in the UV or in the X-ray or in the Gamma rays.

Notes

Summary

0m 35s

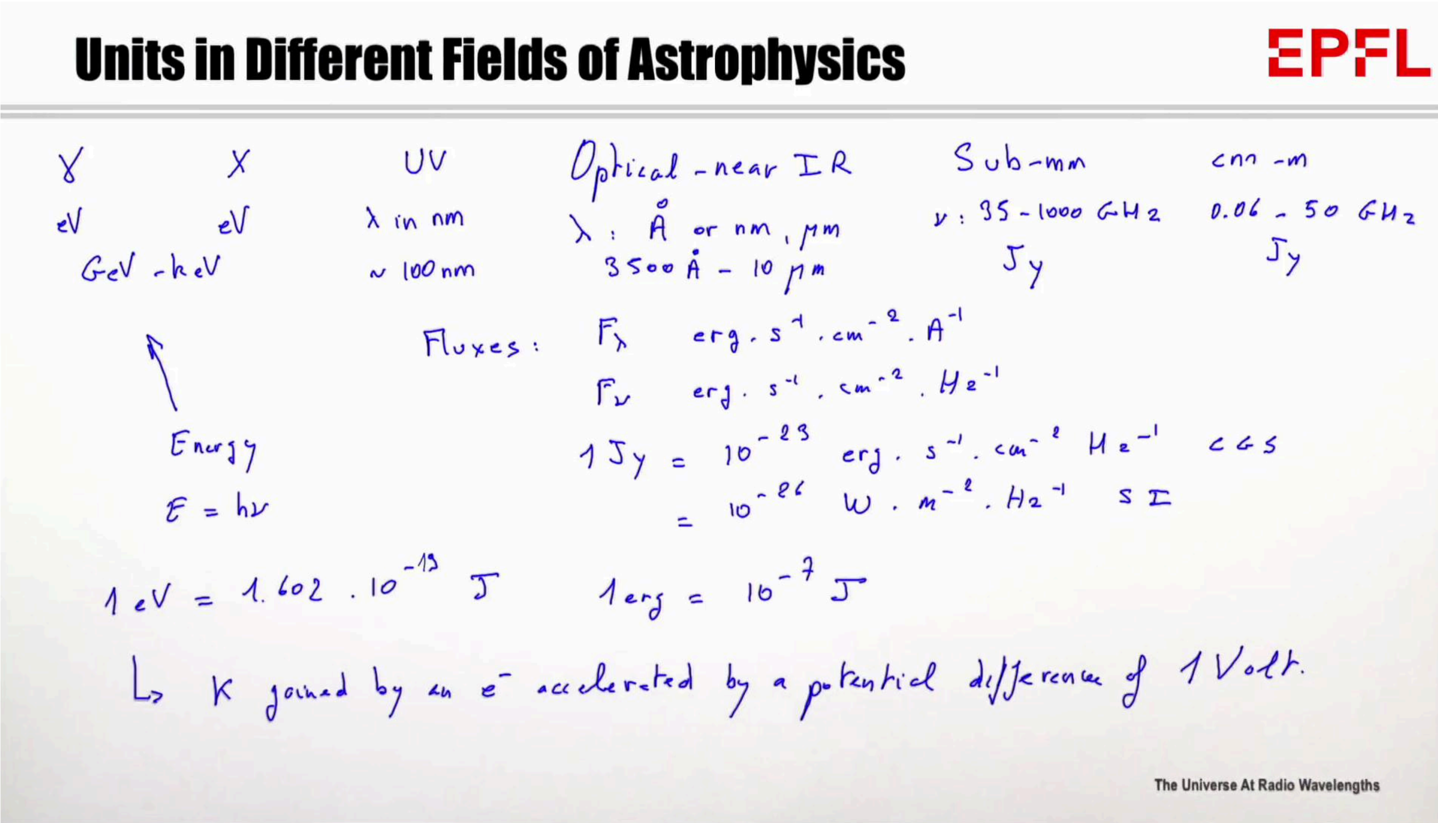


Now in the UV, as I was saying, things are still measured in wavelength usually in nanometers wavelengths are shorter than optical and infrared, photons carry more energy and the X-ray and Gamma rays so since this was developed more by particle physicists at the beginning and these measure things in energies so in electron volts. So electron volts are the kinetic energy gained by an electron accelerated by a potential well by a potential difference of one volt. So that's one electron volt so typical units, typical orders of magnitude here are 100 nanometers and here we speak usually of giga-electron volts or kilo-electron volts so that's high energy astrophysics, UV astrophysics, optical near-infrared and that's the domain the radio domain that's the domain of this course. So here we go from typically 3500 angstrom so below that there is an atmospheric cutoff so all these wavelengths are better observed or observed at all from space and then we go typically to ten micron. Now units are, okay here energy units giga-electron volts, kilo-electron volts, wavelength for the UV, wavelength again for the optical and near-infrared and here when we measure so we measure things in frequencies and fluxes will be measured in the strange units, unit called jansky.

Notes

Summary

2m 13s



So that's, you know, wavelength units, energy units and that's flux units used in the radio. Now fluxes. So that's the energy collected by the detector when you observe an astronomical object and that can be measured as a function of wavelength so 'F' lambda or as a function of frequency and that's then 'F' nu. So in this case we measure things in ergs per second per square centimeter per angstrom or we can measure things in erg per second per square centimeter per hertz. Now flux units in radio astronomy are usually janskys from the name of Karl Jansky, a famous radio astronomer and when jansky is ten to the minus 23 erg per second per square centimeter per hertz. That's in the CGS system or it's also ten to the minus 26 watts per square meter per hertz and that's in the SI system. And then we also spoke of, you know, energy so in this case we measure things as energies, you know, the energy carried by photons is 'h' nu as usual and one electron volt here is 1.602 ten to the minus nine joule and also one erg is ten to the minus seven joule and one electron volt is the kinetic energy gained by an electron accelerated by a potential difference of one volt.

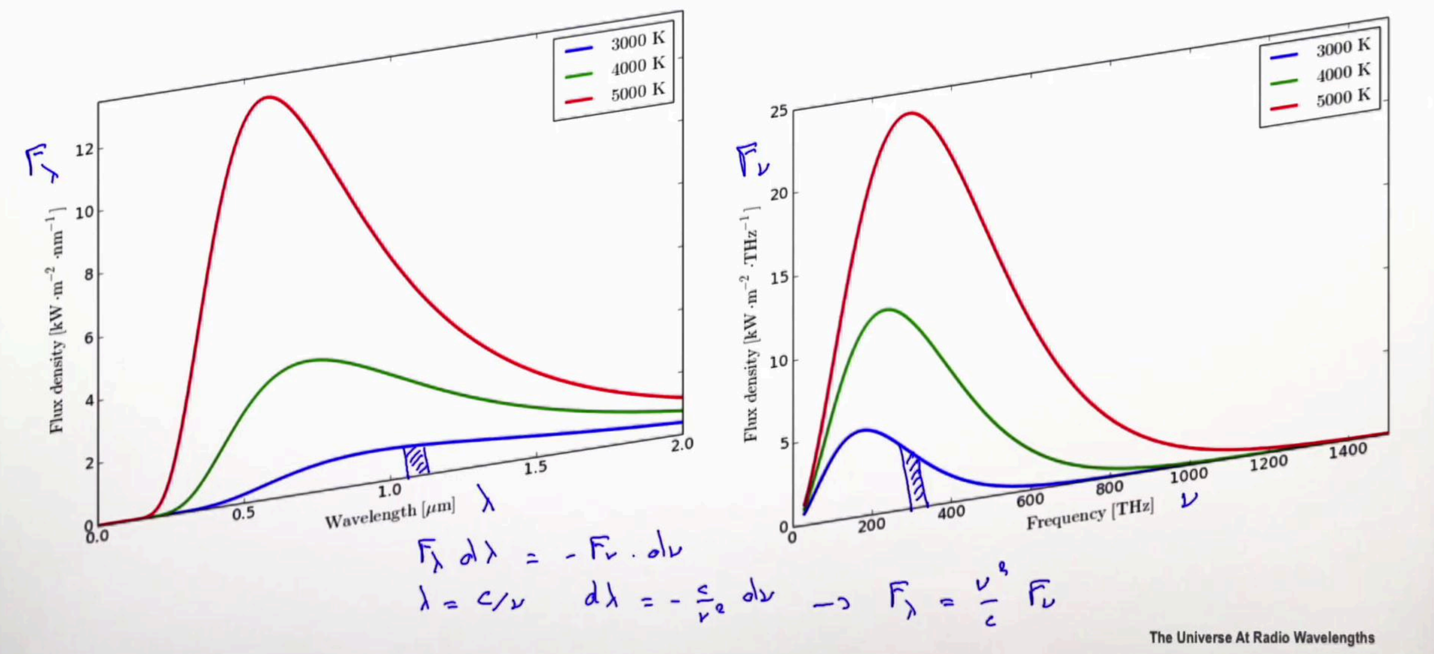
Notes

Summary

4m 02s

How Do Spectra Look Like in Different Scales

EPFL

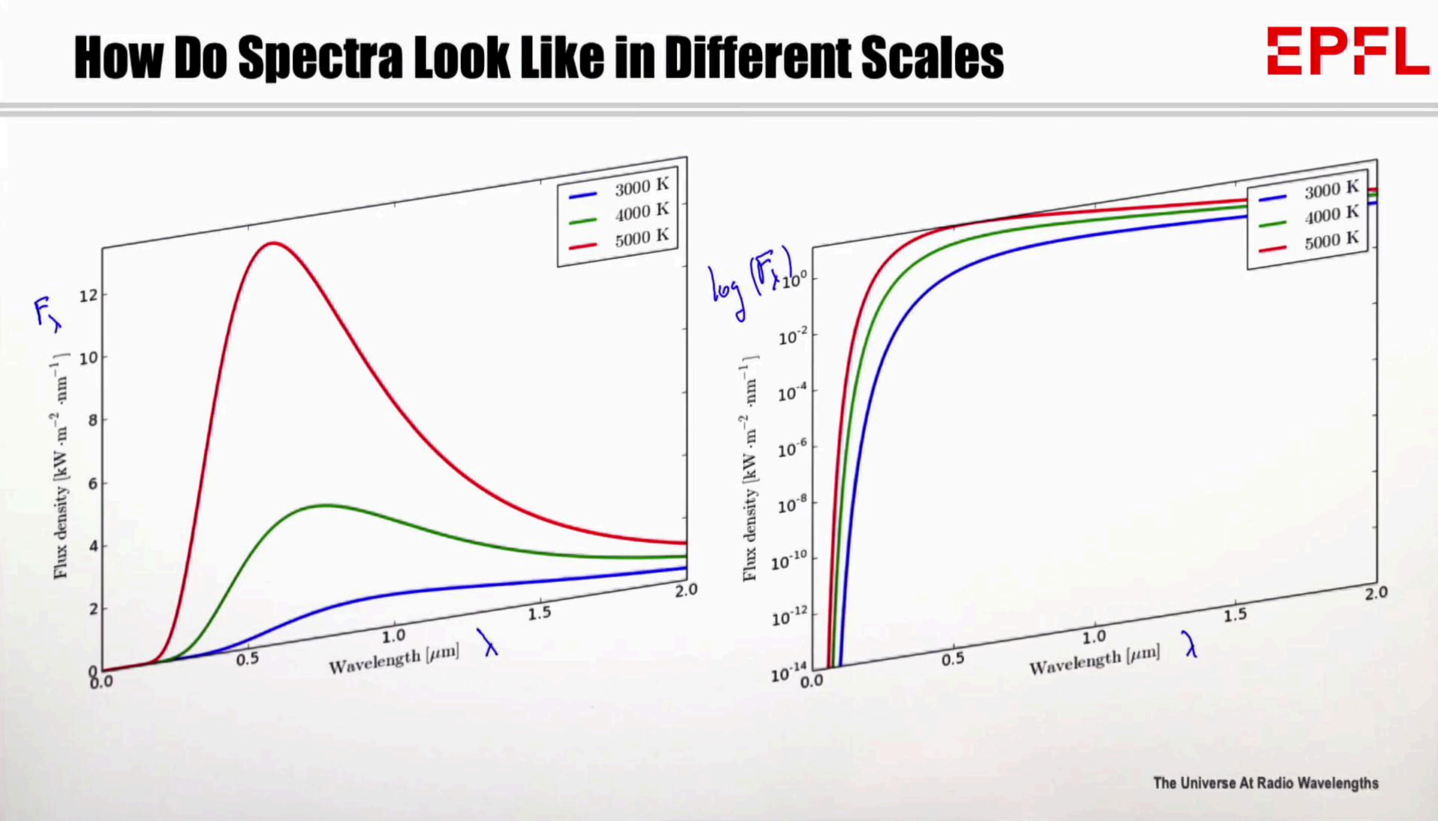


So here are concrete examples of spectra. So here we take the example of a simple blackbody curve. So you have here three blackbodies of different temperatures so you have now Wien's law giving you the position in wavelength or in frequencies of the maximum of the curve and here we show the spectrum as 'F' lambda as a function of wavelength and here we show the same thing but now in units of ‘F’ nu and as a function of nu frequency. Now you notice two things. First, you know, the position of the maximum goes to longer wavelength where the temperature of the blackbody decrease and frequency is the opposite because the two scales are opposite. Now what is common to the two scales is that and if you take some energy in some band here and some energy in the corresponding band in the different in the other scale then the relation you should have is that 'F’ lambda ‘d’ lambda equal minus ‘F’ nu ‘d’ nu. And this is simply because lambda equal 'C' divided by nu and then, of course, ‘d’ lambda equal minus ‘C’ over nu squared 'd' nu. And then you replace 'd' lambda and 'd' nu in the above formula and then you end up with the following expression for the flux expressed in lambda and with its relation to the flux expressed in frequency.

Notes

Summary

6m 27s

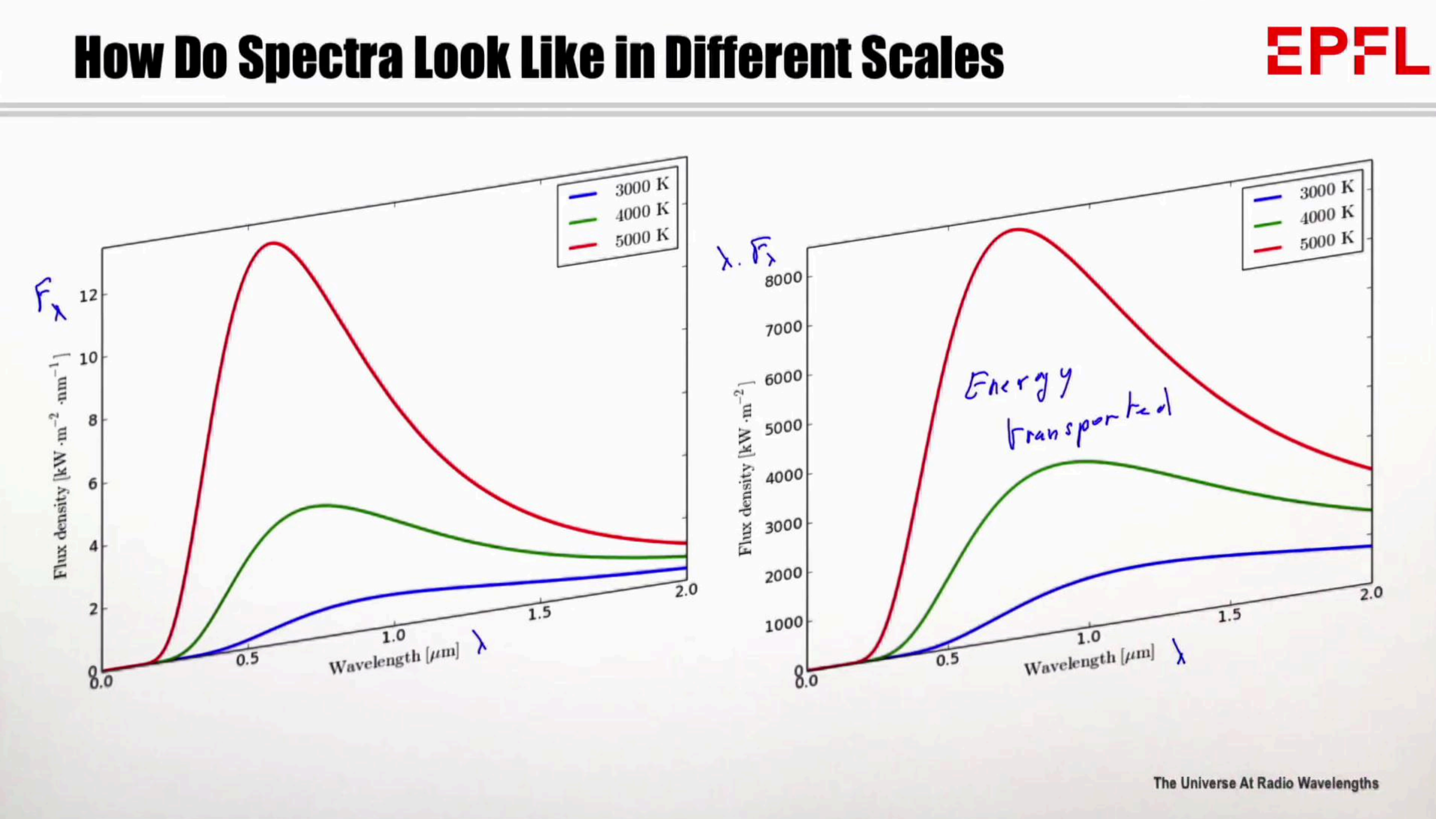


So if you integrate some flux here and some flux here you should get the same energy, of course. And then you have a minus sign here because wavelength go in opposite direction as as frequency so when you integrate here and here you should have a positive number in the two cases. Now, of course, implications on how the spectra look like is not to replace 'F' lambda the 'F' nu here, you just you cannot just, you know, replace lambda by nu. You have to multiply your data by this factor so one curve will be stretched or squeezed with respect to the other. Now another example of how to display things. So now we go back to the blackbody spectra expressed in ‘F’ lambda as a function of lambda and now we just take the log scale. You know it's a very simple thing. Log ‘F’ lambda and things are very much expressed like this just because, you know, there is so much space between the peaks here of the blackbody that you want to to into squeeze a bit these things to show better the differences in the wings of the blackbody so that's now a different way of showing the exact same thing. Here the curves look very different on a linear scale. In log scale, of course, things are more look alike.

Notes

Summary

8m 25s



So we just showed the spectrum in 'F' lambda but if we do this now in ‘F’ nu that's again the blackbody spectrum expressed as 'F' nu as a function of nu and now take the log scale of this and you will see that again in appearance you have changed a lot the spectra. Now you see better much better what happens, you know, at high frequencies and things at low frequencies are kind of squeezed. So as the video says don't be fooled by scales and units. You know, be aware that really the axis as usual in science, in fact, have huge importance. Now last thing. Now these things are not the only way, of course, to show data but they're quite common ways so you can show, for example, flux in 'F' lambda as a function of lambda. That's the thing we have seen now several times but you can also show things in terms of lambda 'F' lambda. So now see the unit here, you know, the lambda unit has disappeared the angstrom of the nanometer minus one has disappeared just because now what you show here with respect to this is the quantity of energy transported by photons as a function of wavelength.

Notes

Summary

9m 44s