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Spectral Lines (part 2)

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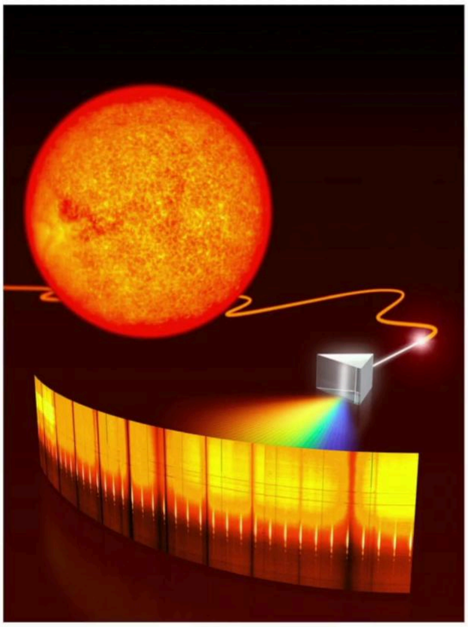

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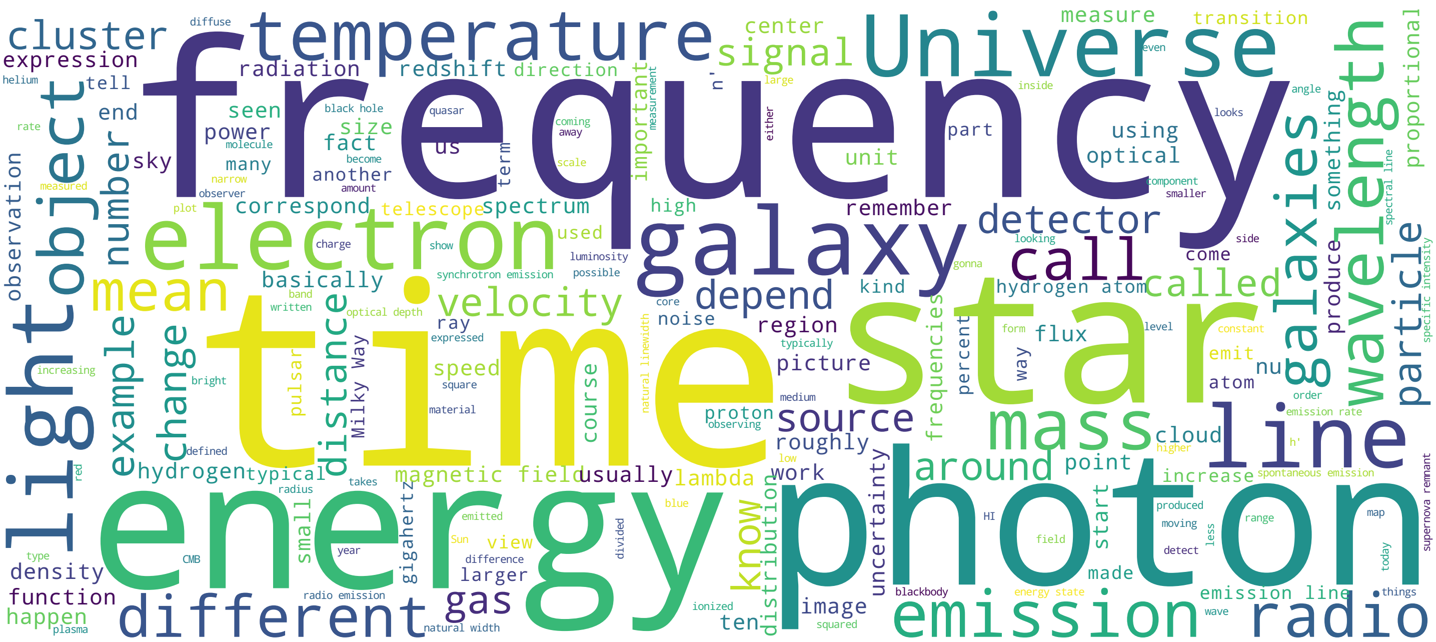

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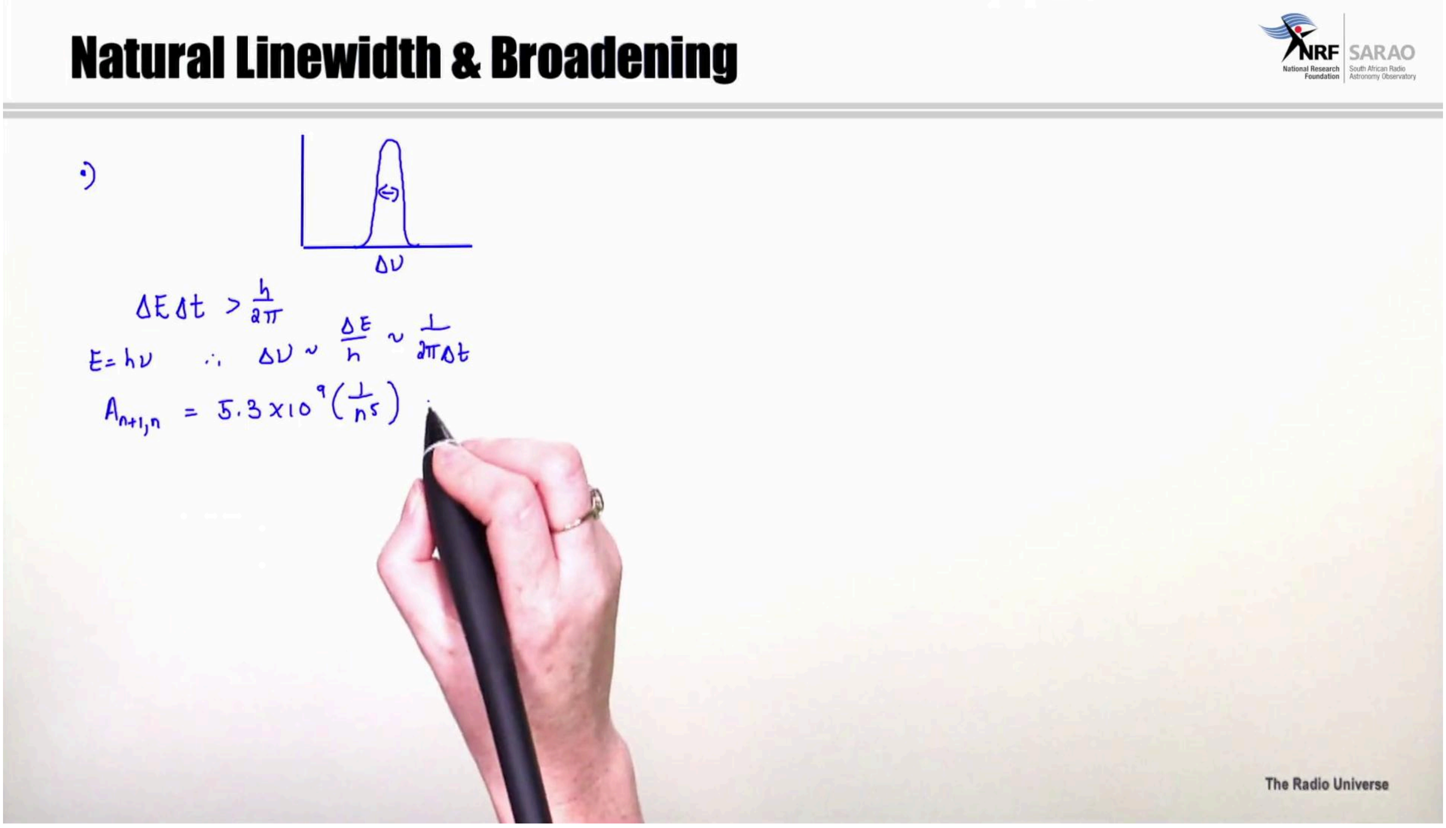
A spectral line isn't just a delta function at one specific frequency. It has some natural width and today's lecture will focus on understanding why that natural width occurs and how changes from that natural width can help us to probe information about the thermal motions of the gas that are producing the line.

Notes

Summary

0m 05s

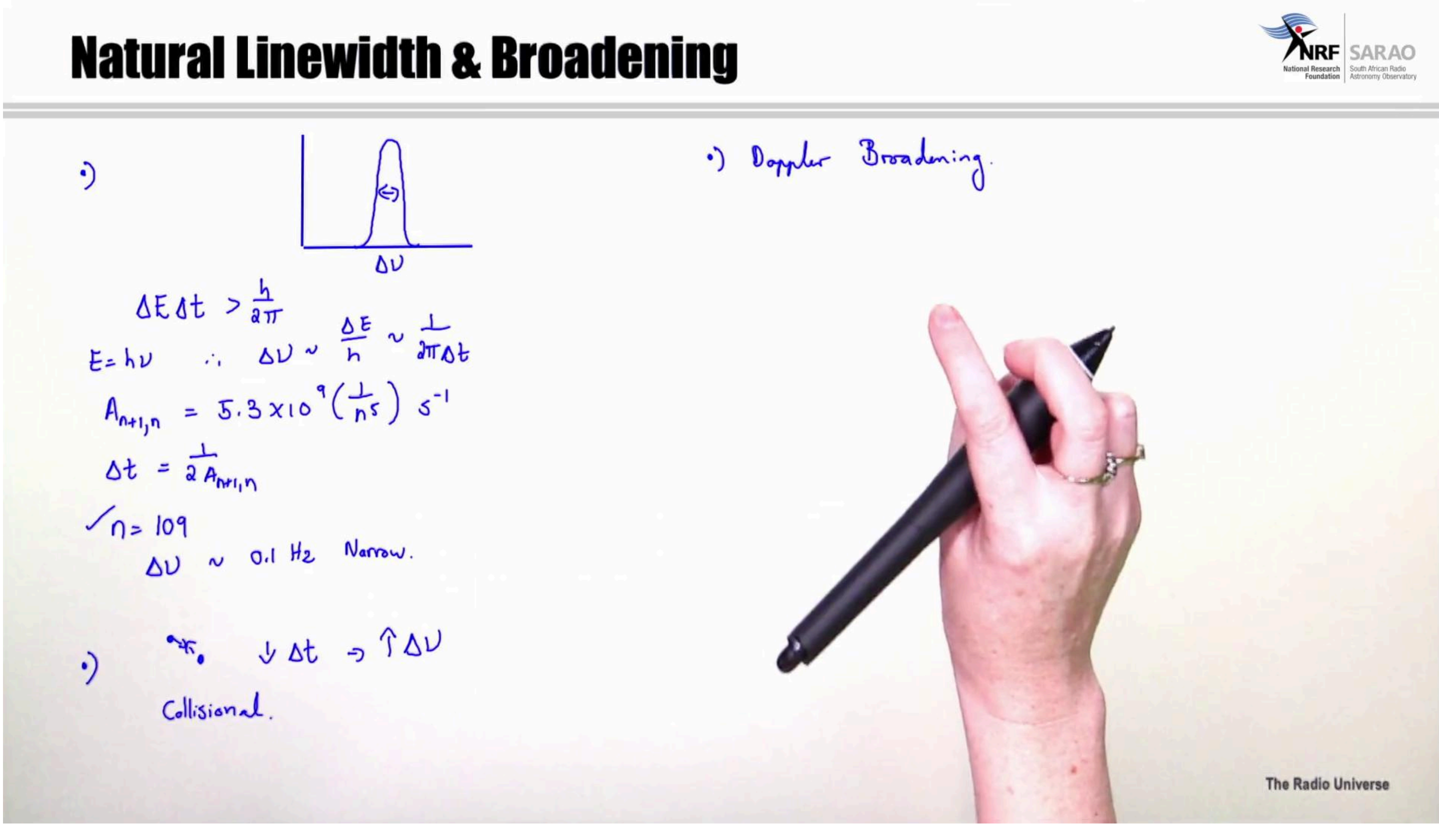


All spectral lines have some natural linewidth. So the line that they emit will have some natural width in frequency space and this natural linewidth is related to how what the rate of spontaneous emission is at this frequency so how likely it is that this transition will happen. Because of the uncertainty principle, there is there is a lower bound on how accurately you can know the energy and the time it takes for the transition to happen. So the uncertainty principle says that the uncertainty in the energy times the uncertainty in time must be greater than 'h' over two pi. And given that energy is equal to 'h' times nu what that tells you is that delta the uncertainty in the frequency or the width in the frequency is got to be equal to delta 'E' over 'h' which is then roughly equal to one over two pi times the uncertainty in the time it will take for this transition to happen. So the spontaneous emission rate is usually given by this expression where you say that 'A', the the spontaneous emission from 'n' plus one to 'n' state and for a hydrogen atom, it's given by this expression where it depends on the principal quantum number of the lowest energy state.

Notes

Summary

0m 25s

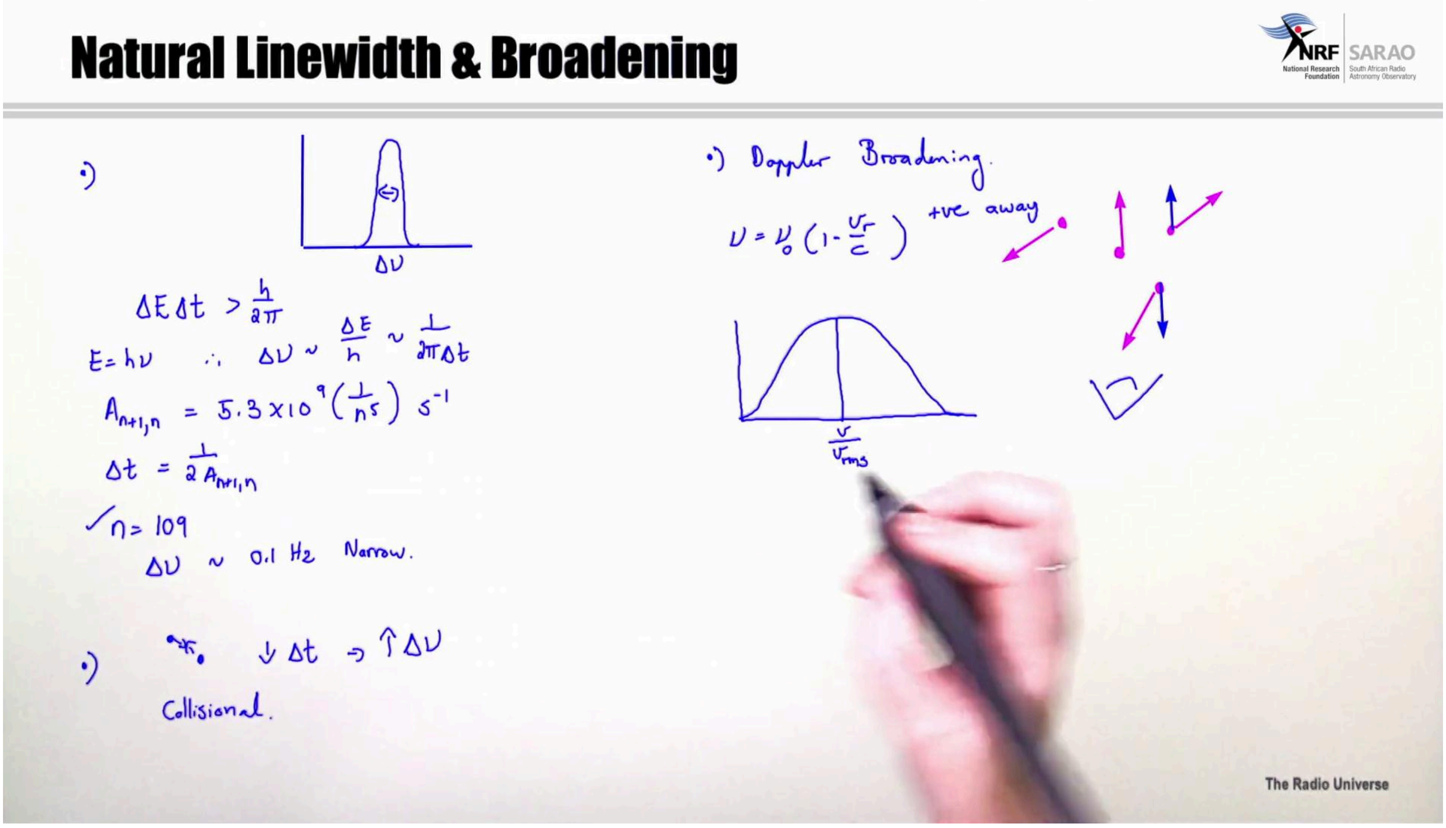


So if you were to use this then you can say that delta 't' here, the uncertainty in the time it takes is roughly equal to one over two times the spontaneous emission rate because there's some uncertainty in the top transition and some uncertainty in the bottom transition. And so if you substitute this into this equation and you use, for instance, 'n' is equal to 109 which is safely in the radio regime then what you end up with is that the natural linewidth of this line is roughly about 0.1 hertz which is very very narrow. Now lines can be broadened because of collisional broadening so as your atoms bump into each other, they de-excite each other and so if the frequency of the collisions is high enough then that will act to increase this emission rate so it will decrease delta 't' and so obviously then that will have the side effect of increasing the width of the line. But for most hydrogen atoms, collisional broadening turns out to be fairly negligible and so it can be mostly neglected. And instead, what is a much more important effect is Doppler broadening. So you'll remember that the Doppler shift is the movement of the frequency of a line because of its apparent motion relative to us.

Notes

Summary

2m 08s

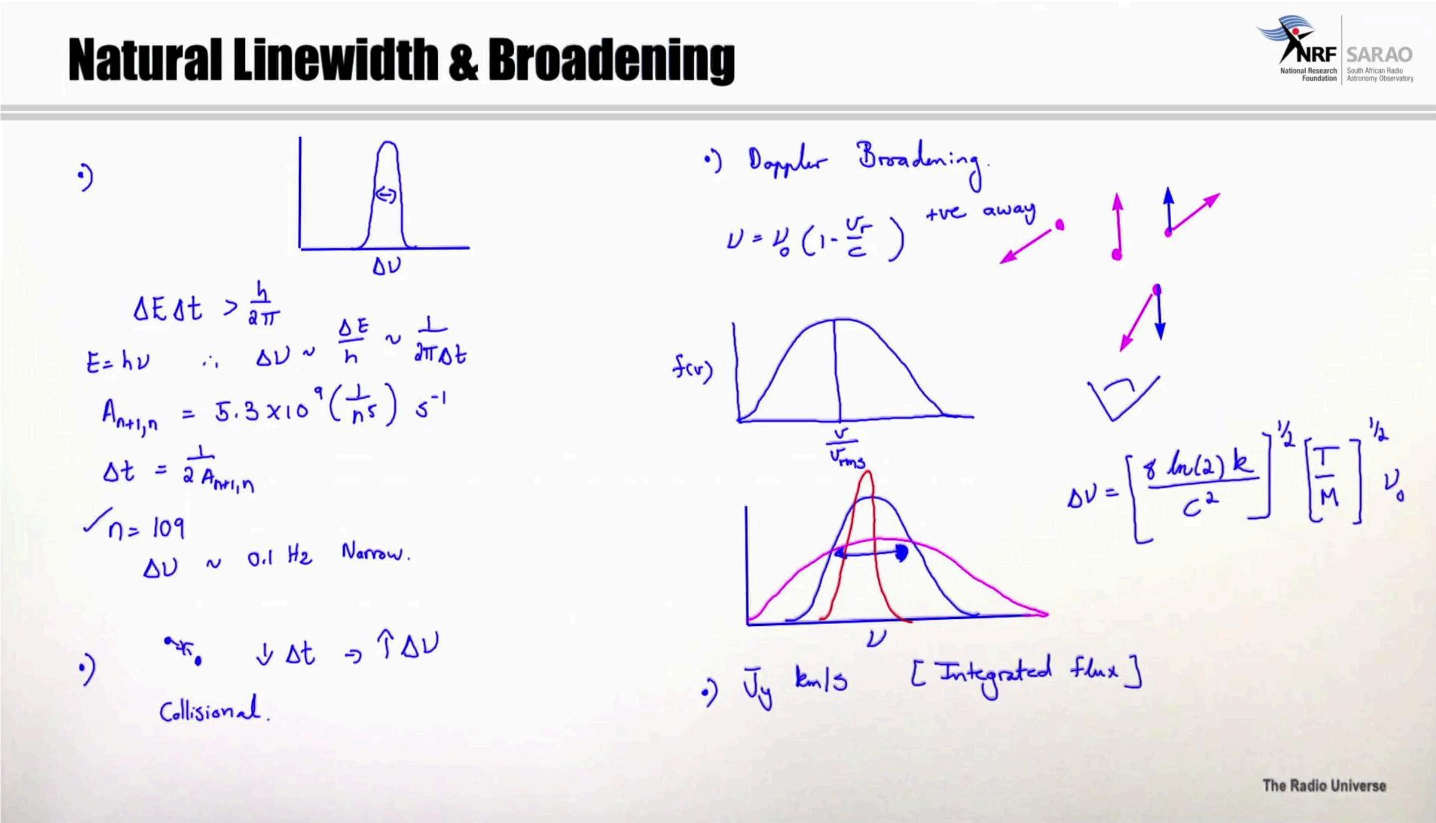


So if you have a collection of you have a collection of particles and each of those particles has some associated velocity because these objects have a temperature and that temperature means that they're moving then some of that velocity will be in the plane of our line of sight to the object we're observing so if we are the observer over here then there will be some velocity relative to our line of sight and that will act to then change the frequency of the line emitted by this object using the Doppler effect. So you'll remember that the Doppler shift is such that the frequency of the observed line is equal to the frequency at rest times one minus the radial velocity over the speed of light where the radial the velocity is positive if it's moving away, away from us. So in local thermal equilibrium what we can say is that you'll know that there is a a well-defined distribution of speeds for your for these particles which depends only on their temperature which, if you remember from one of our earlier lectures, is the Maxwellian speed distribution. So what that looks like is that there will be some well-defined distribution of speeds which peaks around the RMS speed at a given temperature.

Notes

Summary

3m 46s



And so if you know what the speed distribution is then it's possible to turn that into a distribution for the radial velocities here and to work out what impact that will have on your on the linewidth of your actual observed emission line. And so if you do that calculation what happens is that you end up having a Gaussian line here where the width of the line so the full width at half maximum of the line here depends on the temperature and the mass of the object that you're observing. So in that case, the full width at half maximum of the line is given by this expression. So it depends here on the temperature and the mass and the rest frequency of the line that you're observing. One thing to note here is that if you have a narrower line then it will have a taller peak and if you have a broader line then it will have a lower peak. So the same total amount of flux will exist. It'll just be spread out over a larger range in frequencies. And so for that reason it's usually typical to quote the amount of flux in your emission line as the integrated flux over the range of frequencies of the line in units of Jansky's kilometers per second. We then convert this to velocity using the Doppler equation.

Notes

Summary

5m 36s