EPFL NRF SARAO

SN remnants and Diffuse Synchrotron

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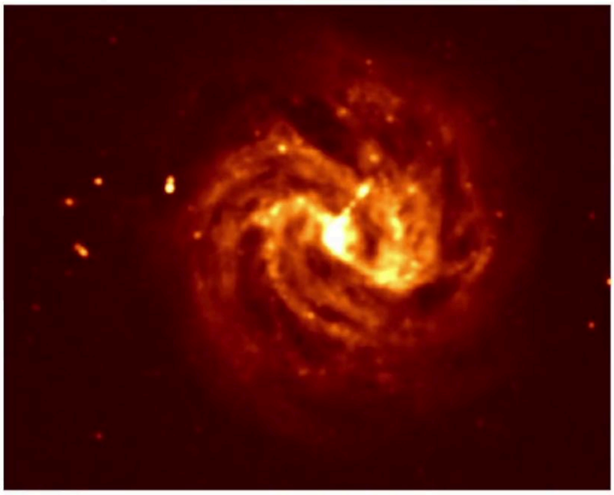

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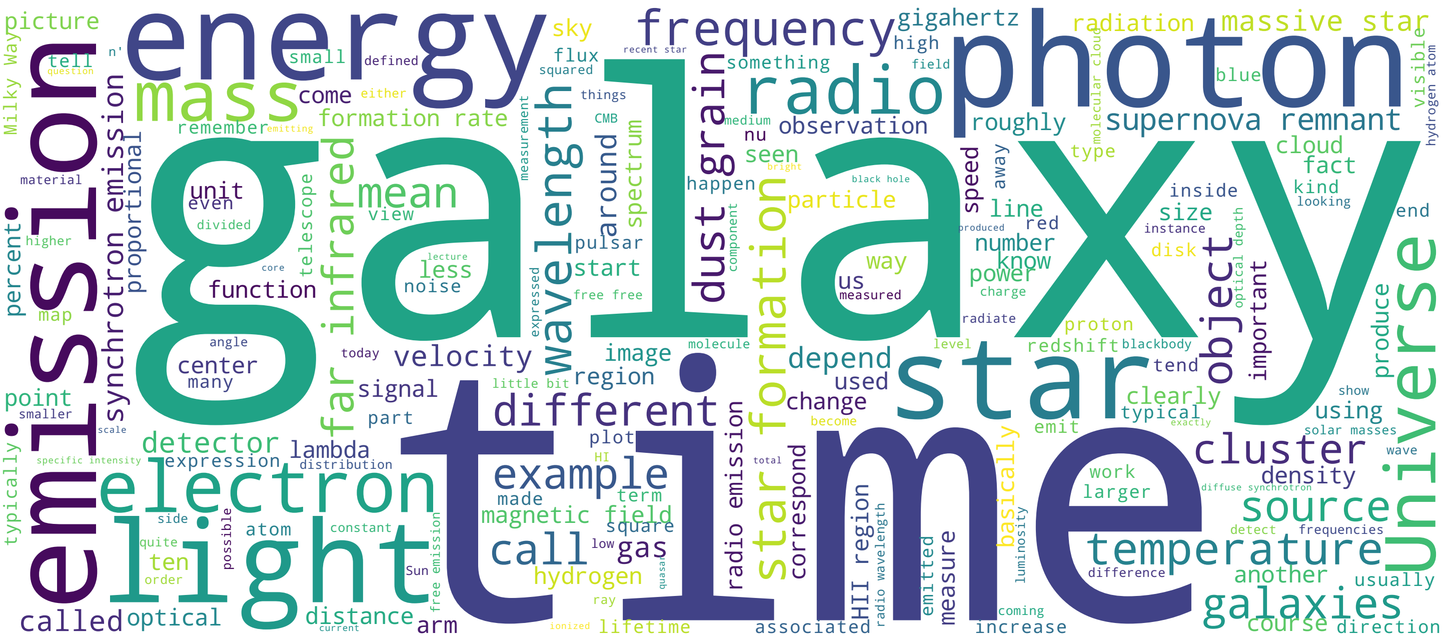

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Video

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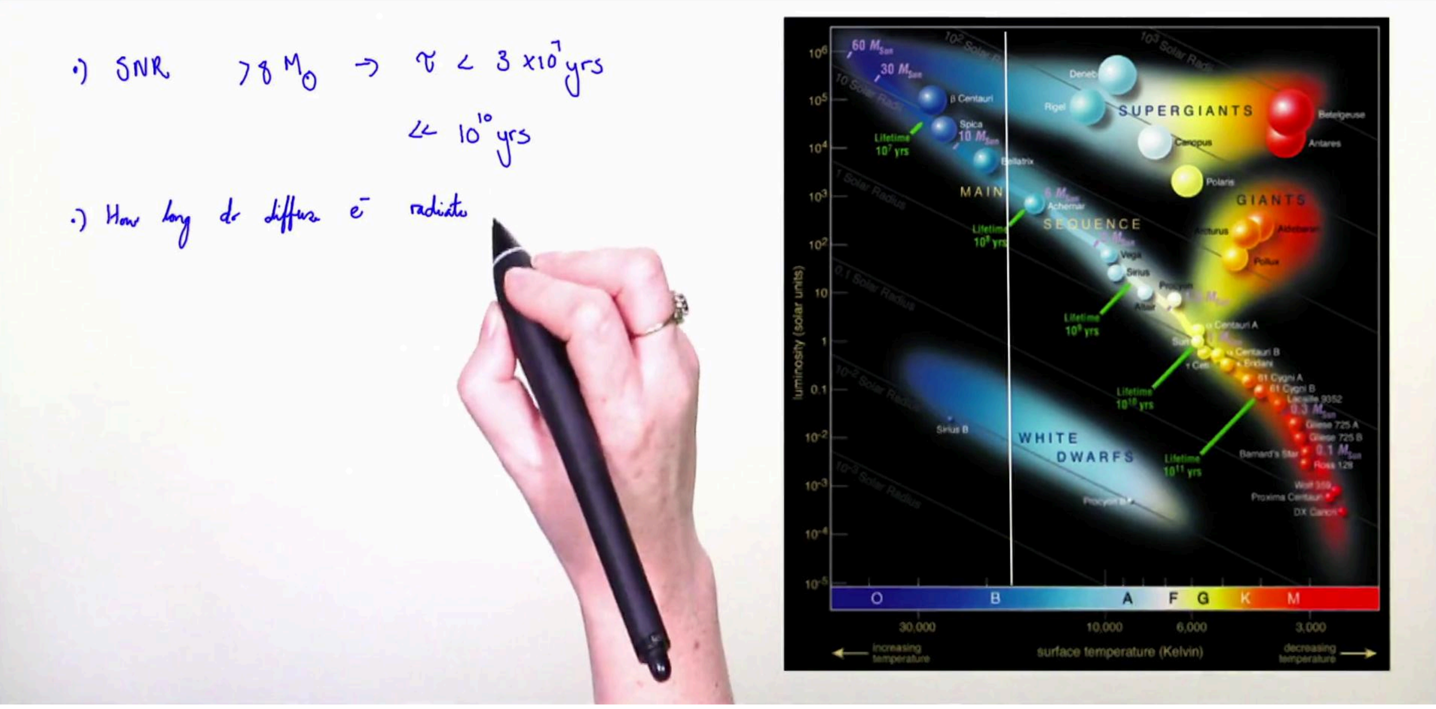
As we continue our exploration of radio emission from normal galaxies, this lecture will focus on the synchrotron component of galaxy radiation and how that can be used to trace the star formation rate of a galaxy.

Notes

Summary

0m 05s

Supernova Remnants and Diffuse Synchrotron



Now if we look at supernova remnants and we consider also which are the stars that are going to produce supernova remnants in this diagram. Well, remember that it's only the very massive stars that produce supernova remnants. So stars that have masses greater than 8-solar masses which are roughly all these stars in the main sequence. So because once again we're dealing with a situation where the supernova remnants are formed by very massive stars. Stars that have a mass greater than 8-solar masses. These stars will have a relatively short lifetime. They'll have lifetimes of less than, say, three times ten to the seven years. So just like with HII regions, supernova remnants are probing things that have quite a short lifetime and while this might seem like a long time to us it's very much less than the lifetime of a whole galaxy which could be, say, ten to the ten years, for instance. This is one estimate of the age of our galaxy. So HII regions and supernova remnants both probe relatively recent star formation. But the question is we also have this diffuse synchrotron component which is a result of electrons that have diffused away from its original supernova remnant and so the question is how long do these electrons continue to radiate for after they've left the supernova remnant?

Notes

Summary

0m 19s

Supernova Remnants and Diffuse Synchrotron

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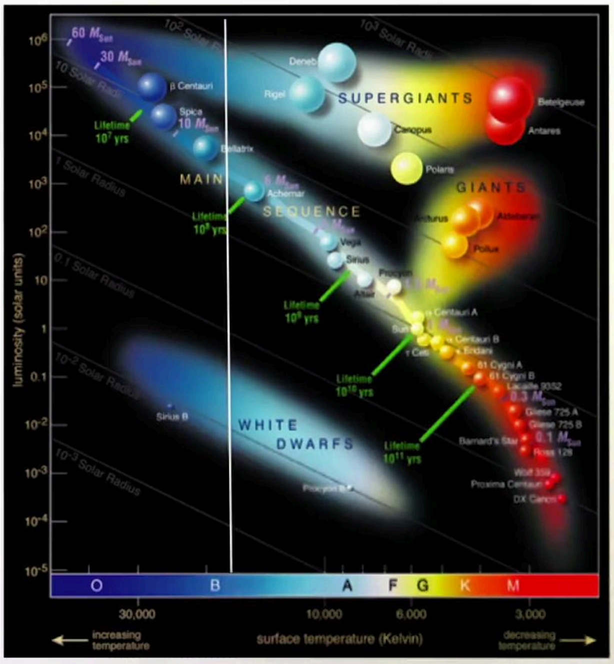
- SNR $> 8 M_\odot \rightarrow \tau < 3 \times 10^7$ yrs
  $\ll 10^{10}$ yrs
- How long do diffuse e^- radiate for?
  B↑ $\tau < 10^8$ yrs
  $L_{NT} \propto SNR \propto SFR_{Mass}$ - current.
- Confined to disk.

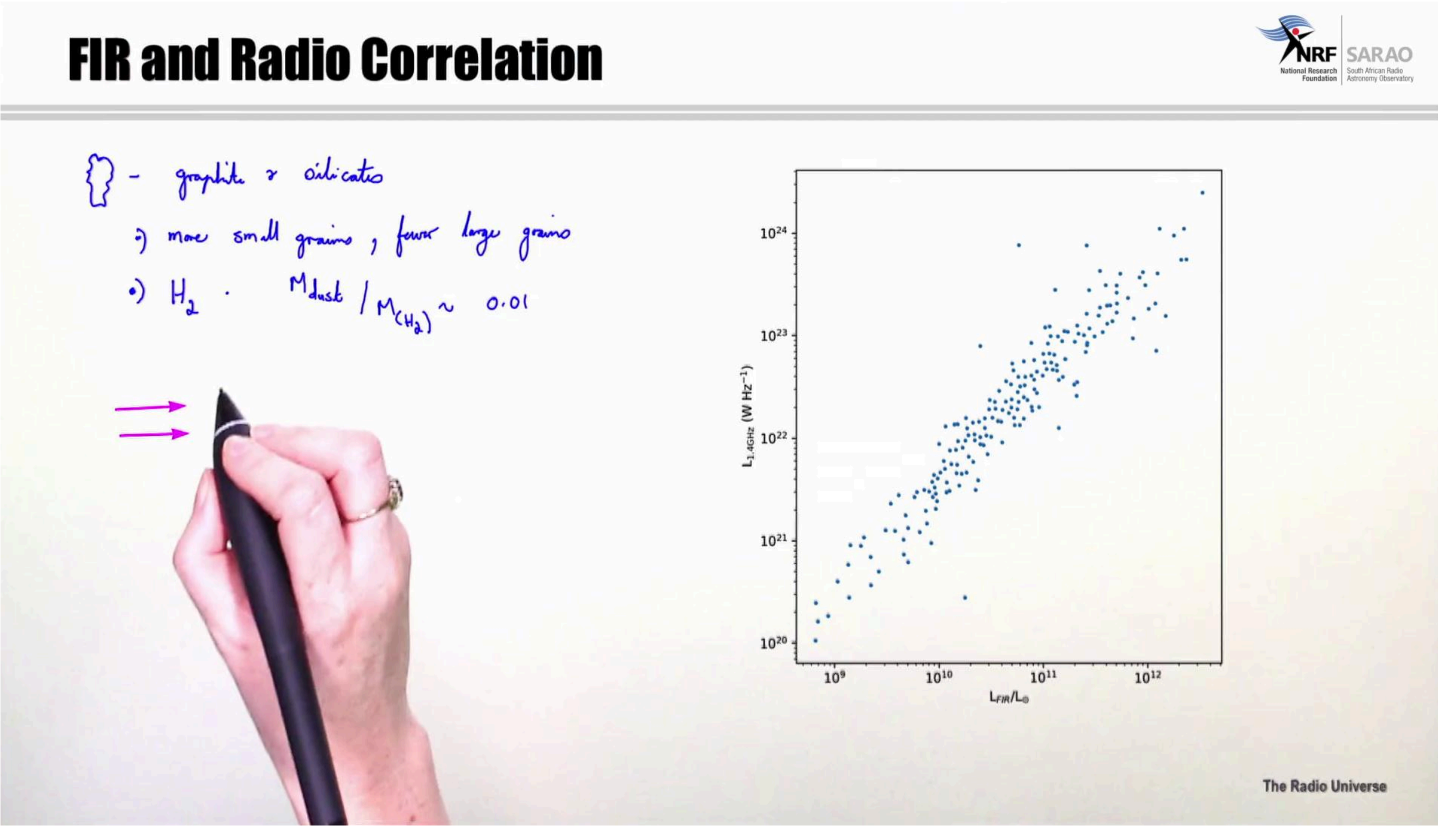


Well, this depends a little bit on the the galaxy that they're traveling in because synchrotron emission depends on the magnetic field of the galaxy which in turn tends to depend on the density of the galaxy. However, a sort of average amount of time that it takes for electrons accelerated in the original supernova to radiate all their power away is of the order of around ten to the eight years. So even the diffuse emission that we see in the galaxy that's not associated with discrete supernova remnants is also probing relatively recent star formation. So we can say that the radio synchrotron emission or the non-thermal radio emission is essentially proportional to the supernova rate roughly because this time isn't very much longer than this time and that is essentially proportional to the star formation rate of very massive stars and it's also essentially proportional to the star formation rate that's sort of current in the galaxy. If you're sensitive to these other this massive stars then what you'll be seeing is the integrated star formation history of the galaxy over its lifetime. And most of the synchrotron emission that we see so this diffuse synchrotron emission is confined to the disk which tends to confirm that it's associated with ongoing star formation. So it's confined to the disk of a spiral galaxy.

Notes

Summary

1m 48s

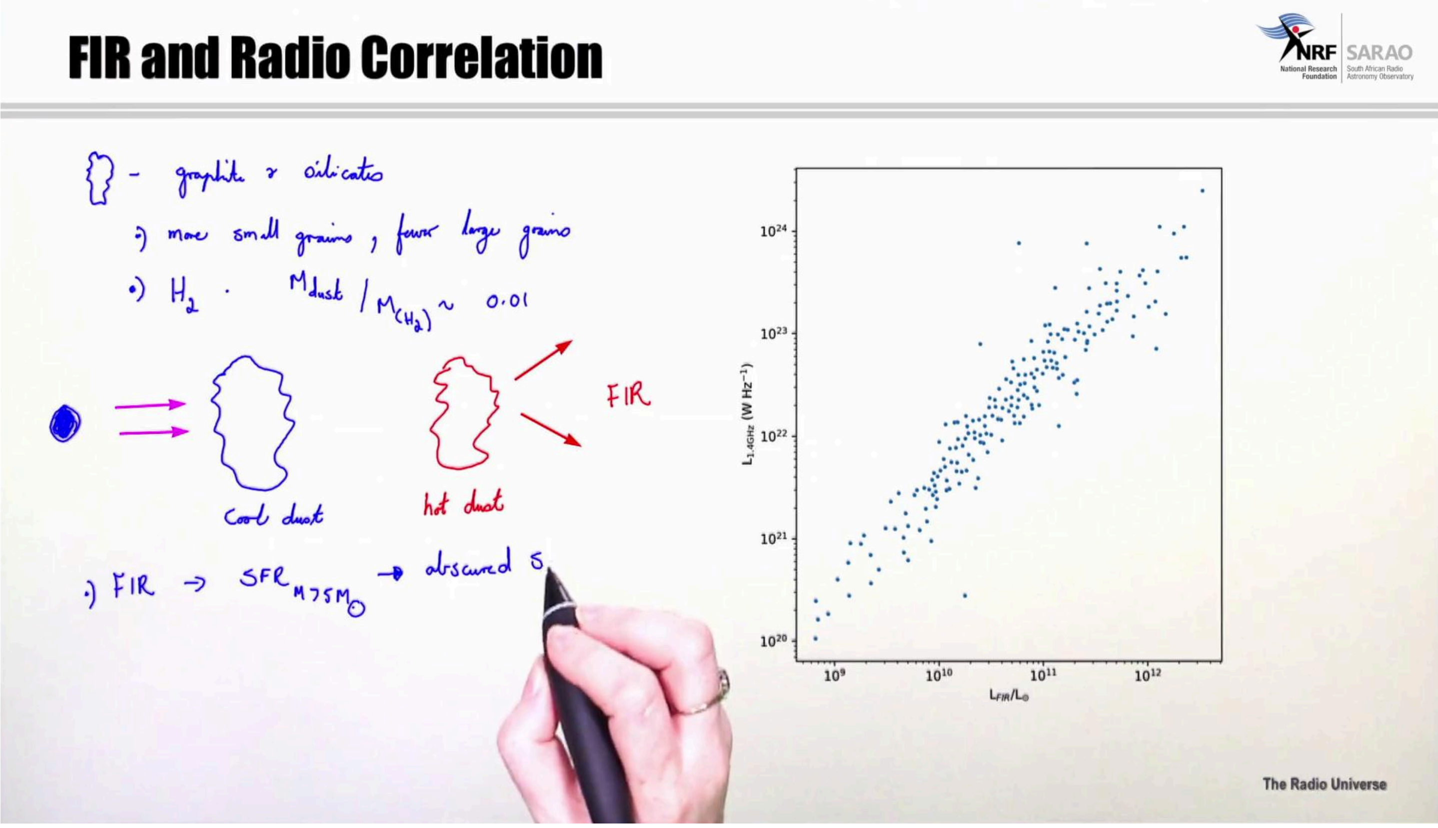


Another kind of emission that you have to consider is the emission that comes from dust grains. So we have dust grains in the interstellar medium and they're mostly made up of graphites and silicates. These dust grains have a grain size distribution where you tend to have more small grains and much fewer large grains. This dust tends to be preferentially distributed in molecular clouds of H2 gas and that's because the conditions here are cool enough so that this graphite and silicates are not condensed by very high temperatures. So in a molecular cloud you typically have a ratio of the mass of the dust particles to the mass of the H2 particles as being around roughly 0.01 so roughly one percent of the mass is associated with dust. And this can be problematic for optical astronomers unfortunately because where the most massive stars form tends to be in the most massive molecular clouds and these tend to have the most dust. Unfortunately for optical astronomers, most optical and UV wavelengths are unfortunately absorbed by these dust grains.

Notes

Summary

3m 24s

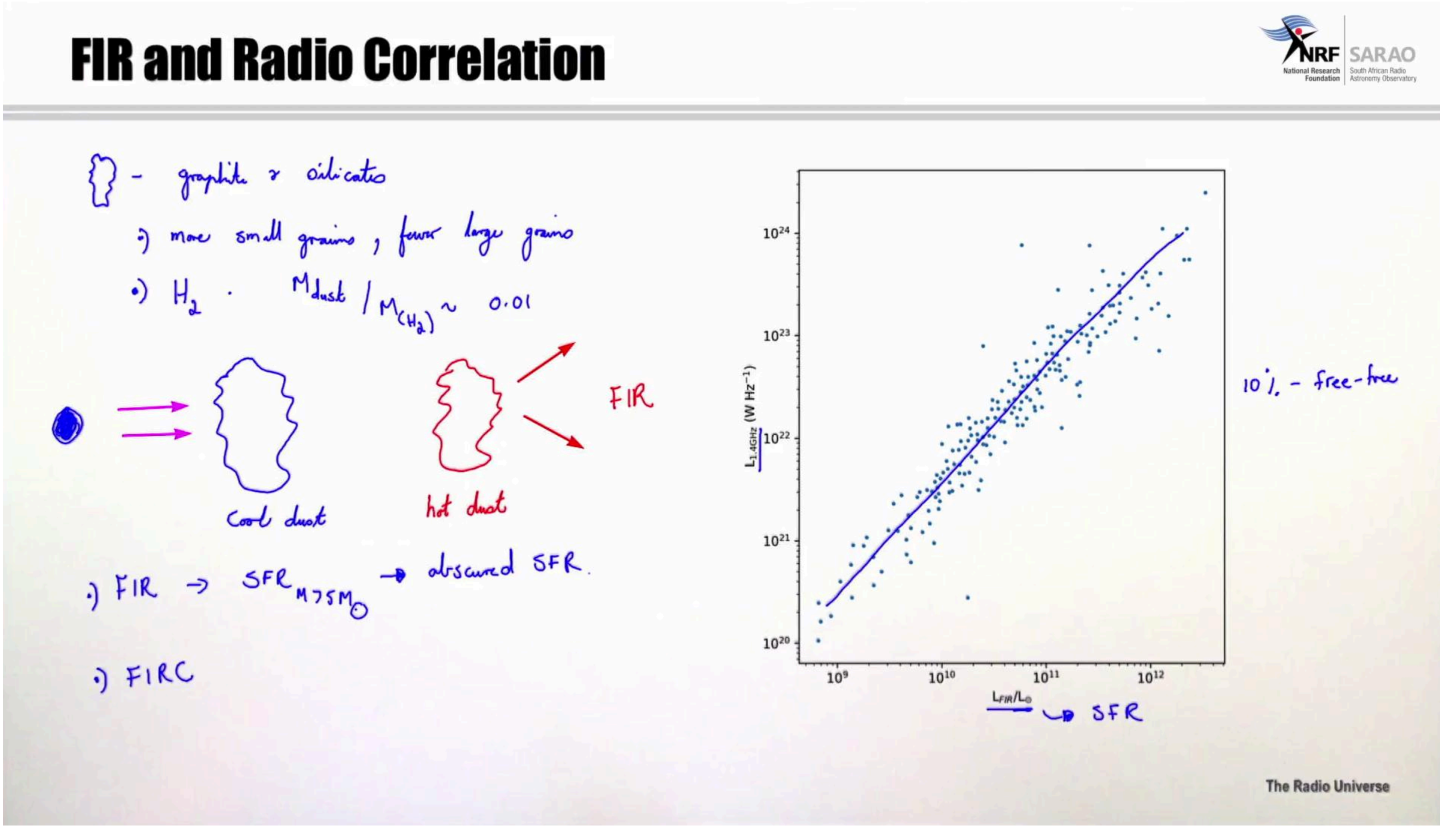


So if you have a young star which is emitting near UV and optical emission then that emission is completely absorbed by an intervening dust grain so if you have a cool dust grain like this then the cloud becomes completely opaque and you're not able to see inside the cloud at optical wavelengths to see this young star as it switches on. However, there is a bit of a saving grace here in that this UV radiation acts to heat up this cold dust grain so that the cold dust grain now becomes a hotter dust grain and this hot dust grain then emits like a gray body so it emits thermal emission which is then at far infrared wavelengths or infrared wavelengths. So from this what you can say is that the far infrared radiation is a very good way to probe star formation for very massive stars where they're very much obscured by the dust and the intervening clouds and you can see dust even in our own Milky Way at night where you can see those dark bands against the sky which is where these dust grains are absorbing stellar light. So the far infrared is actually a very good probe of the star formation rate of very massive stars and as we've said before, the star formation rate of very massive stars is also very much the current and most recent star formation rate and it's very good probe of what we call the obscured star formation rate.

Notes

Summary

4m 45s



There is a very curious relationship between the far infrared luminosity from these dust grains and the radial luminosity from a normal galaxy and if we plot the far infrared here on this bottom axis versus the luminosity at 1.4 gigahertz, what we get is a very very tight correlation and this correlation is called the far infrared radio correlation. Now the far infrared radio correlation is perhaps a little bit unexpected because, in fact, at 1.4 gigahertz only around ten percent of the emission that we see comes from free-free emission. Most of the emission that we see is actually this diffuse synchrotron emission where most of that is associated with these diffuse cosmic rays electrons. So it's perhaps a bit surprising that there's such a tight relationship between it and this far infrared which directly probes the obscured star formation rate. So there is a special model which tries to understand why these things are so tightly related to one another. But before we get to that let's just have a look at an example of what a heated dust grain looks like.

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Summary

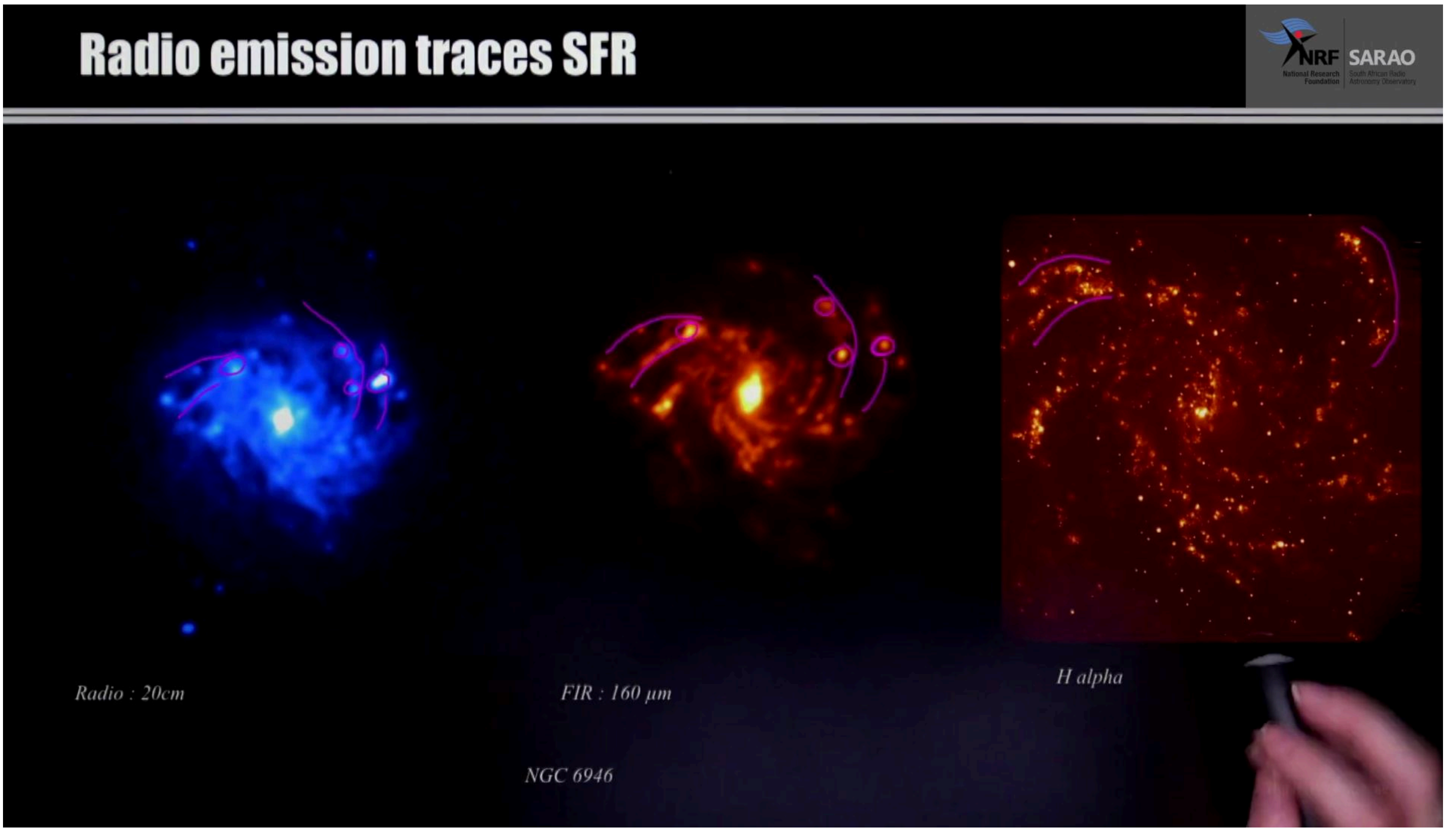
6m 31s

So here's an example of the Sombrero galaxy and you can clearly see in this image that there are these dark lanes in this outer part of the disk which is absorbing the stellar light which is why you have this dark patch here. So this is an optical image and if you look at an image of the same galaxy in mid-infrared where the longer wavelengths are colored red here, you can clearly see that all of those grains are lit up in the mid-infrared. So you can see clearly that they're emitting in this thermal emission after being heated up by the star's light.

Notes

Summary

7m 50s



Within a galaxy we can have a look at what the radio emission looks like and compare it to a far infrared emitter. So in this galaxy here we can see these images not exactly at the same resolution so you have to use your imagination a little bit but you can clearly see that many of the features that are visible in the far infrared are also visible in the radio. For instance, you can clearly see this arm here in the far infrared and that's the same arm as this arm. You can see these little knotty features are also visible at both wavelengths. The same here this arm and this knot over here in the radio and you can see this double arm here. It's also here with also this brighter region being lit up. So it's clear that if the far infrared is tracing the star formation in the galaxy then so is the radio emission. In this plot we have a picture of the H-alpha emission in the same galaxy. This is at a much higher resolution but again you can clearly see that these two spurs here are the same as these two spurs and this arm here is probably this arm over here and what all these little dots are, are the H-alpha emission.

Notes

Summary

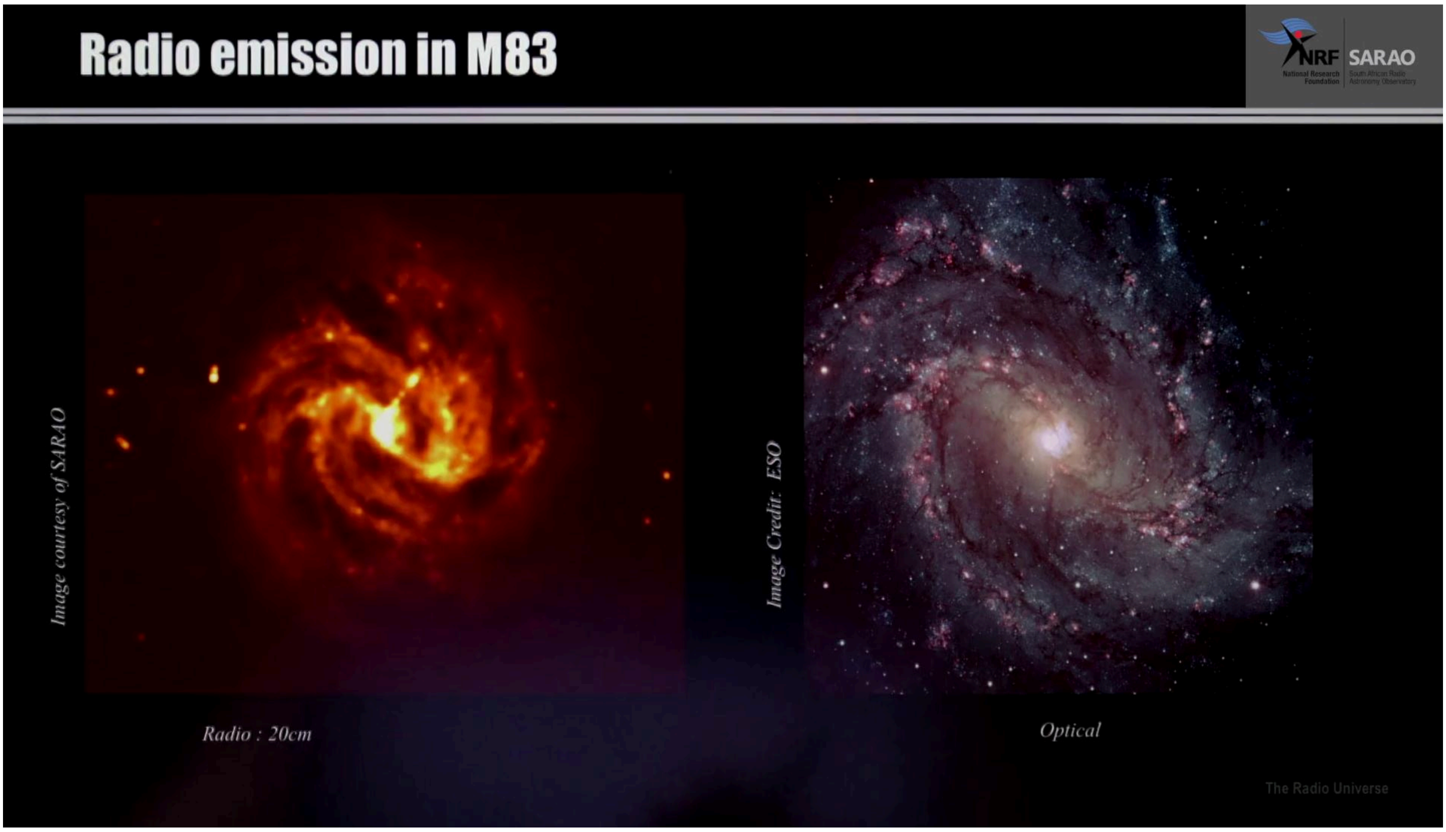
8m 24s

So this is in optical light but you see that these very compact HII regions are not clearly discernible in the radio image here and that's partly because this is a very low resolution image in the radio but it's also because this is an image of all of the light and most of the radio light here comes from the synchrotron emission. So the only way to find these compact HII regions is to try to make a map at multiple frequencies and to try to find the regions where there is a an increase in the contribution from free-free emission. So you can't, it's all mixed in with the synchrotron emission in this picture and you can't separate them very easily without extra frequency information.

Notes

Summary

9m 42s



Here we have another very pretty picture of a galaxy at radio wavelengths so again we see this very clear spiral structure. Here it is at radio wavelength M83 and once again at optical wavelength with all of the HII regions lit up in red.

Notes

Summary

10m 32s