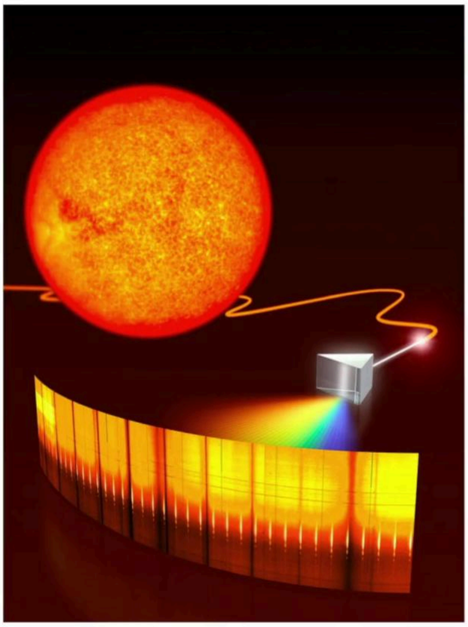
Spectral Lines (part 5)

Kim McAlpine



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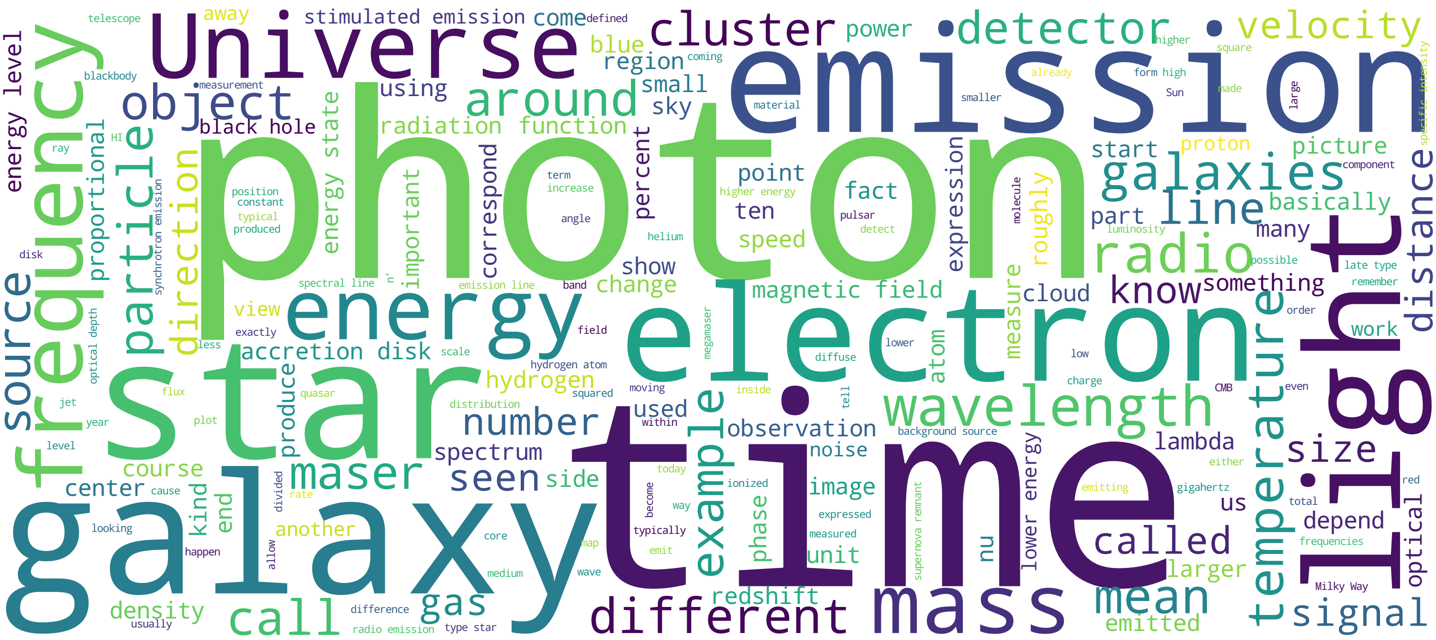

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Video

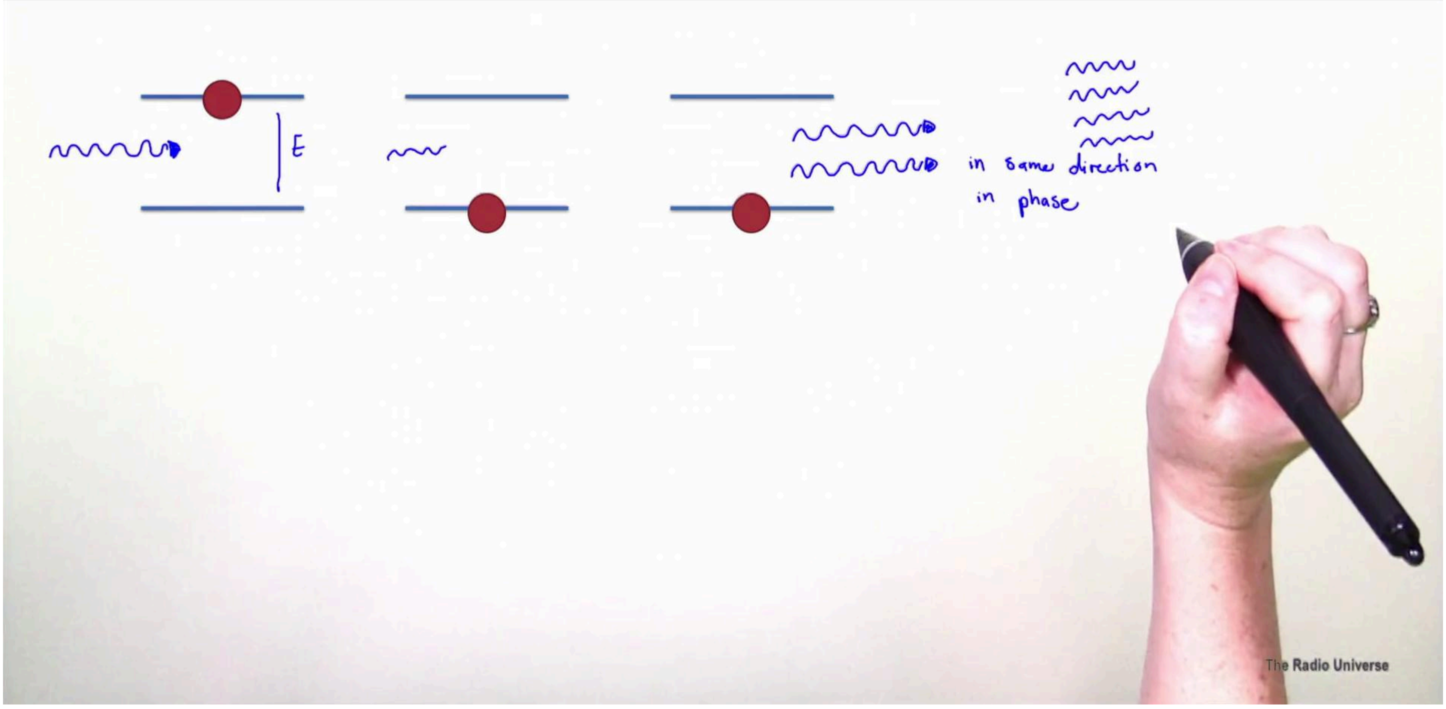
Today's lecture focuses on masers. Masers are a kind of incredibly bright narrow spectral line which gets formed when you have a background source which is emitting into an intervening cloud and if this cloud has a very specific set of energy and velocity states then it's possible for this cloud to actually amplify the background radiation rather than absorb it as we've seen before in the radiative transfer equation. And in today's lecture, we'll learn all about the circumstances that allow this amplification to take place.

Notes

Summary

0m 05s

Stimulated emission



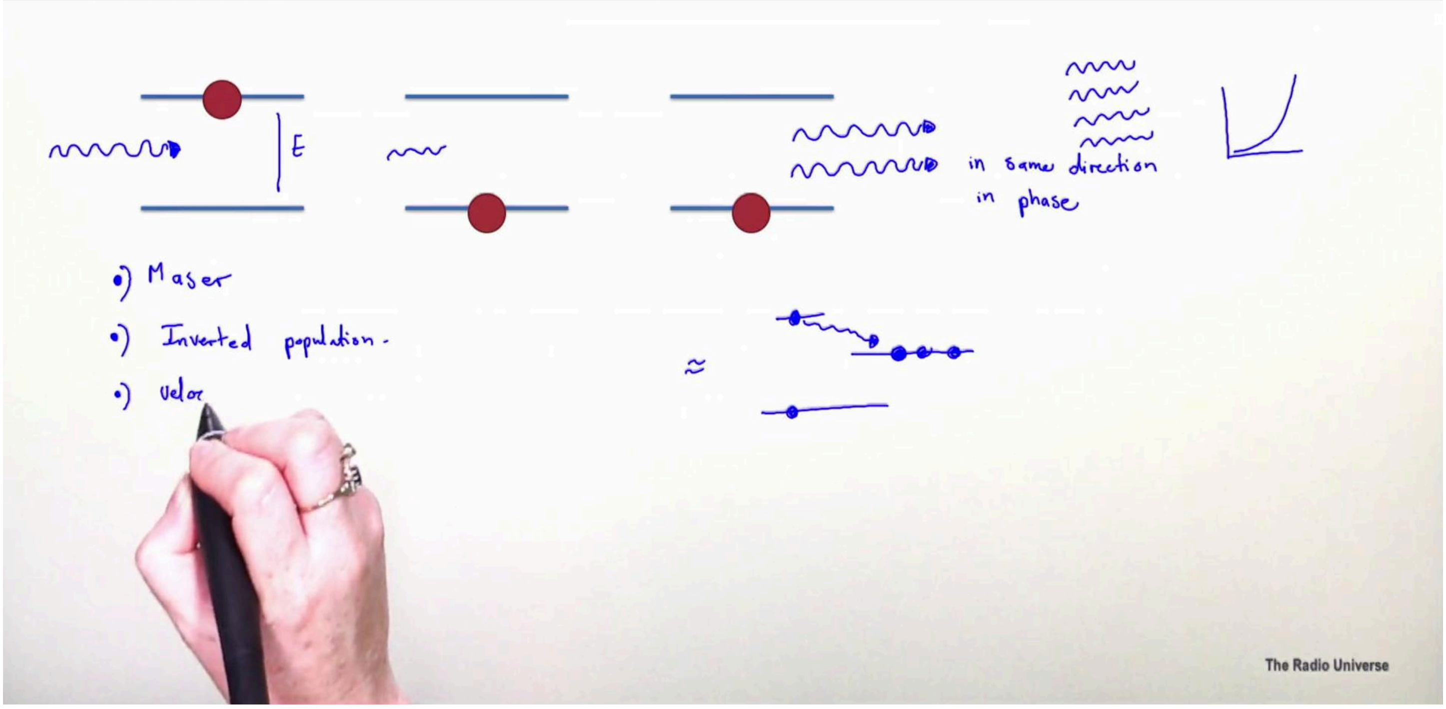
Another type of spectral line emission is stimulated emission. In stimulated emission, you have an atom or molecule that's already in an excited state and if a photon arrives which has exactly the frequency of the difference in these two energy levels then it can stimulate this system to drop to a lower energy level and as it drops to this lower energy level, what you'll end up with is the original photon plus an extra photon which has now been emitted by the system because it dropped to this lower energy level and the important thing about these two photons is that the new photon will be in the same direction as the old photon and it will also be perfectly in phase with the old photon. So when you have normal spontaneous emission, remember it's isotropic. The photon can be emitted in any direction but now this photon is only emitted in the direction that the original photon came from and they're both in phase. And what this results in is that you can have very large amplification of some incoming radiation because imagine now that these two photons find another system which is in the same energy state and cause stimulated emission then what you'll now have is four photons all moving in the same direction and all in phase so they don't destructively interfere with each other.

Notes

Summary

0m 40s

Stimulated emission

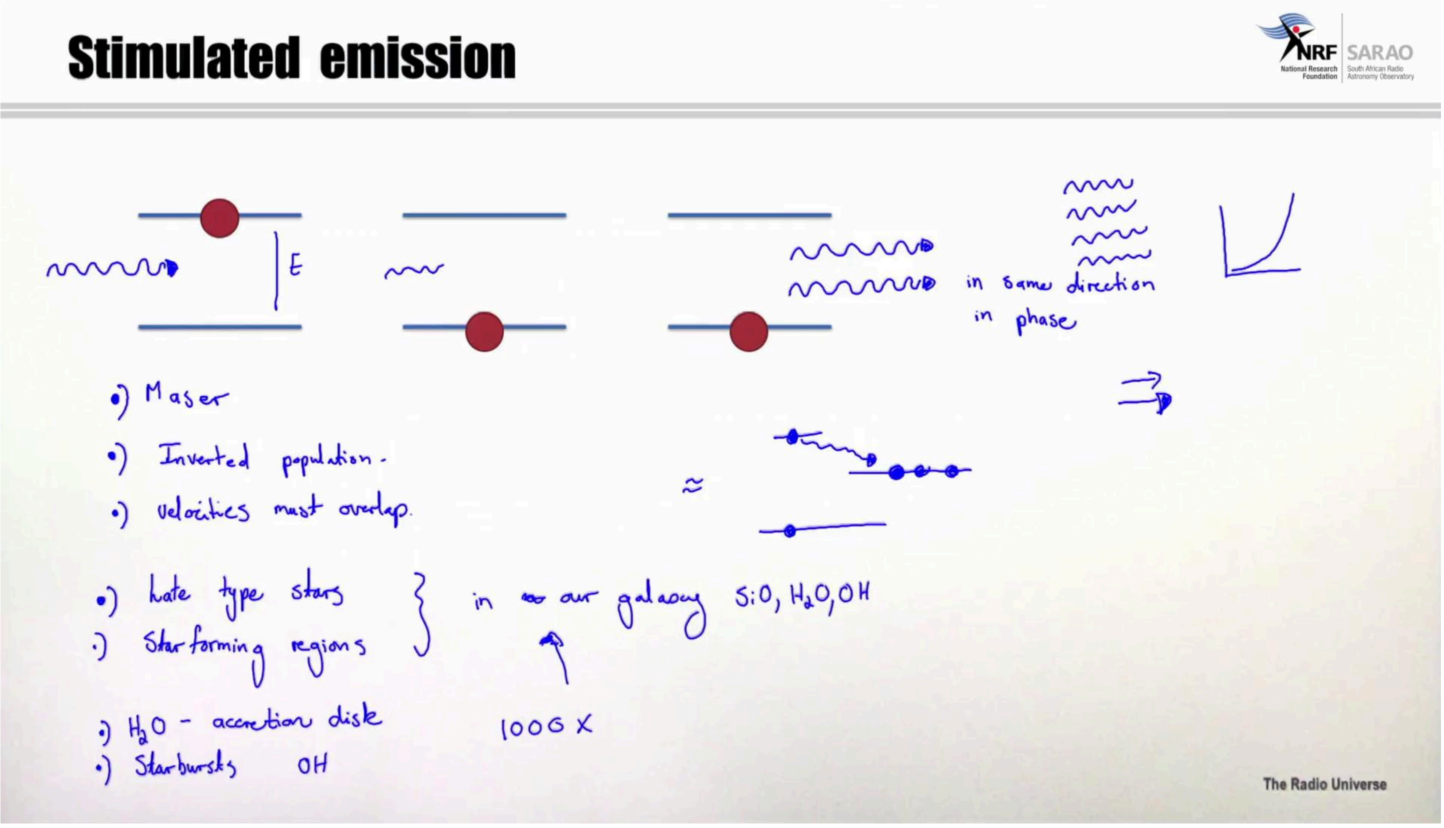


And so if this continues, you can have really an exponential amplification of a background source and that can allow you to have very bright very narrow emission which amplifies a background source instead of absorbing it. This type of emission is called maser emission. Maser stands for microwave amplification stimulated emission radiation so it's the microwave analog of a laser except that here the amplification happens because of the natural conditions of the line. In order to have a successful maser, what you need is an inverted population. So you need this population where many of the atoms are already in this higher energy state and this is usually caused by something like having a system where there's a lower energy state and then something, for instance, a star or some other kind of radiation is exciting this to a higher energy state and this energy state is preferentially de-exciting to some other state which doesn't de-excite very easily so then it becomes highly populated. So you need an inverted population and you also need velocities to overlap.

Notes

Summary

2m 19s

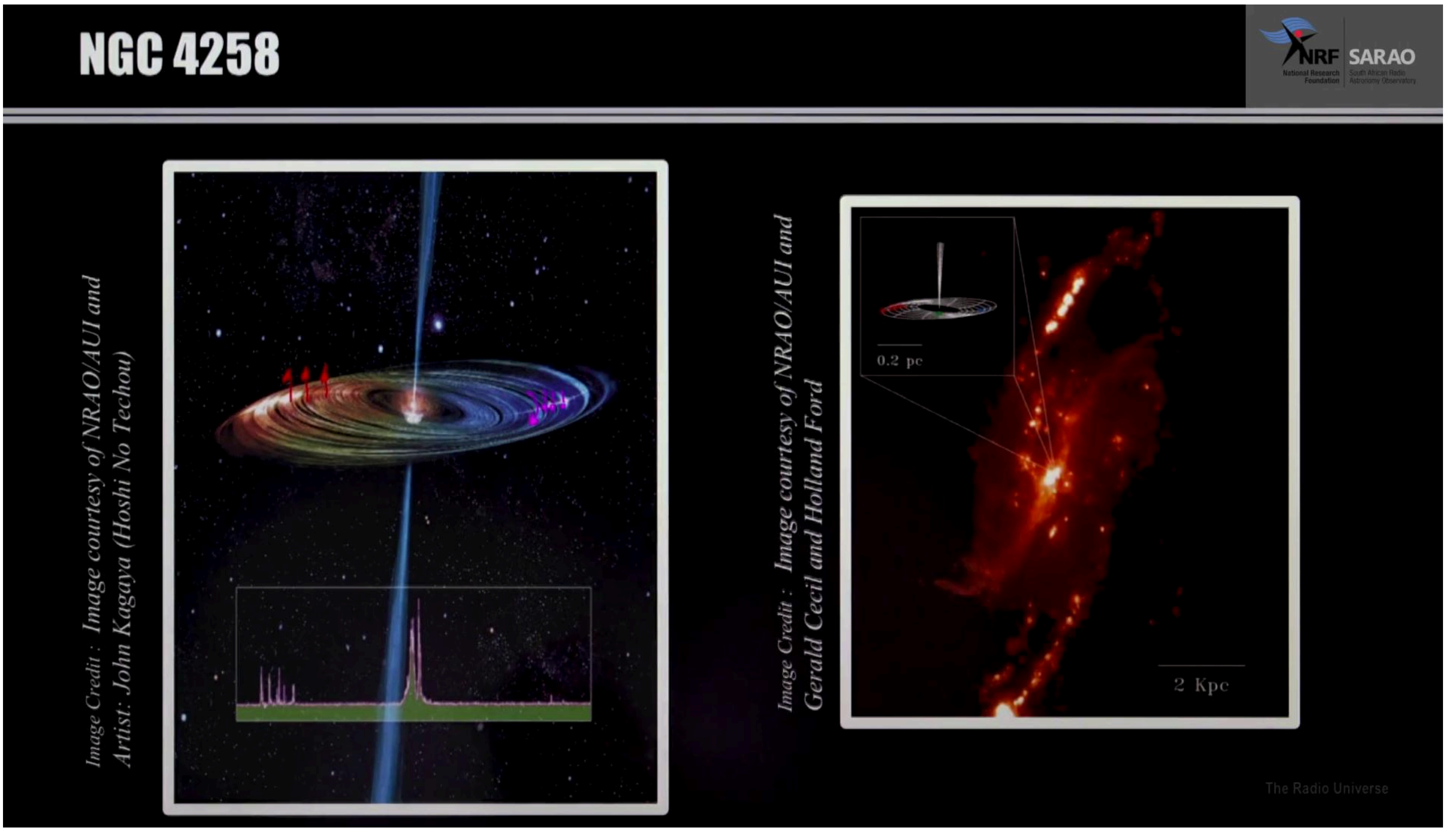


And you can think of that as being that if you have a lot of random velocities here then because of the Doppler shift not all of these frequencies will be at exactly the right frequency to cause the stimulated emission effect so if you have a lot of random velocities then you can't have a maser. You can only have a maser if you have a lot of particles that have the same bulk velocity flow. Masers are commonly found in late type stars where you have pulsations which drive this kind of velocity coherence that you need. You also see them in star forming regions. And these are masers that you see within our own galaxy but there's also something called a megamaser. So megamasers are masers that are seen in other galaxies but they're around a thousand times brighter than the masers we see in our own galaxy. So usually masers are seen from species like silicon monoxide, water and OH and a very famous example of a megamaser is an H2O maser which was found in an accretion disk around a very a supermassive black hole. So you see them in accretion disks and you also sometimes see them in very in a starburst system so very very luminous galaxies with very bright star bursts. And normally you see water masers in the accretion disks and OH masers in these starburst systems.

Notes

Summary

3m 50s

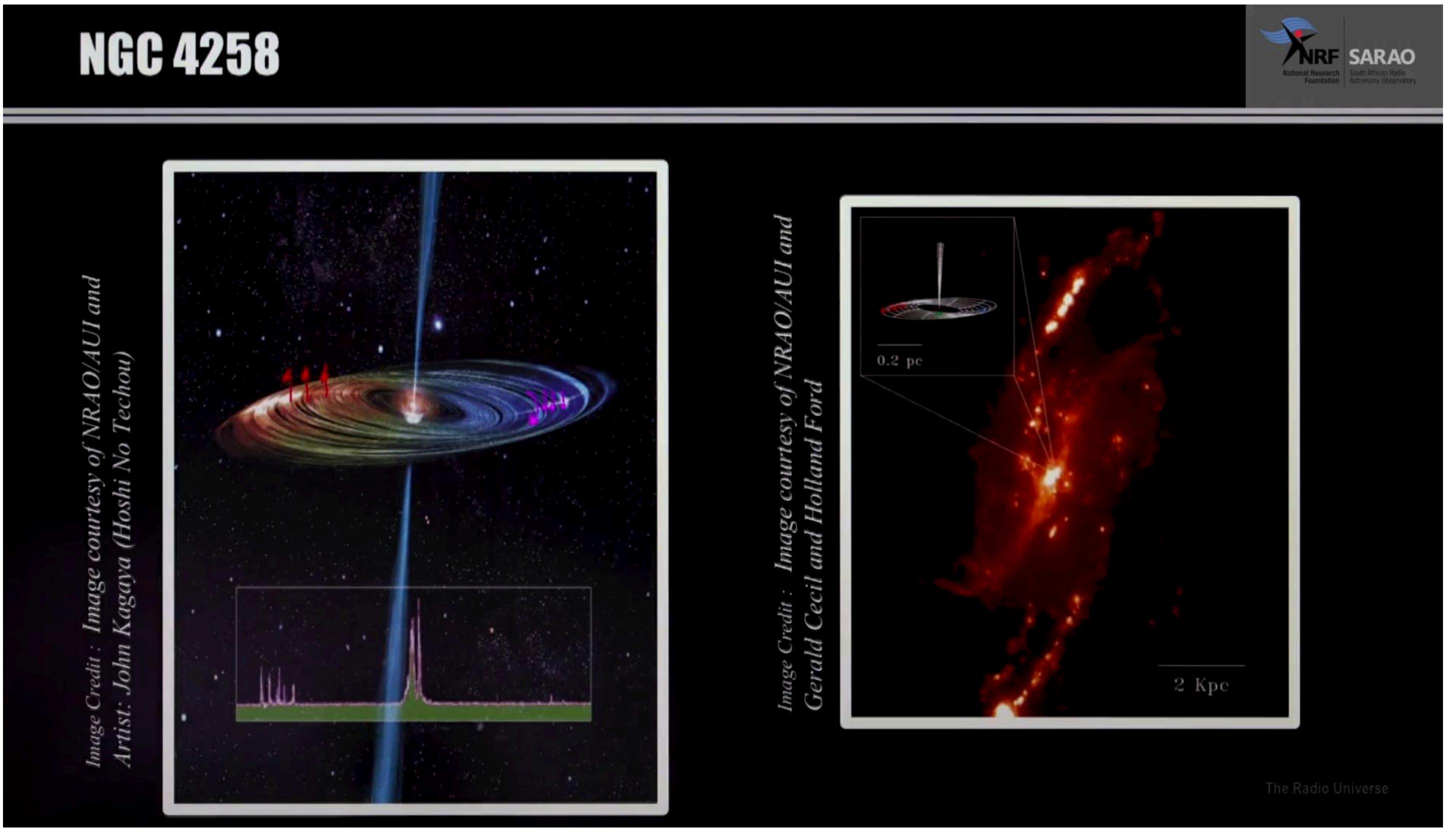


Here is a famous example of one of these water masers in another galaxy around found in an accretion disk. So here what you can see is we have three sets of emission very narrow very bright emission lines. Inside here is a galaxy which has got a super massive black hole and it has two jets so we have this artist impression of the jets and then around that is this warped accretion disk which is not shown to scale. It's very much larger than it would be. You get emission here from the center which is where the maser is amplifying the emission from the background source then over here you have emission from the disk as it rotates towards you so as it's rotating towards us at this point, you get a lot of velocity coherence along the line of sight so all the particles are moving in our direction here which causes this amplification and the same on the other side as the particles go around the disk here, they're all moving away from us and so you get all these particles that have the same velocity along our line of sight and that gives you that amplification.

Notes

Summary

5m 37s

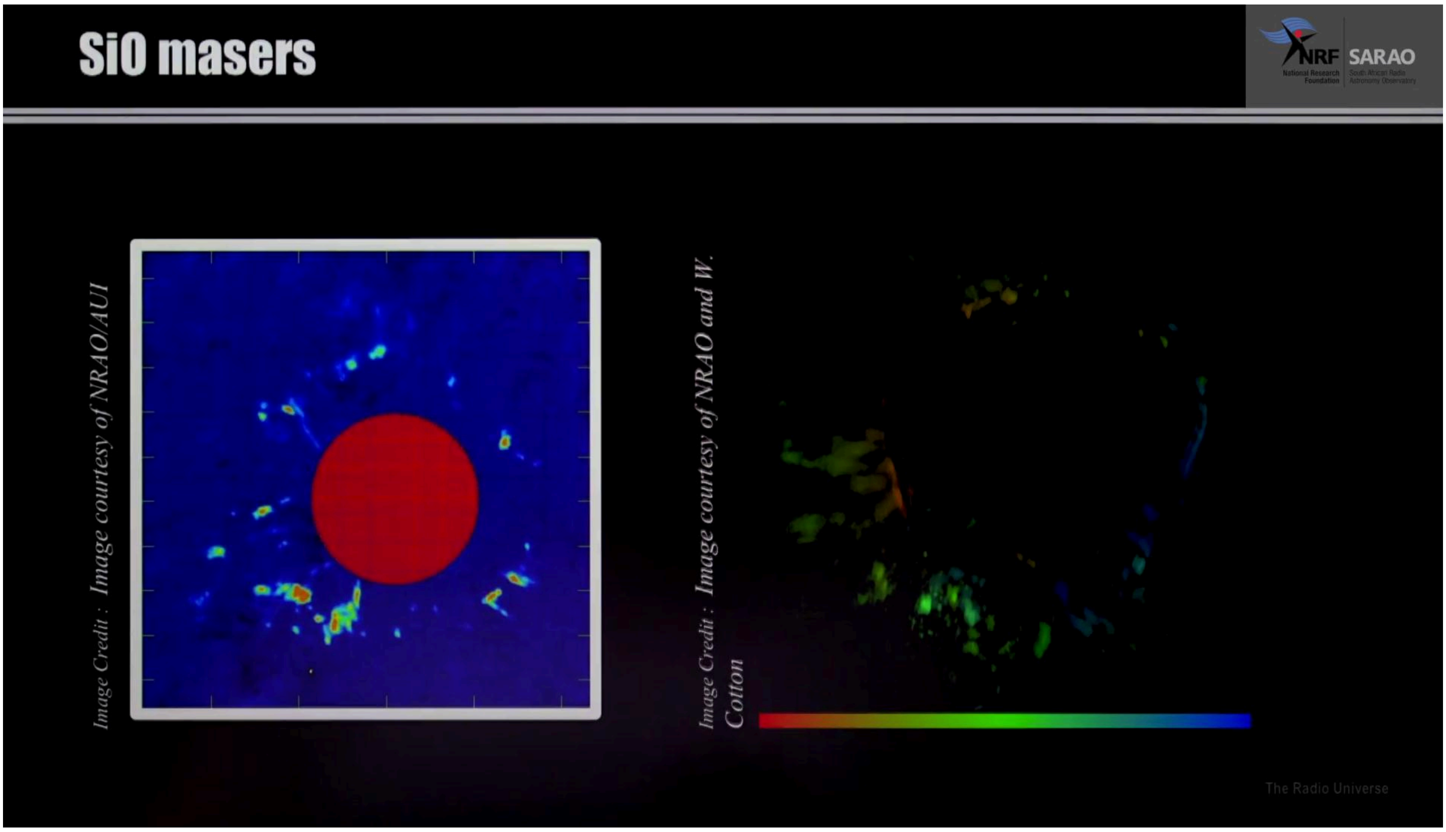


On the other side here this is an attempt to show you what the scale of this is so this is a blown up picture of the galaxy and this shows you the same accretion disk here with the position of the masers plotted on it and it shows you that the disk is about 0.2 parsecs in size and the whole galaxy's scale here is given as two kiloparsecs.

Notes

Summary

6m 51s



This is an example of masers in late type stars. So these are taken with VLBI so they're very high resolution. So this is just a cartoon representation of the star. You can't see the star using VLBI but you can see all these little high brightness temperature features which are all regions where the star is pulsating and this is the same also masers in a late type star where you can see the velocity of the maser as well where blue is towards us as usual and red is away.

Notes

Summary

7m 13s