REU notes

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Probing the AGN Nature of Maser Galaxy hosts

1. Title Slide

Hi. Im here to talk about some interesting things that happen in galaxy centers and in particular an emission that comes from some galaxy centers that is like a laser, but in microwaves at 22 Ghz, called a maser. That might be related to the accretion of matter onto supermassive black holes, known as an active galactic nucleus.

2. Why do we care

So the first question is, why does maser emission matter?

Well, when masers are in a disk configuration around a supermassive black hole, they give us a way to directly measure the black hole’s mass and the distance to its galaxy with a simple geometric formula.

Those measurements in turn allow us to refine our cosmological models and ultimately get a better understanding of the future of the universe.

The problem is, they are hard to find. We only know of 180 masers, which is 3.6 percent of surveyed galaxies, and we only know of only 34 disk masers, which is only 0.7 percent of surveyed galaxies.

But before I get into our attempts to understand masers better and find more of them, let me go into what masers actually are.

3. What are masers.

At its most basic, maser emission is light, basically laser light, but in microwaves at 22 ghz. That means that all the light rays are going the same direction and they are all aligned with each other.

In nature, masers form when there is an energy source near a cloud of gas with water molecules. This gas is hot and high density for space gas. It still is in space, so the molecules aren’t at thermal equilibrium, but its denser than most space gas. Somehow, the molecules get energized until more of them are in an energized state than not. That’s called an inversion of population. Then, all they need is a seed photon coming in at 22 ghz, and they release their energy, in the same direction, also at 22 ghz. That causes a cascade effect which produces the maser ray.

We like to classify masers by their energy source, because that makes a big difference.

4. Types of Masers

So two types of masers are ones that come from star forming areas in our own galaxy, so the energy source is new stars.

Another type is megamasers. They are around a million times more luminous than the star-forming type, and are in the centers of galaxies. Less than 20% of masers are maser disks. Let me tell you what I mean by disks:

We think their energy source is the accretion disk around a supermassive black hole. That provides hot UV and Xray photons which heat the water molecules in these high-density clouds of dust and gas. There’s also these Jets coming from the black hole, but that’s another topic.

The gas clouds reprocess the radiation as maser emission. Also, the central part is very bright at 22 Ghz. Here is the spectrum we see from the center of the galaxy:

The wavelength spectrum can be translated to redshift velocity away from us using this formula. The emission you see at the center is the systemic velocity at 500km/s, which is the velocity of the whole galaxy. Around it are the red and blue shifted maser emissions from the maser clouds which are traveling at high speeds away and towards us as they orbit the black hole.

A system like this is about the only way we can directly measure the distance to the galaxy and the mass of the black hole.

Remember, these useful maser disks are very rare, less than 0.7 percent of all surveyed galaxies

5) AGN

So, we want to find more. To start doing that, we will investigate masers properties, using the properties of the accretion disk around the black hole, which is called an active galactic nuclei or AGN.

AGN form during a period in a galaxy’s life when the black hole is eating a lot of gas and dust.

We know of several ways to detect AGN: Xray signatures, radio, variability in some of these other signatures, mid-infrared which was discussed in detail by Emily McPike, and the two ways we will focus on: Optical lines and Coronal lines. These different detection methods can identify different types of AGN.

Here you can see the spectrum of three types of galaxies: star forming, Liner AGN and Seyfert AGN. These spikes are emissions from specific highly ionized gas ions. This plot shows the optical lines. Coronal lines are similar, but are from even more highly ionized molecules which can only be produced at visible intensities in the accretion disk, so if we see coronal lines, we know its an AGN.

We are going to use these detection methods for AGN to better understand maser disks properties.

6)

So the data we used for this project was

The megamaser cosmology project, or MCP, which was a survey for maser emission, which found about 180 masers, including megamasers and disk masers, and thousands of galaxies which did not have maser emission. Especially the nonmasers needed some cleanup, because there were duplicate galaxies in there, so I made an algorithm to find and remove duplicates by distance. Also, when they were choosing which galaxies to survey, they chose a lot of galaxies which they thought might be likely candidates for masers, so the nonmaser sample is a bit skewed toward AGN.

We compared the MCP data with these AGN data projects:

The coronal line spectroscopic survey, or CLASS, which was a bunch of galaxies in The Sloan Digital Sky Survey which have coronal lines, and a survey the max plank institute did also using SDSS data for optical line emission.

Finally we also compared maser and nonmaser location data in cosmic voids and walls.

7) Coronal line AGN

The first comparison we did was the maser sources being compared to coronal line sources using the MCP and the CLASS data. Since the Coronal line database was taken from the sloan digital sky survey, to do a fair comparison we had to cull down the maser data to just what was in SDSS. Then we found that 7.8 percent of masers had coronal lines, while only 1.5 % of nonmasers had coronal lines. That’s a significant difference, and means that we can use Coronal lines to help find masers.

We also looked at some of the physical properties associated with coronal lines. Ionization potential is a measure of the energy required to ionize the gas to the level needed to make that coronal line emission. As you can see, 40% of masers had a highest Ionization potential of 262.1 electron volts, which corresponds to the Iron leven ion line, while only 6% of nonmasers did, so that might be a useful tool in finding masers.

The same goes for a couple columns in the highest critical density, which is a measure of how dense the gas must be to produce that coronal line.

8) Optical AGN

Next we looked at optical line AGN

Following a process developed by kewley et al, we plotted the relative intensity ratios of specific lines to get a fair comparison. Then you plot the galaxies on these three graphs to compare three line ratios against a fourth ratio. Star-forming galaxies lie under this line on all three graphs, AGN galaxies lie above it. The two types of AGN, Seyfert and LINER, are distinguished by this line on these two graphs. You can classify a galaxy as one particular type if it is in the same area on all 3 graphs. We plotted the nonmasers in blue, and the masers in yellow, surrounded by a star for maser disks. As you can see, the disk masers tend to stay around the Seyfert AGN area, so being a seyfert AGN seems to really increase the chance that the galaxy is a disk maser. Also with the final classification, you can see that the disk masers here are almost entirely Seyfert AGN.

9) Cosmic environment

Finally, we compared the location of nonmasers and masers in the cosmic environment. Galaxies form these threads of high-density and low density galaxies throughout the cosmos. They are in a wall if they are here in a bright area or in a void if they are here in a dark area.   
Well, as you can see, there really isn’t much difference between masers and nonmasers’ location, so our conclusion is that that’s not a good metric to find masers.

10) Conclusions.

So what did we learn from this study?

Basically, there is value in using Coronal line and optical line AGN detection methods in narrowing down the pool of candidates in the search for Disk Masers.

The cosmic environment location data isn’t such a good tool for narrowing the search, at least with the data we have so far.

In the future, we could expand this study using other AGN detection methods such as Mid-infrared and variability. As we find more masers, we also desperately need to run these analyses with more data, because we are working with relatively small numbers here, which increases the error.

Thank you, are there any questions?