An Investigation of Maser Dependence on Host Galaxy Properties

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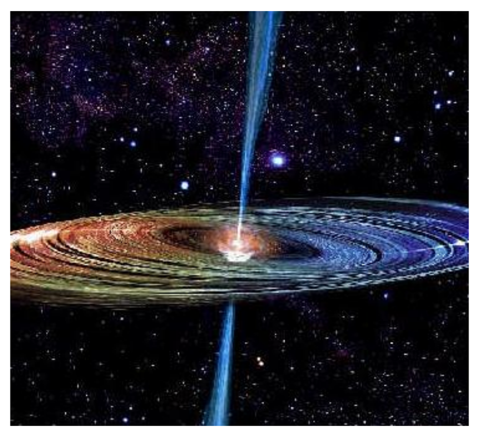
Abstract

Currently the most accurate way to measure the distance to another galaxy is through powerful water mega-maser disks detected in galaxy centers. Such measurements are crucial for constraining the Hubble constant, Ho, which is necessary for understanding dark energy, that constitutes ~74% of the composition of the universe. To date, searches for mega-maser disks remain relatively blind, and therefore inefficient. Only 3-4% of all galaxies searched for maser emission have shown this type of activity. This project investigates for the first time for correlations between maser activity and characteristics of the host galaxy using large statistical samples. We use observations from the Sloan Digital Sky Survey (SDSS) Data Release 7 to compare photometric and spectroscopic properties of galaxies with and without maser activity. We aim to reveal the most statistically significant connections between mega-maser emission and their host optical properties by exploring the role of environment as an indicator of mega-maser activity and comparing optical spectral classifications, central black hole masses, luminosities of specific emission features, and masses and ages of associated stellar populations. By looking in particular into the galactic morphologies and colors, we are able to significantly narrow down the range of properties associated with maser and especially mega-maser activity.

Masers and Mega-masers

MASER: Microwave Amplification by Stimulated Emission of Radiation

Mega-masers: 10^6 (1 million) times more luminous than masers



Left: Artist depiction of water masers around NGC 4258

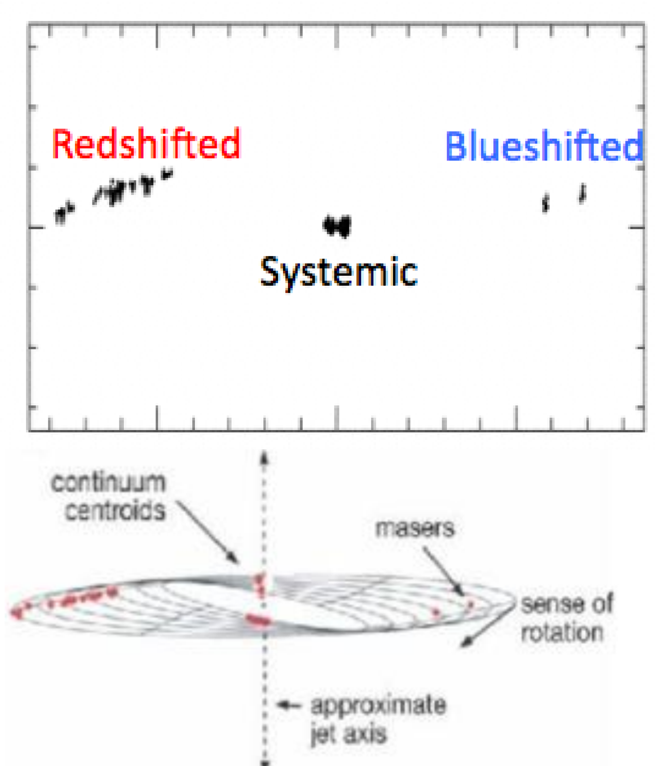
Right: Actual picture of NGC 4258

http://news.discovery.com/space/megamasers-distant-water-and-precision-cosmology.html

http://cseligman.com/text/atlas/ngc42a.htm

Importance of Mega-maser Disks

Mega-maser disks provide the **most accurate** way to calculate distances to distant galaxies, as well as precise estimates of supermassive black hole masses.



Schematic of warped disk with maser locations overlaid

Herrnstein et al. 1996, Bragg et al. 2000

The distance can be determined by the angular size, the centripetal acceleration and the velocity at the specific radii:

$$D=r/\theta,\ a=V_r^2/r,\ d=V_r^2/a\theta$$

Knowing distance is important because it allows for calculation of the Hubble constant:

$$v = H_0 * d$$

H_0 is the expansion rate of the universe, knowing this value more concisely should allow for a better understanding of dark energy and thus to understand how the expansion of the universe will change over time.

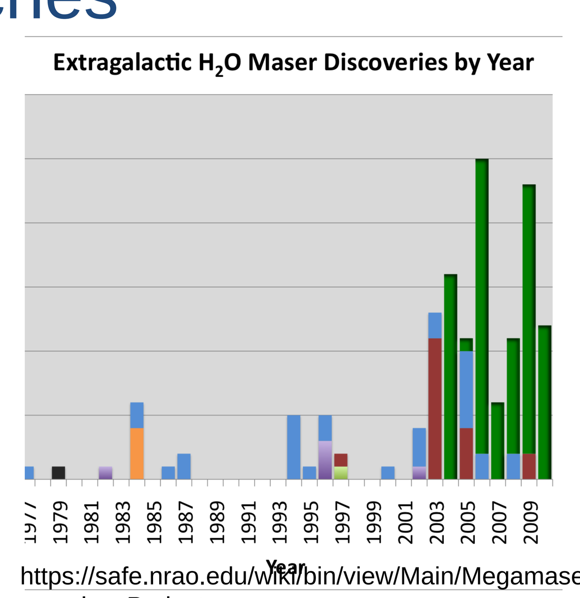
The observed maser velocities are fitted very accurately with a Keplerian model that reveal very accurate estimate of the mass of the central supermassive black hole ($3.6 \times 10^7\ M_{sun}$).

The Need for Better Searches

Finding these mega-maser disks has been difficult, the total number of maser galaxies found is only ~3% of all surveyed, and we need to refine our search methods to become more efficient.

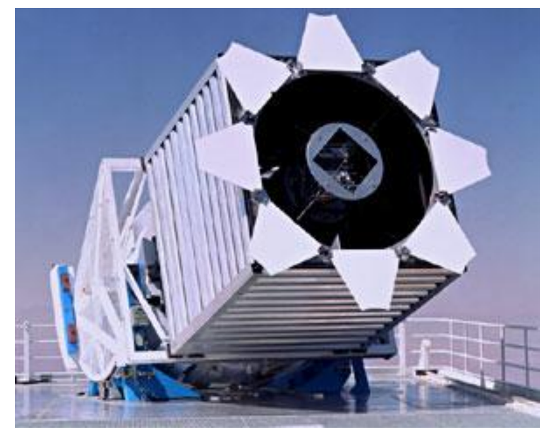
Once Seyfert galaxies, galaxies with AGN, were targeted the number of masers found has increased, but only ~4% of the Seyferts surveyed actually contain them.

Since this graph, the possible Seyferts have all been searched so we need to find ways to continue improving searches!



https://safe.nrao.edu/wiki/bin/view/Main/MegamaserCosmologyProject

Maser and Control Data



http://kicp.uchicago.edu/research/highlights/highlight_2004-10-20.html

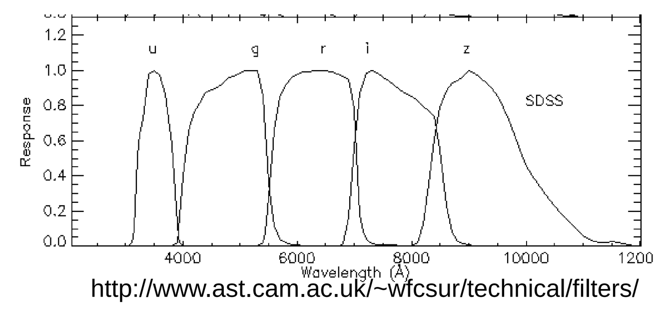
Using the Megamaser Cosmology Project and the SDSS DR 7 we get our samples of:

Photometric data (u,g,r,i,z mags and associated colors):
- 80 masers
- 1608 non-detections (surveyed, but no detections)

Spectroscopic data:
- 50 masers
- 1227 non-detections

Reid et al. 2009, Braatz et al. 2010, Kuo et al. 2011.

http://www.astr.ua.edu/keel/telescopes/nrao.html



http://www.ast.cam.ac.uk/~wlcsur/technical/filters/

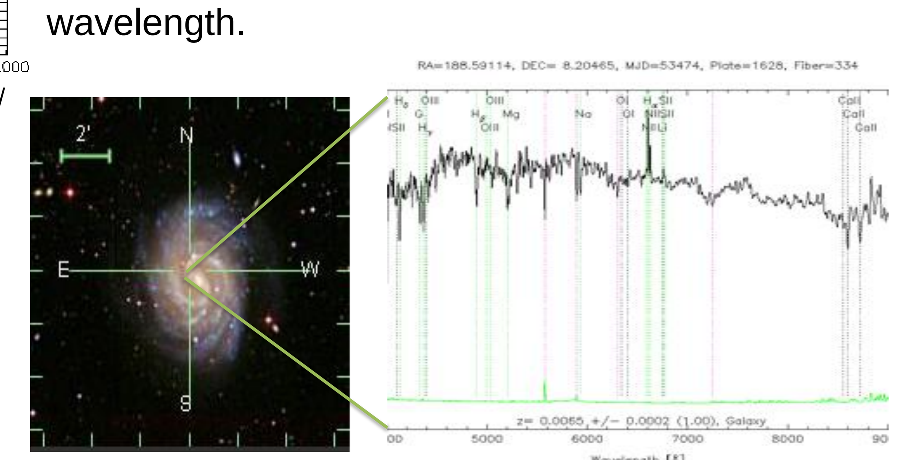
SDSS filters used and the associated responses per wavelength.

Goals of our Analysis

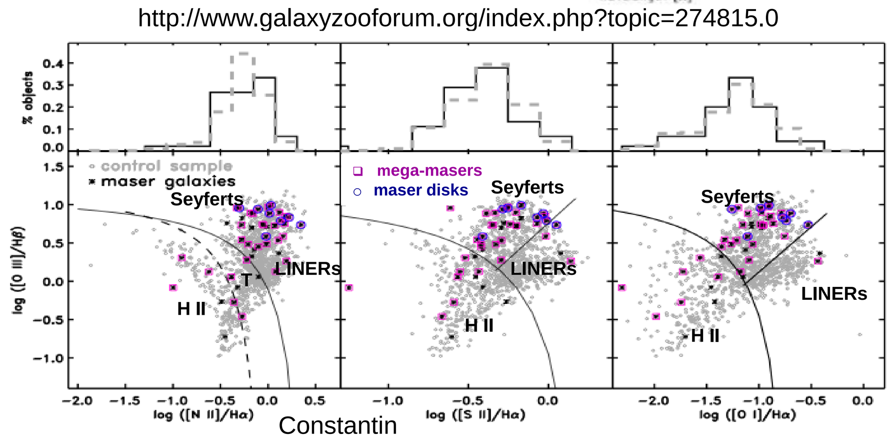
In order to find correlations between host galaxies and mega-maser activity, we investigate:

- Optical spectral classifications: Seyferts, LINERs, Transition, HII (different types of accretion onto the central supermassive black hole)
- Central black hole masses (from velocity dispersions)
- Luminosities of specific emission features
- Masses and ages of associated stellar populations
- Host galaxy morphologies and colors

Mega-maser: $L_{H2O} > 10L_{\odot}$



http://www.galaxyzooforum.org/index.php?topic=274815.0

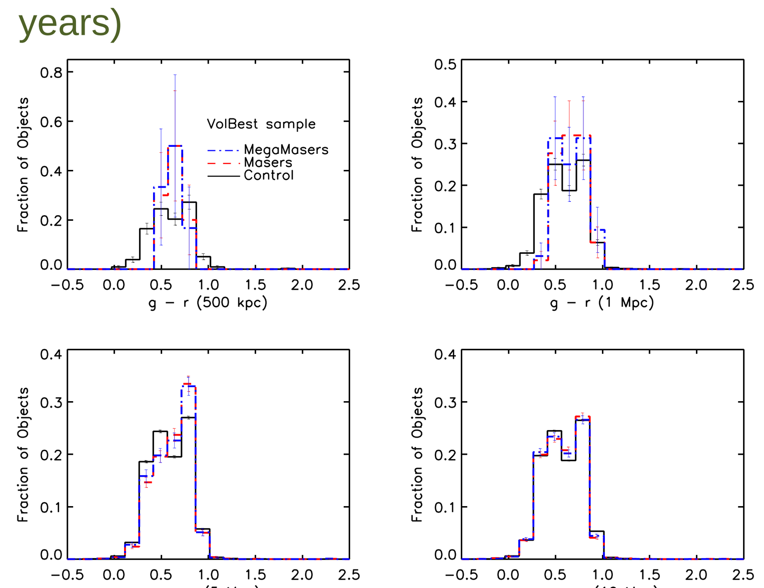


Constantin

We find very similar line-diagnostic diagrams for the **maser** and **control** samples.

Environmental Properties

We investigate the type of extragalactic environments of maser and control galaxies via near neighbor statistics to calculate the average number densities, as well as a comparison of the photometric properties of the neighbors. We consider number of neighbors and their colors within 0.5, 1, 5 and 10 Mpc of the maser and control galaxies. (1pc = 3.26 light-years)



Comparison of g-r colors of neighbors of maser and control galaxies in 4 different volumes.

We find that:
- In the smaller scale environments, the neighbors of maser galaxies appear redder than those of the control systems.
- It is also apparent that the color distributions of the masers' neighbors are more compact, which suggests that their environments are more homogeneous in their properties relative to the control galaxy environments.

Host Galaxy Morphology

We used Galaxy Zoo classifications for:
- 40% of the maser galaxies
- 75% of the control galaxies

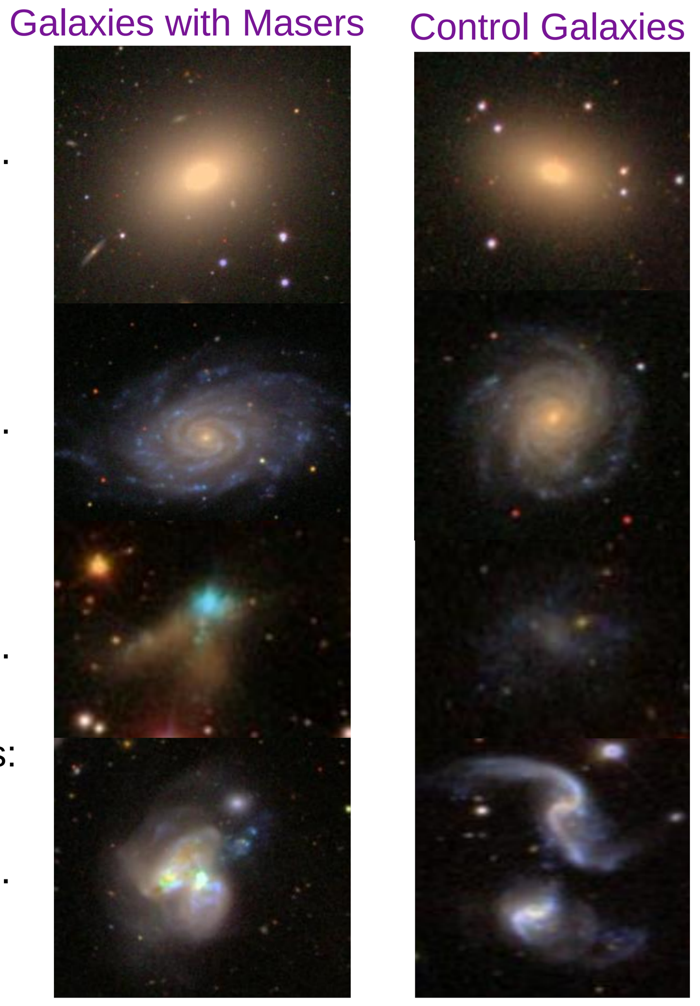
We did the rest!

http://zoo1.galaxyzoo.org/

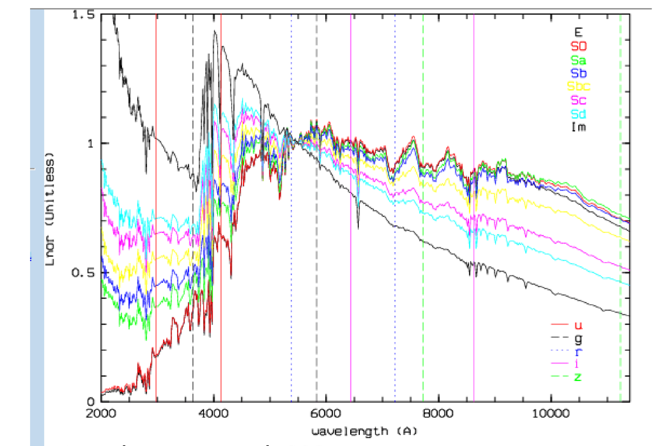
Galaxy Zoo classified galaxies as "Uncertain" if there wasn't an 80% agreement on one specific classification

Galaxies were placed into one of four categories:
1. Elliptical
2. Spiral
3. Uncertain (includes irregulars)
4. Mergers

Galaxies with Masers | Control Galaxies



Galaxy Colors

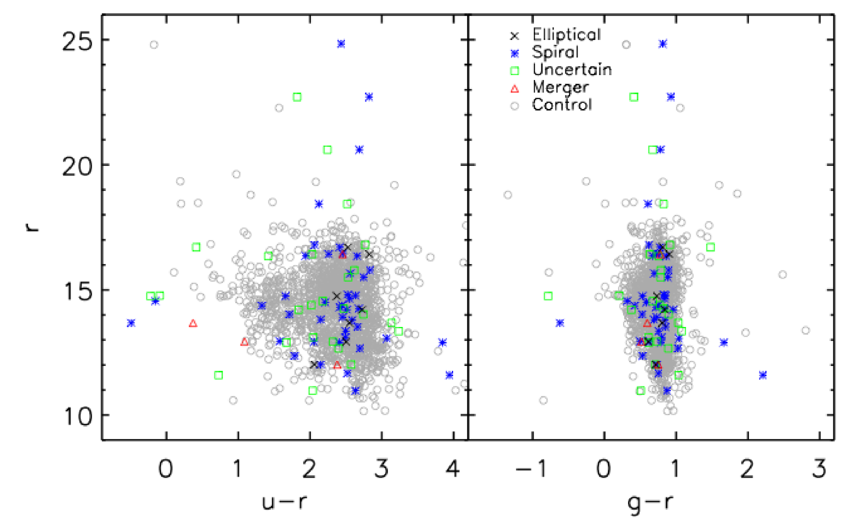


P. Tsalmantza, et al. 2007

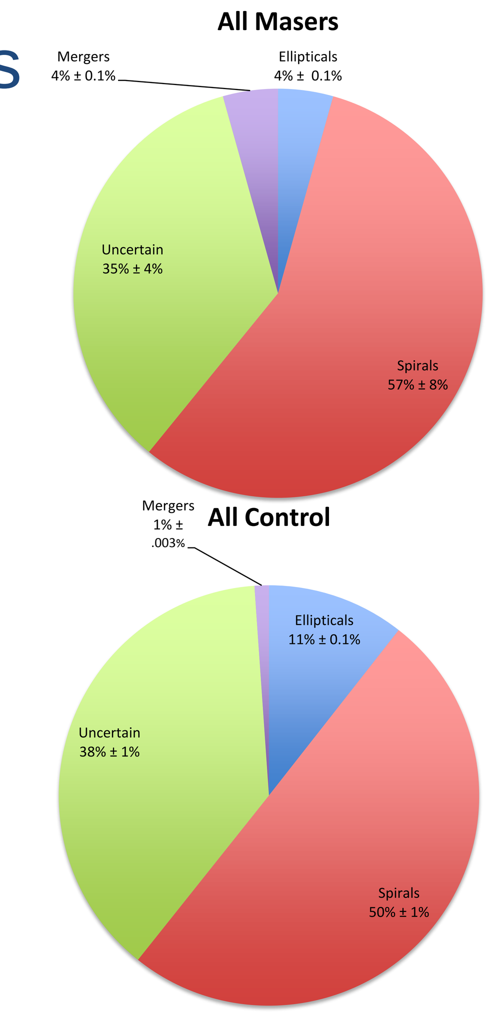
Color in astronomy is a measure of te difference in intensity at different wavelengths when viewed through specialized filters.

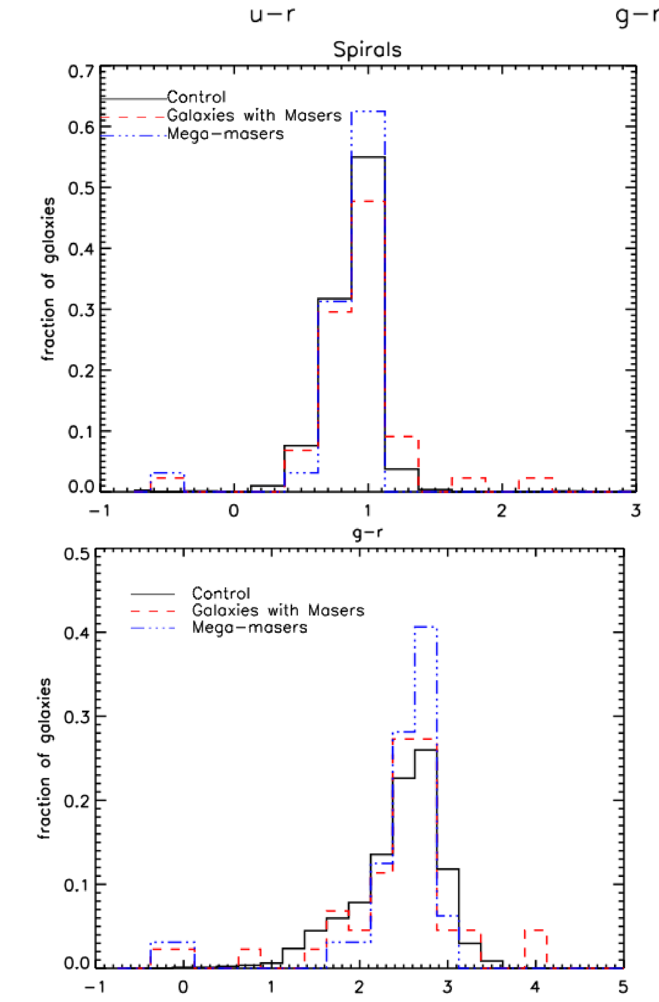
- u-r was chosen because at a u-r ~ 2.22 there is a separation between elliptical and spiral galaxies.
- Similarly g-r was chosen because there is a clear separation between the red sequence with a g-r > 0.8, the green valley with 0.6 < g-r < 0.8, and the blue cloud with g-r < 0.6

Examining the Morphologies and Colors



We find a larger percentage of spirals in the maser sample and a larger percentage of ellipticals in the control sample.

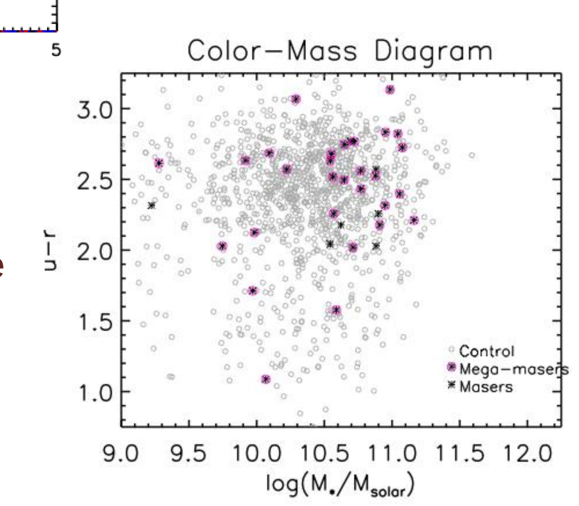


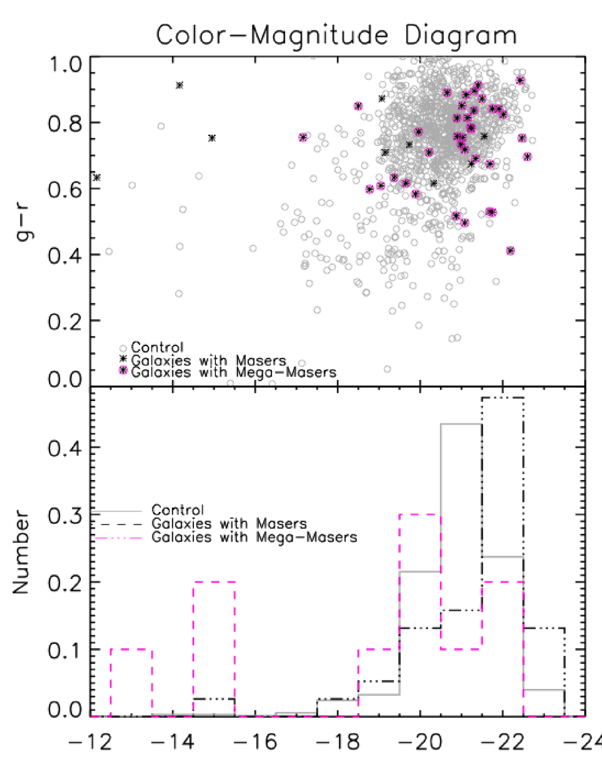


Left: The spiral galaxies with mega-masers show a narrower range in their g-r and u-r colors.

Similar analysis for the ellipticals only shows that the maser galaxies appear redder than the control sample, however, the number statistics for the ellipticals remains small, meaning that the conclusions are not robust.

This plot suggests that the maser detection is somewhat connected to the green color (valley) of the AGN host galaxies.





The galaxies with megamasers are typically more luminous than the control sample galaxies.

Preliminary Results:

Galaxies with the following properties:
- $M_r < -18$
- Morphology = spiral
- $1.5 < u\text{-}r < 3.1$
- $0.4 < g\text{-}r < 1.1$

Have a ~3.6% maser detection rate which is a slight improvement to current searches.

For the Future

- Investigate specifically the mega-masers in a disk configuration
- Expand the morphological distributions to the mega-maser category seperately
- Continue to examine how morphology, color, absolute magnitude, and stellar masses affect the detection rate of mega-maser emission
- Look into the error associated with the detection rate calculations
- Determine how mega-maser emission may be linked to the evolution of the host galaxy

References

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